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Peer Effects in Classrooms: Evidence from Random Assignment

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Peer Effects in Classrooms - Evidence from Random Assignment*

Abstract

We apply a novel approach to estimate the effects of exposure to peers with different attributes by using the predetermined leave-one-out attributes of all classmates in randomly assigned classes. This strategy allows a behavioural interpretation of the peer effect over and above the pure mechanical channel. We find that being exposed to peer groups with attributes conducive to academic achievements, induced by random variations in the shares of classmates with collegeeducated parents, increases exam scores. We show that estimates based on the commonly used leave-one-out measures are highly sensitive to sample selection bias arising from non-random tracking in the sample. We show that estimates based on the commonly used leave-one-out measures are highly sensitive to non-random tracking in the sample.

JEL classification

I20, I24

Keywords

parental education, random assignment, China

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1. Introduction

The peer effect has attracted much attention from economists and the literature has grown exponentially recently (see Sacerdote, 2011). Identifying peer effects in empirical research is challenging due to the selection and the reflection problems (Manski, 1993). This has motivated an emerging literature using random class assignment design, quasi-experiment design, or random control trials (Kang, 2007; Duflo *et al.*, 2011). In a nutshell, academic performance has been affected after the exposure to (dis)advantaged students in a group, measured by family educational background (Kim *et al.*, 2021; Chung and Zou, 2023), repeaters (Huang and Zhu, 2020), left-behind children (Lao *et al.*, 2024), gifted students (Mendolia *et al.*, 2018), rural *hukou* (Xu *et al.*, 2024), migrant status (Wang *et al.*, 2018; Zhang and Zhou, 2023) and other family characteristics. Researchers interpret the variation in the classmates' characteristics as exogenous changes in environment which influences research subjects in the same class, known as the contextual/exogenous peer effect (Bramoullé *et al.*, 2020), that is identified using the *leave-own-out* measure.

However, the fundamental ambiguity of interpreting peer effect using *leave-own-out* variables results from omitted variables and endogenous peer group formation, leaving the impression that the peer effect has been directly driven by classmates' backgrounds. Students tend to form more homogeneous ability peer groups in the presence of endogenous peer group formation (Carrell *et al.*, 2013; Calvano *et al.*, 2022). The recent literature has documented a nonlinear and heterogeneous peer effect (Carrell, 2009; Booji *et al.*, 2017; Garlick, 2018). A positive peer effect among the middle ability group due to fewer interactions with students in the low ability group and a negative peer effect among the lowest ability students when being exposed to high ability peers have been documented (Carrell *et al.*, 2013; Booji *et al.*, 2017).

Interests have gathered on the mechanisms behind the peer effect. The estimation of causal peer effects is achieved by clearly identifying the subject of study and specifying the mechanisms through which peers influence each other (Angrist, 2014). Advantaged students, measuring by pre-determined variables, provide the mechanisms of affecting disadvantaged peers. It has been documented that peer effect results from group incentives and group coordination rather than individual incentives or better peers, implying that the social interaction is a complex but important

source of generating the *social multiplier* (Li *et al.*, 2014; Babcock *et al.*, 2020).¹ We view the peer effects in classrooms, estimated by *leave-own-out* variables, as the impact of studying in classrooms with different students' backgrounds rather than the direct impact of interacting with classmates who have a certain background in the presence of omitted variables. In this paper, we focus on the peer effects of being exposed to students whose parents are degree-educated, working through the quality of an endogenously formed friendship. We contribute to the literature by examining the impact of peer attributes underpinning behavioural mechanisms after the exposure to the exogenous environment changes of classmates in randomly assigned classes which affects the formation of the friendship-based peer group. The exposure to peers with different attributes can generate distinctive peer effects. Hill and Zhou (2023) show that exposure to more local classmates who report anti-migrant discrimination results in lower test scores of migrants. Zou (2024) finds that having more persistent peers improves academic achievements and foster beneficial behaviours. Peer anxiety and peer self-confidence do not generate significant peer effects, whereas peer persistence does (Golsteyn *et al.*, 2021). In this paper, we show being exposed to hard-working peers influences students' performance more than being exposed to peers with college aspirations.

Taking advantage of random class assignment and direct responses on peers' quality, we address the endogeneity of formation of friendship-based peer attributes in a value-added framework by using the *leave-own-out* measures as proxies for peer quality. Using the novel China Education Panel Survey (CEPS) data, we are the first paper to examine the distinctive impacts of peers' attributes on academic performance in **naturally occurring peer groups**, induced by random variations in *leave-own-out* share of advantaged students in the classroom. In this paper, to identify the direct impacts from peers, we reserve the term "**peers**" for the direct source of impact from the endogenous "**peer group**", consisting of the self-reported up to 5 closest friends. In contrast, we use the term "**classmates**" to denote the source of exogenous variation in the environment of a classroom from all other students in a class.

We make two main contributions to the literature in this paper, based on a novel identification strategy which distinguishes between classmates (exogenous environment) and friendship-based

¹ The *social multiplier* in the classroom refers to the idea that an intervention targeting an individual student might result in amplified aggregate effects through positive interactions and peer behaviour "spill-overs".

peers (endogenous groups) and employs leave-own-out measures as instruments in a 2SLS framework. First, methodologically, we emphasize the sensitivity of the commonly used *leave-own-out* approach to imperfect randomization in CEPS, that is showing that peer effect estimates may be biased under lax randomization rule. Specifically, we show that the unbiasedness of *leave-own-out* measures strongly depends on the validity of random assignment and sample selection bias, by exploiting the availability of information on classroom random assignment from alternative sources. While standard balancing tests (Guryan *et al.*, 2009) are insensitive to minor violation of random assignment, estimates of peer effects are highly sensitive to the violation of the random assignment condition. Based on the responses to the classroom assignment question from both principals and subject teachers, we show the sample based only on principals' responses have higher risks of non-randomisation, suggested by disparities in conventional balancing tests.² The bootstrapping results suggest that the samples based on two alternative sample selection rules are likely drawn from different distributions after examining the distribution of balancing test of other measures used in the literature, such as classmates with alcoholic parents (Zhao and Zhao, 2021), and classmates who have repeated grades in primary schools (Huang and Zhu, 2020; Xu *et al.* 2020). The estimates of peer effects are massively diminished in the sub-sample arising from stricter random class assignment rule.

Another contribution is that we show peer attributes drive academic performance more strongly than background, with disadvantaged students benefiting disproportionately from exposure to advantaged peers. Specifically, we show that the impacts of peers on test scores vary by the distinctive behavioural attributes of peers — exposure to hard-working peers increases test scores more than exposure to peers who have higher aspirations for college or have better academic achievements. The results imply that it is not the peers *per se* but peers' attributes such as diligence and college aspiration that generate peer effects and the *social multiplier*. This is consistent with the research examining the relationships between group incentives, peers' personalities and peer effects (Li *et al.*, 2014). The exogenously changed classroom composition alters peers' qualities, resulting in distinctive behaviours and attitudes, which in turn contribute to the higher academic achievements among those being exposed to more productive peers in their peer group. We also

² There is substantial inconsistency in their responses, with disagreements in about 60% of the cases.

observe heterogeneity in social interaction between students of different parental education background and prior educational attainment.

2. Data and baseline empirical strategy

The China Education Panel Survey (CEPS) is a large-scale, nationally representative longitudinal survey starting with two cohorts – the 7th and 9th graders in the baseline survey conducted in the academic year 2013-14 (<https://ceps.ruc.edu.cn/index.php?r=index/index&hl=en>). The baseline survey contains 5 different questionnaires for the sampled students, parents, class headteachers, core subject teachers other than headteachers, and school principals respectively. Moreover, the survey includes a standardized cognitive ability test for students in each grade and an internet-based personality test for all sample students and collects transcripts of important (mid-term) examinations. The CEPS follows a stratified, multistage sampling design with probability proportional to size (PPS), randomly selecting a school-based, nationally representative sample of approximately 20,000 students in 438 classrooms of 112 schools in 28 county-level administrative units in mainland China. In each relevant grade, all students from two randomly selected classes are included in the survey. Using CEPS, researchers have examined peer effects of being exposed to a higher proportion of students with different backgrounds, measured by *leave-own-out* variables. Advantaged backgrounds of classmates, such as children with educated parents (Chung and Zou, 2023), increase the academic achievements. On the other hand, poorer academic achievements have been documented after being exposed to students with disadvantaged backgrounds, such as children with alcoholic parents (Zhao and Zhao, 2021), left-behind children (Zheng and Zhou, 2024), and repeaters (Huang and Zhu, 2020; Xu *et al.*, 2020). In addition, classmates' family backgrounds, such as single child (Cai *et al.*, 2022), higher same-gender ratio (Luo and Yang, 2022), and migrant status (Wang *et al.*, 2018) have been documented to have significant impacts.

Table 1. Roadmap of sample selection

	Steps	Sample composition	Average class size
Data preparation	Linked student, parent, teacher and principal's data in the CEPS 2013-2014 baseline survey	112 school, 438 classes	48.34
	Drop 8 classes due to missing information in teacher's data	112 schools, 430 classes	48.5
	Grade 7 only	112 schools, 218 classes	49.62
	Schools with class-pairs in Grade 7 (sample used for balancing tests in Table A3)	106 schools, 212 classes	49.47
Analytical sample	<i>Lax Rule</i> (Schools with random class assignment in Grade 7 according to principals' questionnaires only)	66 schools, 132 classes	49.04
Of which	<i>Strict Rule</i> (Subset of schools where there is full agreement between principals and all subject teachers)	27 schools, 54 classes	47.49

Our main sample includes all Grade 7 students in the 2013-14 baseline survey, as well as the follow-up survey of the Grade 7 cohort in the following academic year.³ We firstly show how we make use of the responses of both schools' principal and subject teachers on the randomisation of students into classes. Table 1 shows the roadmap of sample selection. Of the 106 schools with full information on class assignment in Grade 7, 40 and 66 schools follow non-random and random assignment rules respectively, according to the principals' questionnaire only. The latter group forms our analytical sample, by what we term the *lax rule* which is in keeping with previous CEPS studies. In contrast, the *strict rule* is defined as random assignment cases with full agreement between principals and teachers, which is satisfied by only 27 (40%) schools in the analytical sample. Table 2 presents the summary statistics. It is worth noting that the average class size of the sample following the *lax rule* is statistically significantly larger than the sample following the *strict rule*.

³ We exclude Grade 9, due to failure of randomisation arising from regrouping, attrition and entry.

Table 2. Summary of variables

VARIABLES	(1)	(2)	(3)	(4)
	Lax rule		Strict rule	
	mean	sd	mean	sd
Cognitive scores in grade 7	0.10	0.87	0.15	0.87
Chinese scores	70.52	9.55	70.51	9.62
Math scores	70.48	9.66	70.39	9.66
English scores	70.57	9.59	70.53	9.53
Peers studying well	2.42	0.60	2.42	0.60
Peers studying hard	2.43	0.63	2.44	0.61
Peers degree-motivated	2.67	0.57	2.70	0.55
Class size	49.04	12.33	47.50	12.04
Rural <i>hukou</i>	0.44	0.50	0.43	0.50
Male	0.51	0.50	0.51	0.50
Single child	0.49	0.50	0.55	0.50
Advantaged child (parental degree)	0.23	0.42	0.26	0.44
Repeaters	0.11	0.31	0.10	0.30
Alcoholic parents	0.46	0.50	0.45	0.50

In the presence of omitted variables, a *leave-own-out* variable of advantaged peers measures the reflection of having higher proportion of advantaged students rather than how advantaged classmates' attributes generate peer effect. Students not exposed directly to advantaged classmates may still be affected by common friends. The *leave-own-out* measures do not shed light on how the peer effect has been generated.

Inspired by the recent development on the peer group formation (Boucher *et al.*, 2014; Jochmans, 2023b; Hill and Zhou, 2023), we employ Two-Stage Least Squares (2SLS) to examine the distinctive peer effects resulting from the interaction with peers having different attributes in a value-added framework. The *leave-own-out* variable across randomly assigned classes is used as instruments to address self-selection into classrooms. Instead of using *leave-own-out* variables as proxies for peers' quality, our data contains detailed responses on peers' behaviours measuring peers' quality directly. Therefore, our empirical strategy estimates the Local Average Treatment Effect (LATE), induced by exposure to exogenous variations in the concentration of advantaged peers.

We make use of the distinctive impacts of being exposed to advantaged students between advantaged and disadvantaged students due to the endogenous peer group formation. A growing

literature has documented the heterogenous peer effect after being exposed to the same classroom environment (Carrell *et al.* 2013; Booji *et al.* 2017). We expect the probabilities of forming friendship with advantaged students to differ by students' family background due to homophily (Calvano *et al.*, 2022). In the presence of endogenous peer group formation, we argue that disadvantaged students may benefit more in a randomly assigned classroom with a higher concentration of advantaged students compared to advantaged students and make use of this variation to bridge the peers' quality and the environment of classrooms.⁴ Following the literature, we employ a value-added framework to estimate the peer effect (Hanushek *et al.*, 2003), in which baseline scores are used to proxy cumulative past inputs. Our empirical specification is below:

$$Qua_{ig}^7 = \gamma_1 Cla_{-ig}^7 * Educated\ parents_i^7 + \gamma_2 Cla_{-ig}^7 + \gamma_3 Educated\ parents_i^7 + \delta X_i^8 + \theta T_{is}^7 + \alpha y_{igs}^7 + \tau S_i^7 + \varepsilon_i \quad (1)$$

$$y_{igs}^8 = \beta_1 \widehat{Qua}_{ig}^7 + \beta_2 Cla_{-ig}^7 + \beta_3 Educated\ parents_i^7 + \alpha y_{igs}^7 + \delta X_i^8 + \theta T_{is}^7 + \tau S_i^7 + \varepsilon_i \quad (2)$$

where y_{igs}^8 represents the standardised cognitive test scores or exam scores for student i in class g in Grade 8, while s denotes the subject. S_i^7 denotes school fixed-effect and T_i^7 denotes teachers' characteristics, including gender, qualification, years of experience, and teaching certificate. To avoid the bias from simultaneity, Cla_{-ig}^7 denotes the *leave-own-out* measure using students' family background, specifically the proportion of classmates with parents having a degree in Grade 7, and X_i^8 denotes the time-invariant individuals' characteristics, family background and attrition rate between Grade 7 and 8. The variable $Educated\ parents_i$ equals one if a student has at least one college-educated parent, a proxy for socio-economic advantage. The interaction between the *leave-own-out* measure and own parental educational background works as the instrument for the endogenous peers' quality Qua_{ig}^7 . γ_1 represents the impact of classmates' backgrounds on observed peers' quality.

⁴ Assume a classroom with 20 students, including 5 advantaged and 15 disadvantaged students. In the presence of endogenous peer group formation, the 5 advantaged students might form a group, leaving the remaining disadvantaged students with limited interaction with the advantaged students. Conversely, in a classroom with 10 advantaged and 10 disadvantaged students, the likelihood of disadvantaged students forming friendships with advantaged students increases.

Qua_{ig}^7 represents the observed peers' quality based on the questionnaire, such as how many of your friends are hard-working or how many friends are going to a university. We measure peers' quality directly using the responses on the characteristics of the up to 5 closest friends in the class and take advantage of the availability of information on all students in the randomly assigned classrooms in the CEPS to derive a precise measure of the pre-determined *leave-own-out* mean characteristics of all classmates in the classroom. The parameter of interest is the coefficient β_1 on Qua_{ig}^7 , which denotes the influence of peers' attributes on test scores. We estimate three specific peers' attributes based on their responses on the question 'Do any of mentioned close friends (i) have excellent academic performance, (ii) are hardworking in studies, and (iii) aspire to attend university?'. The peers' attributes are standardised over the estimation sample to have a zero mean and one standard deviation. In the presence of endogenous peer group formation, advantaged students form friendship with more 'better-quality' friends who are more motivated and have good habits, suggested by Figure A1. It is worth noting that we don't have objective measures for peers' quality and the subjective measures are subject to measurement errors and rely on an assumption that their perception doesn't vary with the composition of classmates with different backgrounds. This is an empirical assumption that we can't ascertain. We have provided a correlation table to show the correlation of students' self-reported peers' quality, proxied by 8 attributes, in Table A1. Those beneficial attributes, such as hard-working, and study-well, are strongly positively correlated with each other and these are negatively with detrimental behaviours and attributes, such as skipping classes, attending game centre, etc. While we can't rule out the measurement errors inherent in subjective measures, the correlation table shows consistency regarding their response on peers' qualities.

<Table A1 Here>

<Figure A1 Here>

Our proposed empirical approach provides the opportunity to examine mechanisms of peer effect, through which individuals' attributes are affected by their peers. Inspired by Angrist (2014), we argue that the peer effect is generated through peers' characteristics and interactions between them rather than merely reflecting peers' background, implying that it is not the peers themselves *per se* but the attributes of peers and the interaction between peers that affect outcomes. Consequently, the peer effect, estimated by the 2SLS strategy exploiting exogenous changes in the

environment in terms of the concentration of advantaged students, estimates the impacts of peers' attributes from the peer group stemming from the connection with students in the presence of endogenous peer group formation. In addition, it allows us to estimate the distinctive peer effects resulting from different attributes of peer groups. For instance, being exposed to students with better academic achievements may not necessarily generate positive peer effect if peer groups are self-formed and peers are not motivated to share the experience on study. On the other hand, having helpful and cooperative peers may increase the interaction between peers and increase test scores by sharing information or motivating each other, implying that different attributes of advantaged classmates may have distinctive impacts.

The identification of causal peer effect relies on the distinctive probabilities of forming friendship with advantaged students arising from their backgrounds, measured by the interaction term (Calvano *et al.*, 2022). It hinges on the assumption that the peers' attributes affect one's own academic performance only through the interaction with peers directly rather than through other channels after the exposure to more advantaged peers. However, there are concerns that the changed classroom environment may affect teacher's behaviours and teaching style, and the general classroom atmosphere, which may in turn may impact students distinctively and hence bias the causal estimates.

To further control teachers' practices, we have included teacher's characteristics, T_i^7 , including gender, qualification, years of experience, and teaching certificate. We also control for class size to ensure that the peer effect is not driven by variation in class sizes. We have included the attrition rate to control for the potential bias arising from attrition in Grade 8.⁵ To the extent that the attrition from random assigned classes is random, the estimated peer effect is valid. The value-added framework will further address possible non-randomisation and idiosyncratic factors.

Although this remains an empirical question and we cannot rule out the possibility, we are cautious to claim our estimates as the causal peer effect. However, we mitigate potential biases by utilising the randomised design. Therefore, we argue that our estimates predominately reflect the impact of interaction with more advantaged peers in classrooms.

⁵ If students' attrition is associated with the unobserved factors in the classroom, the change in class composition may bias peer effect estimates. Due to the relatively small sample size, we could not restrict the analysis further unfortunately.

To investigate how peer groups are formed and to motivate our 2SLS framework, we utilise information on an individual's 5 best friends to examine how the association of one's own behaviour with one's best friends' attributes varies with exogenous increases in the concentration of advantaged students in the classroom, as shown in Tables A2 and A3.

Table A2 presents the association between students who frequently arrive late to class, serving as an indicator of a 'negative' student behaviour, and their peers' attributes in a peer group. Frequently being late for school oneself is associated with fewer detrimental behaviours within one's friend network after the exposure to classrooms with more advantaged peers, as indicated by the interaction terms between individuals' own behaviours and those of their peers, suggesting that students who have detrimental behaviours themselves have 'better-quality' friend network after the exposure to a more beneficial environment. Conversely, when considering one's own time spent on studies, which is regarded as a strong indicator of a good student, the results show that after exposure to a more beneficial environment, individuals' networks exhibit fewer beneficial behaviours compared to classmates who spend less time studying in Table A3.

The results consistently indicate that students with poorer habits benefit more from environments with more advantaged peers in the presence of endogenous peer group formation. This observation motivates our first stage in the 2SLS design, where we exploit distinctive responses arising from students' parental backgrounds following the exposure to exogenous environmental changes.

<Table A2 and A3 Here>

3. Results.

3.1 Peer effect based on value-added model

Following the peer effect literature on the impacts of exposure to advantaged peers, we start by estimating the linear-in-means model on students' test scores based on the value-added framework in Table 3. It is worth noting that the empirical setting differs from previous research. First, we are employing a value-added framework using the test score in Grade 7 as the measure for cumulative academic performance. Second, all our results are based on the strict rule on sample selection. Table A4 presents the results of the balancing test based on the two alternative sample selection rules at both individual- and class-level. In our sample, the results suggest that the proportion of

classmates with degree-educated parents is associated with classmates' *hukou* status and age at both levels based on the *Lax Rule*. Larger classes are also associated with more classmates with educated parents at the individual level under the *Lax Rule*. However, none of these associations has been detected based on the *Strict Rule*.

<Table A4 Here>

We find significant effect of having more advantaged classmates on test scores under three different specifications in Table 3. Having higher share of peers with educated parents in the classroom have positive impacts on test scores, consistent with the literature. Additionally controlling for school-level share of educated parent's peers, which is itself statistically insignificant, has no effect on the main peer effect based on classroom-level measure of advantaged peer. This lends further support to the random classroom assignment assumption. Finally, advantaged students gain nearly half of the positive peer effect arising from having more advantaged classmates compared to their disadvantaged counterparts. The heterogenous peer effects varied by backgrounds suggest the endogenous peer group formation.

Table 3. Peer effects measured by the *leave-own-out* measure using the strict sample

	(1)	(2)	(3)
	Dependent variable: Test scores		
Educated parents peers' share	0.441** (0.20)	0.441** (0.20)	0.536*** (0.20)
Educated parents peers' share at school level		5.387 (12.06)	0.314 (12.33)
Parental degree			0.308*** (0.10)
Educated parents peers' share X Parental degree			-0.281** (0.12)
<i>N</i>	5,856	5,856	5,856

Notes: $y_{igs}^8 = \beta_2 Cla_{-ig}^7 + \alpha y_{igs}^7 + \delta X_i^8 + \theta T_{is}^7 + \tau S_i^7 + \varepsilon_i$. Grade 7-8 panel data. The results are based on the strict sample selection rule. The estimates of having educated parents peers in the third column have excluded students with parents having a degree. Exam scores are normalised by school and standard errors (in parentheses) are clustered at the class-subject level. Control variables include individual characteristics such as corresponding scores in Grade 7, attrition rate, class size, gender, *hukou* (household registration), age, single child, parent's highest education, school and subject fixed effects, and subject teachers' characteristics include gender, age, educational level; teacher characteristics include gender, teaching certificate, experience, and qualification.

Table 4 presents the main results of peer effects based on our empirical framework. Panel A presents the OLS benchmark, which is subject to omitted variable bias discussed above. Panel B and Panel C show the corresponding 2SLS impacts of peers' attributes on test scores and the impacts of having advantaged peers on peers' quality, respectively. In Panel C, we find that while the main effects of classmates with educated parents and having educated parents oneself are both positive, their interactions are negative and substantial, even more than offsetting the benefit of having educated parents in the case of degree motivation. This implies that compared to advantaged students, disadvantaged students benefit much more from a higher proportion of advantaged students due to endogenous peer group formation. With more advantaged students in a class, disadvantaged students have a higher probability of forming friendships with advantaged students, conditional on their own parental background. In Panel B, the results suggest that having advantaged peers (closest friends) has positive impacts on one's own test scores. More importantly, the results suggest that peers may have impacts on test scores through different channels. Although these three attributes all have positive impacts on test scores, the magnitude differs by the quality of the peer. Although the impact of having hard-working peers is less significant, the magnitude is the largest among the three attributes, possibly resulting from the weaker first-stage estimation. We argue that being exposed to peers with similar background but having different revealed characteristics in randomly assigned classes will induce a distinctive peer effect through the nature of characteristics and the way that peers interact.

Table 4. Peer effect of exposure to advantaged classmates

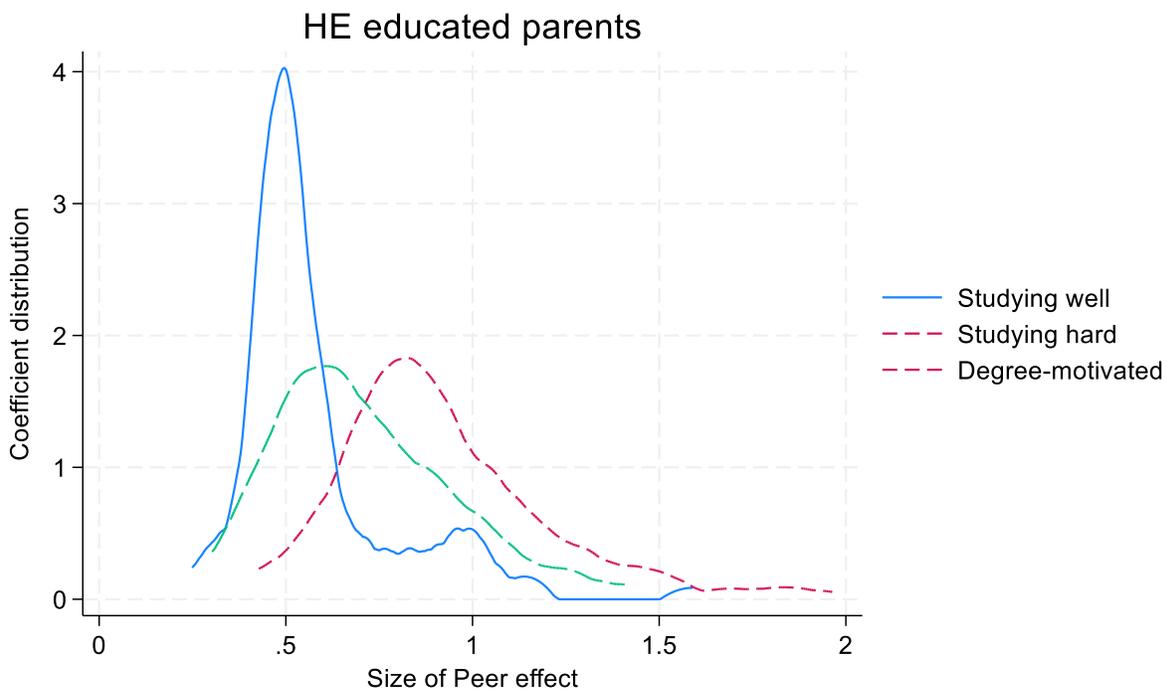
Panel A, OLS			
	(1)	(2)	(3)
	Dependent variable: Test scores		
Peers studying well	0.040*** (0.01)		
Peers studying hard		0.053*** (0.01)	
Peers degree-motivated			0.061*** (0.01)
Educated parents	0.212** (0.09)	0.216** (0.09)	0.220** (0.09)
Educated parents peers' share	0.425** (0.20)	0.401** (0.20)	0.400** (0.20)
Educated parents peers' share at school level	3.889 (11.88)	5.599 (11.65)	4.770 (11.94)
<i>N</i>	5,856	5,856	5,856
Panel B, 2SLS Second Stage			
	(1)	(2)	(3)
	Dependent variable: Test scores		
Peers studying well	0.533** (0.24)		
Peers studying hard		0.908* (0.51)	
Peers degree-motivated			0.660** (0.33)
Educated parents	-0.054 (0.17)	-0.061 (0.19)	0.092 (0.12)
Educated parents peers' share	0.229 (0.25)	-0.236 (0.48)	-0.003 (0.32)
Educated parents peers' share at school level	-14.601 (15.73)	9.023 (22.97)	-1.326 (13.01)
<i>N</i>	5,856	5,856	5,856
Panel C, 2SLS First stage			
	(1)	(2)	(3)
	Peers studying well	Peers studying hard	Peers degree-motivated
Educated parents peers' share	0.575*** (0.17)	0.850*** (0.20)	0.817*** (0.22)
Educated parents	0.678*** (0.16)	0.407** (0.19)	0.327*** (0.11)
Educated parents peers' share X Educated parents	-0.527*** (0.15)	-0.309* (0.18)	-0.426*** (0.14)
Educated parents peers' share at school level	27.972 (17.32)	-9.595 (25.59)	2.486 (11.51)
<i>N</i>	5,856	5,856	5,856

Notes: Grade 7-8 panel data. The results are based on the strict sample selection rule. Exam scores are normalised by school and standard errors (in parentheses) are clustered at the class-subject level. Control variables include individual characteristics such as corresponding scores in Grade 7, attrition rate, class size, gender, *hukou* (household registration), age, single child, parent's highest education, school and subject fixed effects, and subject teachers' characteristics include gender, age, educational level; teacher characteristics include gender, teaching certificate, experience, and qualification. The following regressions have the same control variables unless specified otherwise.

Identifying the peer effect under a strict random assignment design might be subject to low power due to the reduced sample size. Given the idiosyncratic nature of estimating peer effect using random assignment rather than using a field experiment, we provide the sensitivity test for the 2SLS results by bootstrapping, which involves randomly selecting 90% of the sample and generating the distribution of the treatment effect shown in Figure 1.

Panel A in Figure 1 shows the distribution of the treatment effect. It clearly shows that the effect of the ‘studying well’ attribute is stronger and has smaller standard error. Panel B shows that attributes present different robustness of the result by bootstrapping the results by 100 times. Staying with peers studying well is more robust than having friends with the other two attributes, with 63 significant results out of 100 random draws.

Figure 1. Robustness check
Panel A, Distributions of peer effect based on value-added model and bootstrap



Note: The distributions are drawn from 2SLS setting.

Panel B, Treatment distribution based on value-added model and bootstrap

Outcomes	Non-significant	Significant	Total
Peers studying well	37	63	100
Peers studying hard	75	25	100
Peers degree-motivated	73	27	100
Total	185	115	300

3.2. Bias from non-randomisation

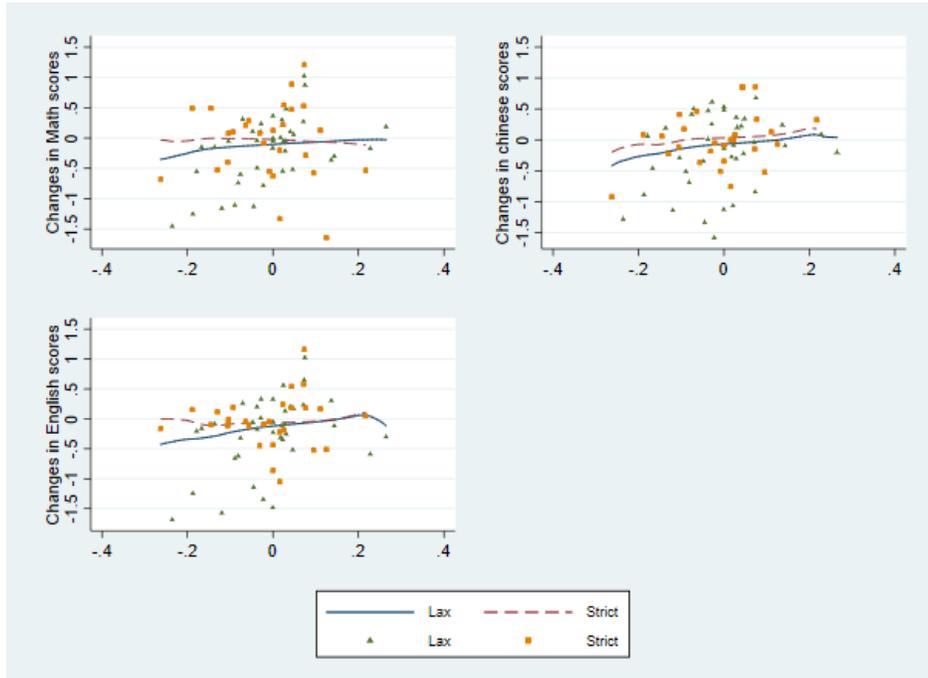
Randomisation is the fundamental identifying assumption underpinning peer effect estimation. Previous research has heavily relied on random assignment classes in the CEPS to account for self-selection into classes.

In this section, we highlight how the *leave-own-out* empirical design could be highly sensitive to non-randomisation which results in biased estimates. To compare with the existing literature examining peer effect using CEPS, we construct a new sample using students in Grade 7, and select the sample based on alternative rules according to the responses from principals and subject teachers on randomisation. We find that there is a strong inconsistency of the responses on randomisation between principals and subject teachers.

We firstly provide visual aid in the differences in sample showing the differences in the impacts on test scores. We then re-examine the balancing tests which are widely used in peer effect literature, shown in Table 5. We then move on to examine the peer effects measured by students' backgrounds and show that peer effect vary significantly by sample selection rules, as shown in Figure 3 and 4.

Figure 2 presents the scatter plots of the within-school class-pair differences in mean academic performances against differences in mean shares of college educated parents. The differences in the polynomial fitted lines between the *lax* and *strict rules* strongly indicate an upward bias in the estimated peer effects if the measurement errors in random assignment under the *lax rule* are overlooked.

Figure 2. Scatter plots of the class-pair differences in mean academic performances against mean differences in advantaged peers share, by random assignment type



Notes: Each dot plots the differences in mean academic performances against mean differences in mean shares of college educated parents for Math, English and Chinese. The fitted lines are based on local polynomial smoothing.

We then show the statistical differences in students’ backgrounds between classes based on the responses, shown in Table A5. We suspect that the responses of principals may not reflect the reality on the randomisation in schools. Based on this feature, in the following section, we examine how the violation of randomisation affects the estimation of peer effects by affecting the extent to which the selected sample violates the validity of randomisation.

<Table A5 Here>

Following Guryan *et al.* (2009), most existing studies of peer effect rely on the balancing test to verify the randomness of sample. We replicate the balancing tests following the previous CEPS studies that have examined the peer effects resulting from different students’ backgrounds, such as educated parents (Chung and Zou, 2023), repeaters (Huang and Zhu, 2020; Xu *et al.*, 2020), and alcoholic parents (Zhao and Zhao, 2021).

We first replicate the balancing tests based on different samples. The first three panels in Table 5 show the balancing tests of three different *leave-own-out* measures, including shares of educated

parents, shares of repeaters, and shares of alcoholic parents based on three distinctive samples. Although the balancing tests in previous research have not suggested significant relationship between the *leave-own-out* measures and individuals' backgrounds, our sample using the lax rule has shown that the shares of educated parents and the shares of repeaters have predictive power in students' backgrounds. Based on the sample using the strict rule, the *leave-own-out* measures shrink massively and become insignificant. We also show that the relationships are still significant after excluding schools following the strict rule, shown in the third column. The sharp differences between the two samples arising from the inconsistent responses on classroom randomisation cast doubt on the validity of randomisation. Moreover, the validity of the balancing test based on *leave-own-out* measures has been questioned by Jochmans (2023a) which argues that the frequently used balancing test (Guryan *et al.*, 2009) fails to detect violations of the null of random assignment. He proposes a revised balancing test to present the correct size in large samples and to address the low power of the original balancing test.

Lastly, we employ the recently developed balancing test by Jochmans (2023a) to investigate the imbalance between the two samples. Panel D shows the results based on two samples, suggesting that the classes based on principal's response on randomisation may have higher risk of non-randomisation.

Table 5. Balancing test

Panel A, Educated parents			
Dependent variable = Parental degree	(1) Lax Rule	(2) Strict Rule	(3) Lax Rule Excluding Classes using the Strict Rule
Educated parents peers' share	0.106** (0.05)	0.042 (0.09)	0.117** (0.04)
Educated parents peers' share at school level	-108.321*** (27.08)	-82.150** (34.58)	-142.817*** (8.87)
<i>N</i>	5,834	2,331	3,503
Panel B, Repeated peers			
Dependent variable = Repeater	(1) Lax Rule	(2) Strict Rule	(3) Lax Rule Excluding Classes using the Strict Rule
Repeated peers' share	0.149*** (0.06)	0.074 (0.06)	0.098* (0.06)
Repeated peers' share at school level	-151.030*** (7.88)	-131.500*** (11.42)	-168.102*** (7.42)
<i>N</i>	5,834	2,331	3,503
Panel C, Alcoholic parents			
Dependent variable = Alcoholic parents	(1) Lax Rule	(2) Strict Rule	(3) Lax Rule Excluding Classes using the Strict Rule
Alcoholic parents peers' share	0.013 (0.02)	0.002 (0.03)	0.032* (0.02)
Alcoholic parents peers' share at school level	-121.102*** (21.37)	-95.731*** (30.14)	-151.171*** (6.76)
<i>N</i>	5,834	2,331	3,503
Panel D, Balancing test following Jochmans (2023a)			
	Lax rule excluding strict sample	Strict rule	
Educated parent's peers	2.13 (0.03)	1.68 (0.09)	
Repeater peers	1.89 (0.06)	-1.34 (0.18)	
Alcoholic parent's peers	-0.20 (0.84)	0.77 (0.94)	

Note: The Guryan's balancing test follows the conventional form: $Test\ score_{ig} = \alpha Characteristic_{-ig} + \beta Characteristic_{-is} + \tau S_i + \varepsilon_i$, where $Characteristic_{-ig}$ and $Characteristic_{-is}$ denote the leave-one-out measures for classes and schools, respectively. S_i denotes the school fixed-effect. The results include T-test (P-value) following the balancing test proposed by Jochmans (2023a). The null hypothesis of the test is absence of correlation.

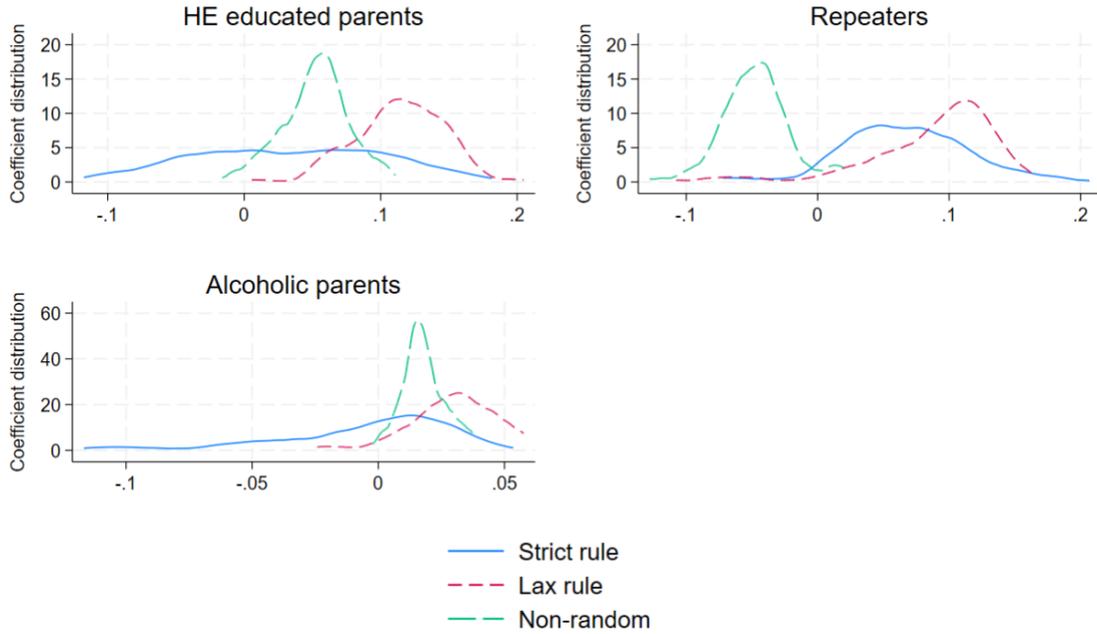
Previous research has made use of both Grade 7 and Grade 9, based on the assumption that the responses on randomisation are correct (Huang and Zhu, 2020). However, due to the pressure on the high-stakes High School Entrance Examination at the end of Grade 9 which is the final year of compulsory education, more schools might be motivated to adopt ability streaming to boost the enrolment into the key high schools.

As the survey designers do not have any control over classes when students progress from Grade 7, we cannot rule out the risk of non-randomisation in Grade 9. We then test if the samples are drawn from the same distribution based on the two sample selection rules in Grade 7 and Grade 9, respectively. We employ bootstrapping to calculate the distribution of the balancing test (Guryan *et al.*, 2009) originating from randomly selecting 80% of the classes based on two sample selection rules.

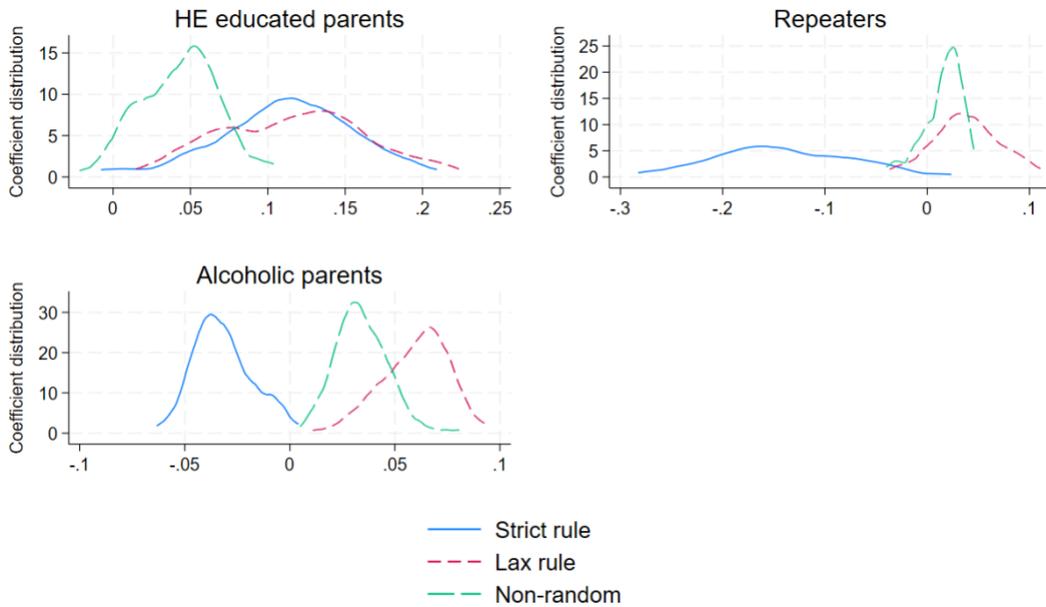
Figure 3 shows the distribution of the result from the balancing test between Grade 7 and Grade 9. The sub-figures in Panel A show the distributions of balancing test estimated from three *leave-out* measures — educated parents, repeaters, and alcoholic parents. Each sub-figure includes three distributions; sample using the lax rule, sample using the strict rule, and non-randomised sample that has not been used in the peer effect research. They show that the distributions of balancing test using different sample selection rules are rather different. The distributions of non-randomised sample are even more centred around zero compared to the sample using the lax rule. This casts doubt on the principals' response on the randomisation. The distribution of balancing test using the strict rule have larger standard error and are closer to zero, compared to that using the lax rule.

Panel B shows the distributions based on Grade 9 classes. As the distribution of non-random sample is even closer to zero compared to both the lax rule and the strict rule, this may suggest that classes in Grade 9 are not strictly randomised due to unobservables. It may result in even more sensitive results when we use the Grade 9 sample.

Figure 3. Distribution of balancing tests using bootstrap
 Panel A, Grade 7



Panel B, Grade 9

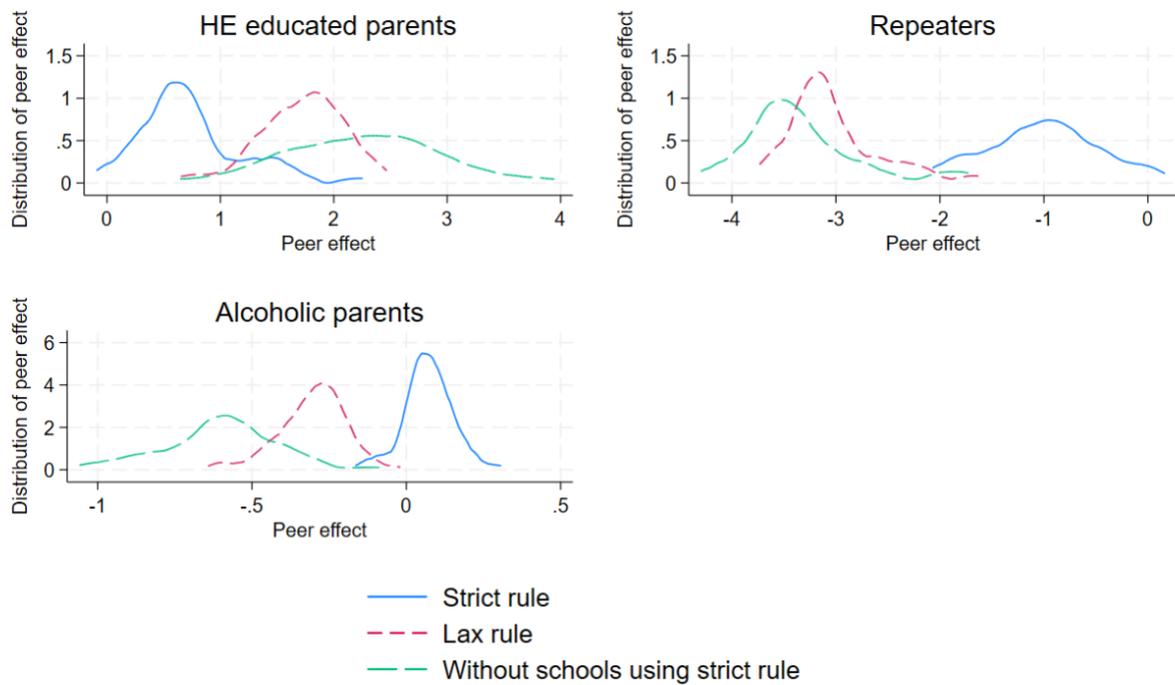


Note: $Test\ score_{ig} = \alpha Characteristic_{-ig} + \beta Characteristic_{-is} + \tau S_i + \varepsilon_i$, where $Characteristic_{-ig}$ and $Characteristic_{-is}$ denote the leave-one-out measures for classes and schools, respectively. S_i denotes the school fixed-effect. The bootstrap randomly selects 80% of the corresponding sample 100 times.

To show the impacts of sample selection rule on the estimation of peer effect, we examine the peer effect following previous research using CEPS. Figure 4 shows the distributions of peer effects in Grade 7, generated from bootstrapping. It clearly shows that the estimated peer effects have largely shifted to the origin when we use the strict sample rule while the results show the largest peer effect after excluding the schools following the strict rule.

Taken together with the evidence above, we conclude that using the lax rule has higher risks of non-randomisation, resulting in larger peer effects. More importantly, the results suggest that peer effects estimated by *leave-own-out* measures might be biased in the presence of possible non-randomisation even passing the conventional Guryan’s balancing test due to sample selection bias.

Figure 4. Distributions of peer effect using bootstrap



Note: Grade 7. Following the setting in previous research, $y_{igs}^7 = \beta_2 Cla_{-ig}^7 + \delta X_i^7 + \theta T_{is}^7 + \tau S_i^7 + \varepsilon_i$. Control variables include individual characteristics, including size, gender, *hukou* (household registration), age, single child, parent’s highest education, school and subject fixed effects, and subject teachers’ characteristics include gender, age, educational level; teacher characteristics include gender, teaching certificate, experience, and qualification.

4. Conclusions.

We contribute to the peer effect literature mainly by uncovering the behavioural aspects of peer effects induced by exogenous changes in environment working through the quality of endogenously formed friendship, and by examining the potential bias resulting from the violation of randomisation in OLS regressions on quality of peers proxied by group means.

Although numerous empirical research has found strong evidence of peer effects on various outcomes, little research has explored the underlying mechanisms of the interaction between peers (Li *et al.*, 2014; Babcock *et al.*, 2020). Interaction within peer groups generates complex peer effects and some studies have argued that peer effects are non-linear (Carrell *et al.*, 2009; Booji *et al.*, 2017; Garlick 2018). We propose to estimate the peer effect by measuring peers' quality directly using predetermined *leave-own-out* measure in randomly assigned classes as instruments to address the endogenous sorting into peer groups. Our empirical framework estimates the peer effect of having more advantaged classmates (with college-educated parents) on test scores, through the attributes of the self-reported friendship-based peer group (i.e. the 5 closest friends). Our results suggest that although the interaction between peers provides the opportunity to generate peer effects, it is peer behavioural attributes that determine how peers impact each other. Friends with similar backgrounds may have many different attributes, of which only a few might really matter for the peer effect in the context of a school environment.

In the presence of endogenous peer group formation, we show that disadvantaged students or students with poorer habits benefit more from environments with more advantaged peers compared to their advantaged counterparts. We then show that being exposed to hard-working peers increases test scores more than simply being exposed to peers who have higher aspirations for college and/or have better academic achievements. This finding implies that it is not the peers *per se* but peers' attributes that generate peer effects and the *social multiplier*. In an education system characterised by very intense competition and growing inequality, future designs of educational policies in China must take the impacts of peer effects seriously.

We also contribute to the debate on the existence of peer effect by examining the impact of non-randomisation, conditional on passing the Guryan's balancing test. Almost half of the class pairs classified as being randomly assigned according to principal's responses on randomisation alone turn out to have significant differences in students' backgrounds. These classes have been

considered as randomly assigned by virtue of passing the balance tests in previous research. This highlights the high sensitivity of the *leave-own-out* empirical design to the non-randomisation, which results in biased estimates arising from sample selection bias. The large and significant peer effects reported in the literature using the CEPS data may arise from the imperfect randomisation between groups. Our results also call into question the statistical power of conventional balance tests in the presence of small non-randomisation in the sample and the validity of randomisation of Grade 9 classes. These findings have important implications on the examination of randomisation in future research on peer effects.

This paper offers three policy-relevant insights. First, this study provides direct impacts of peers' observed characteristics on academic performance which shed light on the benefits of de-tracking in compulsory education in a developing country context. The evidence points to the importance of beneficial peer effect resulting from the interactions with students with beneficial behaviours and attitudes. This echoes with previous findings that students' performance is correlated with their peers' personalities (Golsteyn et al., 2021) and perception (Hill and Zhou, 2023). These behavioural connections highlight the interactions between students in a de-tracking environment where students have distinctive beneficial behaviours and attitudes. In China's high-stakes education system, parents, particularly those of more advantaged children, often push their children into tracked classrooms with academically stronger peers. Our results highlight the importance of interaction and peers' behaviours and attitudes, echoing the findings of Li et al. (2008), who emphasise the importance of collaboration.

Second, schools should introduce interventions to develop healthy working habits and productive culture among students. The positive impacts of social and emotional learning programs have been well-documented in the literature, showing the programs can significantly improve social-emotional competencies and attitudes (Durlak et al., 2011; Cipriano et al., 2023). Our results further show direct impacts of these behaviours and attitudes, suggesting that teachers and principals should focus on students' behaviours and attitudes which may generate the '*social multiplier*'. Although children's backgrounds are pre-determined, their behaviours and attitudes can be changed as a result of an intervention. Schools can create environments where can foster beneficial behaviours and attitudes, such as effort-based mindsets (e.g., Growth Mindset interventions).

Finally, schools and teachers should promote social integration of students in classrooms in light of the beneficial interactions with productive students. Teachers play a vital role in fostering group dialogue and collaborative work between students (Webb, 2009). Peer effects are non-linear and arise from within friendship networks. It is crucial that schools provide interventions to promote interactions between students, especially the interaction between advantaged and disadvantaged students, resulting in improved friendship quality. The exposure to beneficial behaviours and attitudes can translate into improved academic outcomes.

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Appendix:

Figure A1. Endogenous peer group formation with distinctive attributes

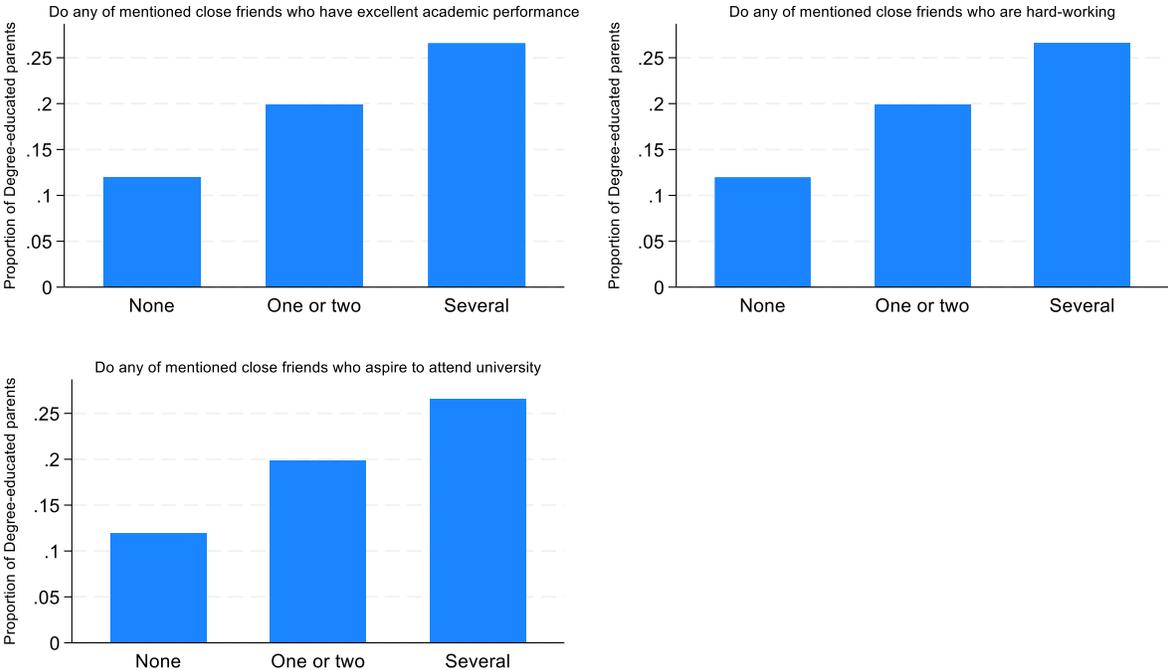


Table A1. The correlation of the subjective responses on peers' quality

	Study well	Hard-working	Degree expectation	Skip class	Having been disciplined	Fighting	Smoking and drinking alcohol	Game centre
Study well	1							
Hard-working	0.64	1						
Degree expectation	0.47	0.49	1					
Skip class	-0.06	-0.07	-0.11	1				
Having been disciplined	-0.09	-0.08	-0.10	0.52	1			
Fighting	-0.10	-0.12	-0.14	0.52	0.58	1		
Smoking and drinking alcohol	-0.09	-0.09	-0.12	0.53	0.51	0.61	1	
Game centre	-0.11	-0.11	-0.13	0.47	0.47	0.57	0.60	1

Table A2. Peers' attributes of students who frequently attend class late

	(1)	(2)	(3)	(4)
	Peers's attributes			
	Study well	Hard-working	Degree expectation	Skip class
Educated parents peers' share	-0.101*** (0.02)	-0.088*** (0.02)	-0.089*** (0.02)	0.096*** (0.01)
Frequent late arrivals	0.032 (0.13)	0.404*** (0.13)	0.153 (0.13)	0.315*** (0.08)
Educated parents peers' share X Frequent late arrivals	0.189*** (0.06)	0.034 (0.06)	0.126** (0.06)	-0.187*** (0.04)
<i>N</i> = 5,847				
	(5)	(6)	(7)	(8)
	Peers's attributes			
	Having been disciplined	Fighting	Smoking and drinking alcohol	Game centre
Educated parents peers' share	0.165*** (0.03)	0.161*** (0.02)	0.090*** (0.02)	0.112*** (0.02)
Frequent late arrivals	0.217** (0.10)	0.180** (0.08)	0.192*** (0.07)	0.349*** (0.09)
Educated parents peers' share X Frequent late arrivals	-0.222*** (0.08)	-0.283*** (0.06)	-0.171*** (0.05)	-0.222*** (0.05)
<i>N</i> = 5,847				

Note: The specification follows equation 1. The variable 'frequent late arrivals' measures the extent to which the student agrees with the statement that they frequently attend class late. A value of 1 indicates 'totally disagree', while a value of 4 indicates 'totally agree'. The dependent variables are based on the question 'Do any of mentioned close friends have the following attribute?', The responses range from 1 to 3, where 1 indicates no friends exhibit such behaviour, 2 indicates 1 or 2 friends, and 3 indicates several friends. The attributes of their best friends between column 1 and column 8 include whether they have excellent academic performance, hardworking in studies, aspire to attend university, skip classes, break school rules, get into fights, smoke or drink, and frequently go to internet cafes or game arcade. The small discrepancy in the number of observations results from missing values. Table A4 follows the same specification.

Table A3. Association between individual's study time and the attributes of their peers

	(1)	(2)	(3)	(4)
	Peers's attributes			
	Study well	Hard-working	Degree expectation	Skip class
Educated parents peers' share	0.027*** (0.01)	0.025*** (0.01)	0.023*** (0.01)	-0.001 (0.00)
Time spent on study	0.296*** (0.11)	0.455*** (0.12)	0.291** (0.11)	0.131** (0.06)
Educated parents peers' share X Time spent on study	-0.087*** (0.02)	-0.077*** (0.02)	-0.077*** (0.01)	0.026** (0.01)
<i>N</i> = 5,463				
	(5)	(6)	(7)	(8)
	Peers's attributes			
	Having been disciplined	Fighting	Smoking and drinking alcohol	Game centre
Educated parents peers' share	-0.009* (0.00)	-0.002 (0.00)	-0.004 (0.00)	-0.007 (0.00)
Time spent on study	-0.040 (0.05)	-0.133*** (0.05)	0.030 (0.03)	0.106* (0.06)
Educated parents peers' share X Time spent on study	0.043*** (0.01)	0.010 (0.01)	0.014 (0.01)	0.018* (0.01)
<i>N</i> = 5,463				

Note: The specification follows equation 1. The time spent on study includes time on homework of teachers and parents and time on tutorials. The small discrepancy in the number of observations results from missing values.

Table A4. Balancing test

	(1)	(2)	(3)	(4)
	Dev = Proportion of classmates with degree-educated parents			
	Individual-level		Class-level	
	<i>Lax rule</i>	<i>Strict rule</i>	<i>Lax rule</i>	<i>Strict rule</i>
Class size	0.004*** (0.00)	0.000 (0.00)	0.001 (0.00)	0.002 (0.00)
Male	0.001 (0.00)	0.002 (0.00)	0.146 (0.16)	0.669 (0.51)
Rural hukou	-0.004** (0.00)	-0.000 (0.00)	-0.153 (0.09)	-0.164 (0.25)
Age	-0.003*** (0.00)	-0.001 (0.00)	-0.126 (0.09)	-0.075 (0.22)
Single child	0.000 (0.00)	-0.002 (0.00)	0.076 (0.17)	0.184 (0.21)
Male teacher	0.011** (0.00)	-0.003 (0.01)	0.041 (0.06)	-0.013 (0.12)
Teacher's qualification (Diploma)	0.040** (0.02)	0.049* (0.03)	0.094 (0.12)	0.394 (0.29)
Teacher's qualification (Degree-adult)	0.030 (0.02)	0.036 (0.03)	0.026 (0.12)	0.123 (0.20)
Teacher's qualification (Degree)	0.033 (0.02)	0.033 (0.03)	0.015 (0.11)	0.004 (0.13)
Teacher's experience	0.000* (0.00)	-0.000 (0.00)	0.001 (0.00)	-0.006 (0.01)
Teacher's qualification	-0.004 (0.01)	-0.021 (0.02)	-0.059 (0.14)	-0.271 (0.16)
constant	0.431*** (0.06)	0.572*** (0.07)	1.946 (1.31)	1.346 (3.12)
<i>N</i>	14,595	5,724	132	54

Note: The regressions control for school fixed effect.

Table A5. Balancing test by class assignment type

	Non-random	Random assignment	
		Lax	Strict
Educated parents peers' share	10.0%	10.6%	7.4%
Repeated peers' share	10.0%	4.5%	0%
Alcoholic parents peers' share	30.0%	13.6%	7.4%
Obs (class-pairs)	40	66	27

Note: Proportion of within-school class-pairs with statistically significant different means in key characteristics at the 5% level.