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Should you compete or cooperate with your schoolmates?

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Should you compete or cooperate with your schoolmates?

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This paper presents empirical evidence from the Programme for International Student Assessment 2003 survey on the role of students' attitudes towards competition and cooperation in mathematical literacy achievement. While individual competitive attitudes are positively correlated with test scores, the reverse occurs when considering the aggregation of individual attitudes. Similarly, while individual cooperative attitudes exhibit a negative correlation with test scores, the opposite is true in the aggregate. We provide an interpretation of this 'fallacy of composition' based on public good production and incentives to free riding, which is prevented by social norms held valid in a small or homogenous group.

JEL classifications: I21; J24

Keywords: cooperation; competition; PISA; student attitudes

Introduction

The standard application of the educational production function approach correlates student competences with parental background, school resources, and peer effects, which are considered as inputs (Hanushek and Woessmann 2011). Less attention is devoted to students' attitudes, which in general are generated by the interaction between the teacher and the class. In this paper, we provide robust empirical evidence that these attitudes matter for student achievement. In particular, we focus on cooperative or competitive attitudes, as self-reported by the students, an area of investigation that is more often covered by educationalists.[1]

While the learning process may be affected by both intrinsic and extrinsic motivations (Malone and Lepper 1987), educationalists usually consider the former as more effective than the latter one in enhancing the acquisition of knowledge, and in a parallel fashion they regard group learning as more effective than individual learning (Shachar and Fischer 2004). In addition, group work requires caring for others, thus reinforcing the sense of community belonging.[2] Discussing with classmates involves reconciliation of multiple perspectives through the medium of dialogue, and this collaboration develops a higher abstraction and elaboration skills.

Moreover, group activity allows for individualized attention for low-achieving students, as well as providing high achievers with an opportunity to improve their understanding of the subject while illustrating it to the group. In group learning,

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students of different abilities obtain a personalized motivation, provided that group composition does not mix extremes that are too far apart. Students with different levels of achievement have different attitudes to group learning. Rather common in this stream of literature are the findings that low achievers seem to gain more from group learning than high achievers, and that high achievers are more inclined to gain recognition of their level of ability through competition in the class.[3]

Increasing empirical evidence suggests that group learning yields superior outcomes in terms of students' motivation and achievement. Whatever teaching technique is adopted in a class, and irrespective of the students' age or subject taught, most of the literature stresses the advantages of cooperative learning.[4]

Cooperative learning, however, is not a spontaneous phenomenon. As Blumenfeld et al. (1996) point out groups work according to implicit or explicit norms that regulate individual contributions and individual accountability is essential to ensure generalized cooperation.

As economists, not only are we particularly sensitive to such a caveat, but we cannot miss the strong similarities that learning in groups has with the provision of (impure) public goods. Group learning has positive externalities, since all students seem to improve their achievements. However, individual incentives favour free riding and these incentives are increasing in student's ability, since the most brilliant students are those who contribute more to group learning, with a greater benefit for the 'worst' (i.e. the less able) ones. The economics literature about the provision of public goods stresses a similar strategic conflict between individual incentives and social optimum, although the theoretical prediction of no cooperation is systematically rejected by experimental evidence (see for instance the meta-analysis in Zelmer 2003). In fact, positive contributions are always observed in the first rounds, and such a puzzle has been explained either with the presence of 'rational cooperators' who try to reach the social optimum at least in the first rounds (Kreps et al. 1982) or by other-regarding preferences (see Fehr and Schmidt 1999 among the others). Although the public good component of knowledge has already been stressed for instance by Stiglitz (1999), we could not find in the literature any application of such a strategic dilemma to the behaviour of students in class. In such a complex environment, group norms may also reverse individual incentives. In fact, the emergence of cooperation is likely to be influenced by the socio-cultural environment where learning takes place (Cox, Lobel, and McLeod 1991). The environment shapes the incentives and the attitudes of participants, rewards or penalizes the leaders, and reinforces or weakens stereotypes.

In the sequel, instead of observing purposely arranged experiments of teaching styles, we resort to students self-declared attitudes with respect to cooperation or competition in class work, and we study the correlation with individual achievement, as measured by test scores.[5] As long as students' attitudes are a good proxy for the actual behaviour of students and test scores are good proxies for actual learning, we may draw inference on the impact of cooperation onto learning. However, we consider the possibility of divergence between the individual and the social optimum, because it may be personally convenient to act in a competitive manner while the others are open to cooperation: think of receiving solutions to a test by cooperative classmates, while not reciprocating. This opens the door to a fallacy of composition, because as long as all students behave in the same way, none will pass solutions to others.

In the present paper, we use data from the 2003 wave of the OECD's *Programme for International Student Assessment* (PISA), which gather comparable information on students enrolled in schools located in many different countries and provide a standardized measure of student competences (our proxy of learning). We make use of the 2003 survey, because it contains an array of questions regarding students' attitudes towards cooperation and competition that have not been replicated in the 2006 survey.[6] Although such a data set does not allow us to observe the process that effectively takes place in the class, it has the great advantage of providing a large-scale analysis based on a standardized measure of performance, while paedagogical and psychological literature usually relies on small case studies. We study the correlation between students' attitudes and performance, showing that there is an individual incentive to compete, but a group advantage in adopting cooperative strategies. This result is robust against alternative specifications. We also show that attitudes affect learning with differential intensity, according to the environment experienced in class (size and homogeneity).

In the second part, we put forward a possible interpretation of our empirical findings, by proposing a model where each student allocates his/her effort between two types of activity, cooperation or competition. Cooperation provides positive externalities in terms of knowledge to the entire group of students irrespective of individual contribution. Competition has a private return only, which is increasing in ability. As a consequence, under spontaneous ordering there is an excess of competition and limited cooperation. However, when group norms are modified (for instance because a teacher may favour group learning or because peers penalize selfish behaviour), these conclusions can be reversed.

Empirical analysis

The OECD's PISA surveys are designed to collect information on real-life competences from 15- to 16-year-old students, on a comparable cross-country base. These surveys are conducted every 3 years, and cover reading, mathematical and scientific literacy, and problem-solving, with a dominant area in each wave. The 2003 wave has been conducted in 41 countries with a primary focus on mathematical literacy. The PISA survey provides an extremely rich set of explanatory variables that can be linked to students' performance, ranging from individual characteristics and family background, to characteristics of the school and of national educational systems.

In the 2003 PISA questionnaire, there are also some questions concerning students' learning approach. Two sets of questions concern their preference for competitive learning[7] and cooperative learning,[8] respectively, which are not mutually exclusive. In fact, it may well be that a student wants to outperform his/her classmates and at the same time has preferences for cooperative learning. This information on students' learning attitudes has been summarized by the OECD researchers (using principal component analysis) into two variables (COOPLRN and COMPLRN – see OECD 2004).

PISA project surveyed students by schools and not by classes, with an average of 33 students tested per school. In the following analysis, we consider school averages as the best available proxy of class averages. We use students' test scores as a measure of the knowledge possessed by each student.[9] For each student in the sample, we compute the average attitude in the school towards competitive and cooperative learning, excluding his/her own opinion.

From the original data set (276,165 observations), we drop countries where the distribution of test scores is too dissimilar from the rest of the sample (65,393 cases excluded) and/or there are missing information (59,727 observations with at least one missing in one of the relevant regressors).[10] After excluding individuals in schools with less than 10 students (3301 observations), we also keep students enrolled in the modal grade (by country) or in the ±1 range with respect to it (discarding 5525 observations), because the other students could represent rather peculiar sub-samples (either in terms of ability, or in terms of attitudes towards cooperating with others, for instance repeating students might face rather dissimilar peers). Finally, we are left with 145,012 students spanning 33 countries; descriptive statistics are summarized in Table 1, while Table 2 displays average students' attitudes by country, where the international mean in the PISA data set has by construction been set equal to zero and the standard deviation to one.

We know from the extensive literature on student performance (see among others Wößmann 2003; Ammermüller 2005) that individual test scores are positively correlated with a number of variables, although scholars disagree about their causal

Table 1. Descriptive statistics – PISA 2003.

Variable	Number of observations	Mean	Std. dev.	Minimum	Maximum
Test score in maths	145,012	522.36	87.87	109.16	849.00
Grade	145,012	9.70	0.66	8	12
Female	145,012	0.51	0.50	0	1
Age of student	145,012	15.79	0.29	15.17	16.42
Highest parental occupational status	145,012	49.87	16.24	16	90
Highest parental education (years)	145,012	13.18	3.12	0	17
Computer facilities at home	145,012	0.11	0.96	−1.68	1.05
Index of home possessions	145,012	0.10	0.92	−3.79	1.94
Hours all homework	145,012	6.42	5.76	0	30
How many books at home	145,012	3.65	1.37	1	6
Proportion of girls	145,012	0.50	0.19	0	1
Student/teacher ratio	145,012	13.60	4.92	1.379	70
school size	145,012	735.84	483.85	19	6000
How many students attend math class	145,012	23.36	7.37	1	80
Average school occupational prestige	145,012	49.59	7.73	23.67	75.59
Average school parental education	145,012	13.12	1.70	2.81	17.00
Teaching style: maths club	145,012	0.20	0.40	0	1
Teaching style: maths competition	145,012	0.70	0.46	0	1
Individual cooperative learning	145,012	0.02	0.96	−3.13	2.74
Individual competitive learning	145,012	−0.01	0.95	−2.84	2.45
Tracking*	145,012	0.52	0.50	0	1

*Countries classified as tracked according to the distribution of the type of secondary school attended (variable PROGN): Austria, Belgium, Czech Republic, Germany, Greece, Hong Kong (China), Hungary, Ireland, Italy, Japan, Korea, Luxemburg, Macao (China), The Netherlands, Portugal, Russian Federation, Slovakia, Spain and Turkey.

Table 2. Students' attitudes by countries included in the analysis – PISA 2003.

Country	Number of observations	Competitive learning (mean)	Cooperative learning (mean)
Australia	10,103	0.079	0.292
Austria	3191	−0.017	−0.319
Belgium	6405	−0.051	−0.343
Canada	15,737	0.168	0.180
Czech Republic	4723	−0.050	−0.112
Denmark	2798	0.239	−0.043
Finland	5129	−0.156	−0.312
Germany	3094	0.019	−0.062
Greece	3148	0.182	0.282
Hong Kong (China)	3165	−0.026	0.082
Hungary	3420	−0.115	−0.467
Iceland	2502	−0.282	0.284
Ireland	1974	−0.125	0.076
Italy	9781	0.070	−0.098
Japan	3479	−0.688	−0.439
Korea	4262	−0.774	−0.044
Latvia	3499	−0.142	−0.115
Liechtenstein	267	0.219	−0.232
Luxcsembourg	2524	−0.180	−0.005
Macao (China)	829	0.186	0.015
The Netherlands	2709	−0.123	−0.470
New Zealand	2810	0.163	0.160
Norway	2641	0.016	−0.303
Poland	4005	0.119	0.099
Portugal	3025	0.307	−0.104
Russian Federation	4279	−0.070	−0.060
Slovakia	5730	0.231	0.053
Spain	7405	0.060	0.002
Sweden	3608	−0.199	−0.034
Switzerland	5925	0.182	−0.316
Turkey	2288	0.315	0.670
UK	7198	0.143	0.205
USA	3359	0.282	0.396
Full estimation sample	145,012	0.016	−0.012

Note: Descriptive statistics refer to the whole estimation sample.

interpretation in some cases (see for instance Hanushek 1997, *vs.* Greenwald, Hedges and Laine 1996, on the role played by school resources). Among such variables, there are family background (parental education, parental socio-economic status, number of books at home, internet connected computer at home, and proxy for durables possession), some proxies of school resources (instructional time, number of computers, and class size), and some institutional indicators (existence of central exit examination systems, source of funding).

In Table 3, we report OLS estimates of the correlation of students' test scores, measures of family background and our measure of attitudes. Country fixed effects are included, all estimates use final student weights and heteroskedastic robust standard errors are clustered by school. In column (1) we consider the individual attributes replicating known results: girls are worse than boys in numeracy; age (measured in months, since they are all 15 year old) is associated with better performance; parental background (measured by parental occupational status, parental years of education – linear and squared – possession of durables including books and internet-connected computers) is positively associated with students' tests. We also include a proxy of individual effort, which is given by the amount of hours per week spent on 'homework or other study set by your teachers'.

Potential self-selection into schools is dealt with in column (2): we add student/teacher ratio (as proxy for available resources), which affects competences though with a low magnitude, fraction of girls (never significant), and math class size (linear and squared), yielding an inverted *U*-shaped relationship with test scores. We also consider the possibility of self-selection by family background in schools, especially in countries where the secondary school level is tracked, by including the average occupational prestige and education of parents in the school, which come out both positively and significantly associated with student scores. Eventually, we include two measures of the math *teaching styles* adopted in the school (and reported by the school head): whether in order to promote students' engagement with mathematics, the school promotes mathematics competitions and/or mathematics clubs. The former activity should stimulate competitive attitudes among the students, while the latter should spur cooperative behaviour (at least among the club members). Both variables, which may also be proxies of the general interest of the school in mathematical activities and performance, are positively associated with test scores, with similar magnitudes of impact.

We now introduce student self-reported attitudes in column (3) of Table 3. Students expressing competitive attitudes have a higher average performance, while the opposite occurs for those more in favour of group (cooperative) activity. In other words, at the individual level, even after controlling for teaching styles, there is a prize associated with being competitive while being cooperative implies a penalty. However, we obtain a reversal of this intuition in column (4), once we introduce the average attitudes expressed by the students in the school (computed excluding his/her own attitude). Other things being equal, students in schools where competitive attitudes are prevalent do not achieve higher average test performance, while they do when cooperative attitudes towards learning prevail.

In order to appreciate the overall impact of attitudes, let us consider the following thought experiment. If we start from a neutral situation (all students express no preference for either cooperative or competitive attitudes, i.e. $\text{COOPLRN} = \text{COMPLRN} = 0$) and we observe that students preferences towards competition increase by one standard deviation, we will obtain an overall increase in test score of $+3.0$ (as a result of $9.036 - 6.018$). On the contrary, if we simultaneously increase preferences for cooperative learning we obtain an increase of $+8.21$ (as a result of $-3.919 + 12.132$), which is more than twice and half the previous effect. Thus, we confirm the finding of the educationalist literature: promoting cooperative attitudes among students is more beneficial than promoting competition, at least in terms of competences as measured by average test scores.

As there may be differences by gender, columns (5) and (6) report estimates for females and males, respectively. The main difference with respect to column (4) is

Table 3. Performance in math tests – PISA 2003.

					Females	Males	Tracked	Untracked	
	1	2	3	4	5	6	7	8	9
Grade	27.782***	26.813***	27.392***	27.503***	26.211***	29.325***	31.219***	23.598***	27.421***
	(1.536)	(1.352)	(1.374)	(1.358)	(1.642)	(1.906)	(1.715)	(1.936)	(1.350)
Female	−17.889***	−19.336***	−17.345***	−17.376***			−19.997***	−14.886***	−17.295***
	(1.228)	(0.963)	(0.957)	(0.953)			(1.236)	(1.431)	(0.950)
Age of student	−4.091**	−2.932*	−3.013*	−2.983*	−3.918*	−1.991	−2.913	−2.063	−2.825
	(1.928)	(1.769)	(1.775)	(1.749)	(2.211)	(2.453)	(2.028)	(2.963)	(1.737)
Highest parental occupational status	0.715***	0.464***	0.459***	0.459***	0.467***	0.453***	0.220***	0.756***	0.457***
	(0.039)	(0.035)	(0.035)	(0.035)	(0.046)	(0.050)	(0.042)	(0.055)	(0.035)
Highest parental education (years)	0.618	0.119	0.368	0.344	0.407	0.41	0.517	0.43	0.388
	(0.614)	(0.532)	(0.527)	(0.525)	(0.656)	(0.767)	(0.575)	(1.240)	(0.528)
Highest parental education squared	0.060**	0.011	−0.002	−0.001	0.004	−0.015	−0.008	−0.007	−0.004
	(0.028)	(0.025)	(0.025)	(0.025)	(0.033)	(0.035)	(0.028)	(0.052)	(0.025)
Computer facilities at home	6.455***	4.701***	4.769***	4.802***	4.437***	4.891***	6.106***	3.743***	4.866***
	(0.919)	(0.817)	(0.818)	(0.815)	(1.050)	(1.071)	(1.020)	(1.232)	(0.812)
Index of home possessions	8.943***	5.273***	4.774***	4.836***	5.592***	4.028***	1.897*	6.512***	4.832***
	(0.884)	(0.832)	(0.844)	(0.841)	(1.166)	(1.144)	(0.997)	(1.296)	(0.841)
Hours all homework	1.949***	1.458***	1.327***	1.323***	1.552***	1.067***	1.184***	1.345***	1.307***
	(0.123)	(0.108)	(0.108)	(0.107)	(0.126)	(0.149)	(0.136)	(0.158)	(0.106)
How many books at home	11.921***	10.113***	10.222***	10.203***	9.991***	10.420***	8.864***	11.751***	10.199***
	(0.490)	(0.461)	(0.461)	(0.460)	(0.614)	(0.624)	(0.546)	(0.723)	(0.460)
Proportion of girls		2.346	2.638	0.973	−3.929	13.235	3.576	11.464	1.023
		(5.398)	(5.385)	(5.443)	(6.805)	(8.873)	(6.106)	(8.980)	(5.456)
Student/teacher ratio		−0.975***	−0.977***	−0.953***	−0.721***	−1.025***	−0.848***	−1.310***	−0.948***
		(0.207)	(0.205)	(0.199)	(0.189)	(0.226)	(0.217)	(0.433)	(0.198)
School size		−0.001	−0.002	−0.001	−0.004*	0 (0.003)	0.003	−0.002	−0.002
		(0.002)	(0.002)	(0.002)	(0.002)		(0.003)	(0.002)	(0.002)
How many students attend math class		2.825***	2.869***	2.880***	2.697***	2.973***	1.039*	5.182***	3.007***
		(0.392)	(0.390)	(0.389)	(0.588)	(0.430)	(0.602)	(0.653)	(0.389)

(*Continued*.)

Table 3. (*Continued*.)

					Females	Males	Tracked	Untracked	
How many students attend math class squared		−0.026***	−0.027***	−0.027***	−0.023*	−0.030***	0 (0.012)	−0.064***	−0.032***
		(0.008)	(0.008)	(0.008)	(0.012)	(0.009)		(0.014)	(0.008)
Average school occupational prestige		1.955***	2.010***	2.035***	1.636***	2.510***	2.383***	1.619***	2.031***
		(0.233)	(0.232)	(0.234)	(0.232)	(0.300)	(0.348)	(0.268)	(0.233)
Average school parental education		9.197***	9.169***	9.223***	9.089***	9.191***	10.603***	3.460**	9.102***
		(1.153)	(1.153)	(1.158)	(1.205)	(1.379)	(1.501)	(1.628)	(1.161)
Teaching style: maths club		1.819	1.504	1.395	−0.14	2.569	5.515	−2.144	1.468
		(2.665)	(2.679)	(2.672)	(2.854)	(3.306)	(4.019)	(3.203)	(2.663)
Teaching style: maths competition		8.870***	8.928***	8.581***	9.930***	6.753**	14.050***	2.702	8.427***
		(2.245)	(2.267)	(2.257)	(2.409)	(2.861)	(2.739)	(3.571)	(2.257)
Individual cooperative learning			−3.704***	−3.919***	−3.402***	−4.357***	−0.255	−7.909***	−9.977***
			(0.534)	(0.508)	(0.700)	(0.746)	(0.547)	(0.806)	(1.716)
Individual competitive learning			8.960***	9.036***	8.769***	9.330***	9.161***	8.263***	7.708***
			(0.558)	(0.512)	(0.729)	(0.752)	(0.548)	(0.934)	(1.696)
School average cooperative learning				12.132***	7.910*	16.809***	13.859**	6.178	30.789***
				(4.173)	(4.314)	(5.198)	(5.955)	(5.180)	(8.608)
School average competitive learning				−6.018	−7.061*	−6.006	4.912	−28.007***	−35.120***
				(3.794)	(3.952)	(4.792)	(4.696)	(5.458)	(9.097)
Individual cooperative learning × class size									0.238***
									(0.064)
Individual competitive learning × class size									0.049
									(0.061)
Average cooperative learning × class size									−0.781**
									(0.332)
Average competitive learning × class size									1.163***
									(0.335)
Number of observations	145,012	145,012	145,012	145,012	73,791	71,221	75,431	69,581	145,012
R^2	0.300	0.370	0.377	0.378	0.380	0.375	0.430	0.328	0.379
Log-likelihood	−832,951	−825,392	−824,537	−824,438	−416,389	−407,458	−427,919	−394,930	−824,267

*Significant at 10%; **significant at 5%; ***significant at 1% – errors clustered by school – country fixed effects included – observations weighted by student final weight.

that males seem to benefit more from a more cooperative environment (i.e. where average cooperation is higher) than females. Since in the sample boys also exhibit higher levels of competition and lower levels of cooperation, increasing cooperation should be more effective for more competitive individuals.

Stronger personal ties, and cooperation, are likely to depend on the homogeneity of the group (see Alesina and La Ferrara 2000). If we divide countries between comprehensive secondary school systems and tracked ones, we expect larger within-school heterogeneity in the former group, because in the latter students can self-select into more homogenous groups. Columns (7) and (8) report results for tracked and untracked educational systems, respectively. We find that the positive returns to average cooperation are higher in tracked systems, while we observe a negative return to average competition (only) in untracked systems.

In the provision of a public good incentives to free-ride increase with the number of agents because the returns to contributions become more and more diluted. Therefore, we have explored whether the previous findings change if we add the interaction between class size and individual and average attitudes in the specification of column (9). Our predictions are met by the data: the interaction between average cooperation and class size is negative and that of average competition is positive, both statistically significant at the 1% level. The results of a specification including interactions by class size are also shown graphically in Figure 1, where the increase in predicted performance is computed for different class sizes given a unitary change of either competitive or cooperative attitudes (both at the individual and school average levels). The graph shows that for small groups of students cooperative attitudes tend to be associated with higher gains in terms of test scores than competitive ones. When the group size crosses the threshold of 28 students the reverse situation applies. This suggests that incentives to adopt cooperative behaviours are stronger under strong personal ties, which are likely to be more frequent in small groups.

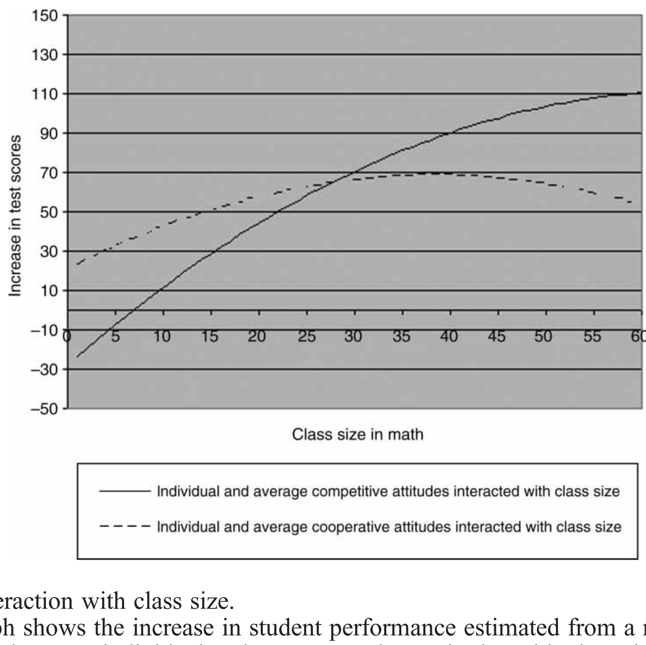

Figure 1. Interaction with class size.
Note: The graph shows the increase in student performance estimated from a model including the interactions between individual and average student attitudes with class size.

Similar results are obtained when we use student/teacher ratio as an alternative proxy for group size.

We have considered various robustness checks. In the first one, in order to assess the sensitivity of our results to the specific composition of the estimation sample, we re-estimate the model in column (4) of Table 3 in 50 random extractions of 50% of observations (without replacement) from the original sample, and we always obtain coefficients on individual and average cooperative attitudes that are statistically significant, with the same sign of column (4), and very close in magnitude. The results are also robust to allowing coefficients on all covariates but those on the four attitude variables to vary by country.[11] Baseline results are also confirmed using the PISA 2000 survey, although they cannot be directly compared with the findings in Table 3 because of differences in the framing of the questions about attitudes, in the main focus of the survey (reading), and in the dimension and composition of the sample.

In general, we do not give to coefficients on attitudes a causal interpretation. Indeed, students' time/effort allocation to the production of public and private knowledge is likely to depend on their ability, which also affects their performance.[12] Hence, student behaviour is likely to be endogenous, and we may accordingly expect a positive spurious correlation between individual competitive attitudes and performance driven by student individual ability. However, our result of a positive correlation between average cooperative behaviour and mathematical literacy is not easily predicted by the same argument, i.e. average ability within the group (note that signs are inverted with respect to individual attitudes), and we maintain that this is likely to partly reflect a true effect of average attitudes on student performance. We tried to implement an instrumental variables strategy to tackle this problem (using attitudes on other issues) but, unfortunately, PISA 2003 data do not provide a sufficient number of variables suitable for the identification of the four potentially endogenous variables we are dealing with.

Finally, we tested whether competitive and cooperative attitudes have a different impact at different quantiles (25th, 50th, and 75th percentiles) of student's knowledge (which is correlated with unobservable components of ability once we control for family background according to our model). When considering comprehensive educational systems, we observe that individual competitive attitudes display returns that are increasing in ability, while those of individual cooperative attitudes are approximately constant (and negative). As far as tracked educational systems are concerned, incentives (i.e. returns) to individual competitive behaviour are lower and slightly increasing in student's ability, while disincentives for individual cooperative attitudes do not depend on ability and are almost non-existent compared with non-tracked systems.[13]

A suggested interpretation

In this section, we show that most of our empirical results can be rationalized in a framework of individual rational choice of each student, facing the existence of an externality in knowledge formation. As long as the acquisition of knowledge encompasses features typical of the provision of a public good, we can replicate a divergence between individual and collective optima. We start by postulating that each student cares about his/her optimal level of knowledge, and faces the problem of allocating his/her time and/or effort between individual work and collective work.[14] We assume that *private knowledge* is produced through time/effort allocated to individual learning, while *public knowledge* is achieved through learning in a group, which requires sharing knowledge with others. The simplest way of formalizing such an idea is the following:

$$U_i = \alpha_i p_i + \tilde{s} - \frac{1}{2}(p_i)^2 - \frac{1}{2}(s_i)^2 \quad (1)$$

where U_i is the individual utility, p_i is the time/effort devoted to individual learning by student i, whose ability is α_i. The interaction $\alpha_i p_i$ represents what we term *private knowledge*, i.e. what students learn on their own.[15] The time devoted to group learning (s_i) generates instead *public knowledge* ($\tilde{s}$), defined as:

$$\tilde{s} = \frac{1}{\sigma_\alpha n} \sum_{i=1}^{n} \alpha_i s_i. \quad (2)$$

Consistently with the empirical evidence, we assume that the production of public knowledge is decreasing in students' heterogeneity represented by the standard deviation of their ability in the class, σ_α. A possible interpretation is that peer effects are more intense in more homogenous groups.

If we define a learning approach as *cooperative* when a larger amount of time/effort is devoted to the production of public rather than private knowledge, i.e. when $s_i^* > p_i^*$, the first-order conditions would imply that *all students would optimally choose to be competitive*. In fact, the following optimal choices emerge:

$$\arg\max_{p_i}[U_i] = p_i^* = \alpha_i \quad (3)$$

$$\arg\max_{s_i}[U_i] = s_i^* = \frac{\alpha_i}{\sigma_\alpha n} \quad (4)$$

with the contribution to public knowledge that decreases in students' heterogeneity and group size, approaching zero when the number of students becomes very large and heterogeneity is positive and non-decreasing in n. Notice that $p_i^* \geq s_i^*$ whenever $\sigma_\alpha n > 1$. Abler students are those who put more time/effort in both types of learning, and less able students are those who benefit more from public knowledge whenever its amount is positive (since they obtain more public knowledge than they contribute to), rationalizing the idea that less able students are more inclined to cooperative learning because they benefit more from it.

But the prediction of the absence of cooperative individuals is disconfirmed by the empirical evidence, and therefore we need to revise our set-up in order to rationalize actual behaviours of students. One possibility is to assume that students enjoy cooperative learning because they like interacting with their classmates. Alternatively, a selfish behaviour in terms of learning could likely be punished in terms of exclusion from the social activities inside and outside the class:

$$U_i = \alpha_i p_i + \tilde{s} - \frac{1}{2}(p_i)^2 - \frac{1}{2}(s_i)^2 - \mu(p_i - s_i), \quad \mu > 0. \quad (5)$$

The last term indicates that a cooperative learning approach ($s_i > p_i$) generates a good reputation among the classmates, therefore implying a positive utility, while the opposite holds when a competitive learning approach ($p_i > s_i$) is chosen. The optimal amounts now become, respectively:

$$\arg\max_{p_i}[U_i] = p_i^* = \alpha_i - \mu \tag{6}$$

$$\arg\max_{s_i}[U_i] = s_i^* = \frac{\alpha_i}{\sigma_\alpha n} + \mu. \tag{7}$$

The opinion of classmates, modelled in this simple way, has the effect of shifting time/effort from competitive to cooperative learning without changing the overall amount of time devoted to studying.

The threshold level of ability that divides the students characterized by a competitive learning approach from those characterized by cooperative learning is obtained by equating equations (6) and (7). *Competitive learning* occurs for all students characterized by a level of ability

$$\alpha_i > \frac{\sigma_\alpha n}{\sigma_\alpha n - 1} 2\mu, \tag{8}$$

which is increasing in the strength of classmates' beliefs and decreasing in the degree of heterogeneity (σ_α) and the size (n) of the group. Therefore, other things being constant the model rationalizes a positive correlation between ability and propensity to adopt a *competitive learning* approach.

Now let us see what happens to the amount of knowledge of the whole class, as measured for instance by a standardized test that is comparable across different classes. We define the total knowledge K of a class simply as the sum of the total knowledge acquired by each student, recalling that individual total knowledge is the sum of individual learning ($\alpha_i p_i$) and shared knowledge ($\tilde{s}$). Notice that public knowledge affects the outcome of every student, irrespective of both individual participation in group activities and individual ability. In this way, the public knowledge $\tilde{s}$ is counted n times when computing the score of the class. Therefore, the total knowledge of a class is by construction increasing in the degree of cooperation within the class, matching the empirical evidence that students performance is increasing with aggregate cooperation.[16] The stronger the social preferences for cooperation, the larger the amount of public knowledge produced and therefore the larger the amount of total knowledge.

If we accept that in more homogeneous environments the opinion of classmates is likely to be more relevant, we expect to observe that tracked educational systems, characterized by a more homogeneous student intake within schools, should display a relatively higher degree of cooperation and a lower degree of competition. Moreover, since we believe that group working is more productive when involving extremes that are not too far apart (for instance in terms of ability), we have modelled public knowledge as a decreasing function of students' heterogeneity (see equation (2)). Therefore, the model also rationalizes that tracked educational systems should display a higher return to aggregate cooperative behaviour, in line with the empirical evidence.

Summing up, we have shown that it is possible to rationalize the fallacy of composition that we have highlighted in the previous section. Whenever individuals are to allocate their time/effort between privately rewarded and spill-over generating activities, they do prefer the former (like individual learning). If we take into account the loss in terms of social reputation associated with individual behaviour, however, results may be reversed.

Conclusions

In the present paper, we show another occurrence of 'fallacy of composition'. Using a survey conducted in 2003 by the OECD-PISA consortium, we exploit attitudes towards competitive or cooperative learning. We study the correlation among these attitudes, family background and student test scores. When controlling for different aspects of family background and school resources, we show that test scores are positively correlated with individual competitive attitudes and negatively correlated with individual cooperative ones. However, the situation is reverted when we take into account the peers' attitudes: learning in a competitive environment is detrimental to average knowledge, while a cooperative environment favours average performance. This counterintuitive result holds stronger, the smaller is the class size.

We also show that these findings are strengthened in more homogenous environments as represented by tracked educational systems, because we provide evidence that those systems raise substantially the returns to cooperation both at individual and aggregate levels, probably thanks to a greater homogeneity of the student intake.

Most of such findings can be rationalized by a simple theoretical model that compares the production of knowledge to the provision of a public good, showing that private incentives do not necessarily coincide with public ones. In such a framework – where public knowledge represents the public good at hand – this leads to a suboptimal provision of cooperation, due to free-riding incentives. In fact, students' knowledge increases with individual competitive behaviour and with average cooperative behaviour.

The free-riding problem is attenuated whenever reputation among peers is relevant for the individual and/or when heterogeneity in group abilities is limited. The first effect is obtained by means of a positive utility impact of cooperative behaviour via classmates' opinions, while the second derives from the assumption that the production of public knowledge is decreasing in the heterogeneity of the group. As a consequence, tracked educational systems should display a relatively higher degree of cooperation and a lower degree of competition, as well as a higher return to cooperation.

So, should one compete or cooperate with his/her schoolmates? The answer to our starting question is that, in spite of individual incentives, cooperation is the learning attitude that yields superior outcomes in terms of average students' achievement. This finding provides evidence in favour of teaching styles aimed at fostering group learning, in line with many contributions of the educational literature. Moreover, the paper suggests that when evaluating the pros and the cons of comprehensive *vs.* tracked educational systems, policy-makers should also take into account the potential negative consequences on student learning that switching to more comprehensive systems may have by reducing the average degree of cooperation among students.

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Notes

1. See Abrami et al. (2000) and Watkins (2005) for a thorough review of the literature.
2. See for instance Watkins (2005) and Cowie and Berdondini (2001).

3. See Shachar and Fischer (2004), p. 83.
4. Zammuner (1995) reports evidence of text quality of individual writing *vs.* dyadic writing/revision in an experiment conducted among fourth graders. She finds higher quality improvement under individual writing and dyadic revision. Hänze and Berger (2007) study the impact of the jigsaw cooperative learning method (i.e. when each student is assigned a specific task in the group activity) in 12th grade physics classes, showing positive effects on intrinsic motivation, experience of competence (especially among low achievers) and activation of deeper level processing.
5. Again, there are many contributions in the economic literature that analyse individual competitive *vs.* cooperative behaviour along different dimensions like gender (Booth 2009, among the others) or ethnic background (Cox, Lobel, and McLeod 1991), but up to our knowledge nothing applied to educational production functions.
6. Similar questions on competitive and cooperative attitudes were raised in 2000. We made use of them as robustness check on our conclusions. See below.
7. Students have to assess how much they agree with the following statements (questions n.37a-37c-37e-37g-37j):

   - *I would like to be the best in my class in mathematics*
   - *I try very hard in mathematics because I want to do better in the exams than the others*
   - *I make a real effort in mathematics because I want to be one of the best*
   - *In mathematics I always try to do better than the other students in my class*
   - *I do my best work in mathematics when I try to do better than others.*

8. Students have to assess how much they agree with the following statements (questions n.37b-37d-37f-37h-37i):

   - *In mathematics I enjoy working with other students in groups*
   - *When we work on a project in mathematics, I think that it is a good idea to combine the ideas of all the students in a group*
   - *I do my best work in mathematics when I work with other students*
   - *In mathematics, I enjoy helping others to work well in a group*
   - *In mathematics I learn most when I work with other students in my class.*

9. Actually, PISA data contain five plausible values for each student, since each student was tested on a subsample of questions. We report here the regressions using as dependent variable the average across the five plausible values; the difference with respect to using the 5 plausible values and the 80 balanced repeated replications is only a very small overestimate of the standard errors, which does not change our results (available from the authors).
10. The countries excluded for not possessing at least 10% of students in the top quartile are Brazil, Indonesia, Thailand, Tunisia, Uruguay and Yugoslavia. France is excluded because it does not contain information on school size and student/teacher ratios.
11. In a third check, we replicate the same estimates country by country, allowing also the coefficients on attitudes to vary. Results are more robust as far as individual attitudes are concerned, not surprisingly given the small number of different observations about aggregate attitudes within countries. Moreover, some country samples turn out to be rather small affecting the statistical significance of the results.
12. This feature is also captured by the theoretical model in section 3, see equation (8).
13. These additional results are available from the authors upon request.
14. We partly deviate from the educational literature previously outlined, which views ‘cooperative learning’ as an activity mainly taking place in class and induced by teachers. We implicitly refer to situations where students are free to choose how to allocate their time/effort and whether to work alone or in groups. Therefore, it mainly applies to study time outside class hours, including for instance student homework done in group.
15. The disutility of learning is modelled separately for private and public knowledge to ensure the existence of internal solutions. Notice that we are shifting from students’ attitudes

towards cooperation/competition (as recorded in the empirical analysis) to a choice variable in terms of time/effort allocation in our sketch model presented here.

16. When class size is sufficiently large, and reputation about being a cooperative person is irrelevant, a purely competitive outcome emerges with individual contribution to public knowledge going to zero: as a consequence public knowledge is also equal to zero.

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