China Economic Review 77 (2023) 101896

Contents lists available at ScienceDirect

China Economic Review

journal homepage: www.elsevier.com/locate/chieco

The externalities of preschool attendees in middle school classes☆

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ARTICLE INFO

JEL:
I20
I10
J24

Keywords:
Preschool program
Random assignment
Cognitive outcomes
Mental health

ABSTRACT

Using a nationally representative survey dataset on middle school students in China, this paper examines whether and how exposure to more classmates with a preschool experience affects students' cognitive and non-cognitive outcomes. We make use of the random class assignment rule, required by China's education law, to address the potential selection bias from class sorting. Our results show that exposure to more classmates with a longer preschool duration significantly improves students' cognitive and non-cognitive outcomes, whereas exposure to more classmates with a shorter preschool duration does not have such significantly positive effects, offering evidence of the dosage effects of attending a preschool program from the perspective of externalities. We further demonstrate three possible mechanisms through which the effects operate and quantify the explanatory power of each mechanism in driving the effects.

1. Introduction

Since the pioneered work by Cunha and Heckman (2007), skill formation in early childhood has received increasing attention in economics and other social sciences. Early education programs, among others, are viewed as effective interventions that help foster early cognitive and noncognitive skills. Despite the extensive evidence on the private benefits of early education

☆ The authors would like to thank the Editor and two anonymous referees for their valuable comments. We also would like to acknowledge the support from Natural Science Foundation of China (No. 71873123, No. 72034006), National Office of Philosophy and Social Sciences (No. 18FJY026, No. 18ZDA081, No. 20&ZD076), Social Science Fund of Zhejiang Province (No. 20JDZD004) and the Fundamental Research Funds for the Central Universities at Zhejiang University (No. 2017FZA202) and Jinan University (No. 19JNKY06).

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https://doi.org/10.1016/j.chieco.2022.101896
Received 16 June 2021; Received in revised form 11 November 2022; Accepted 24 November 2022
Available online 29 November 2022
1043-951X/

programs,[1] prior studies have at least two shortcomings. On the one hand, existing studies provide limited evidence of the social benefits of these programs. Children's valuable skills acquired in early preschool programs may also directly and indirectly benefit their peers in later life via social interactions, thus generating spill-over effects of these programs. Neidell and Waldfogel (2010) and Williams (2019) are two exceptions that provide some evidence of the external effects of preschool programs in the context of the US.[2] On the other hand, most studies look at the effects of attending an early education program, but say little about the dosage effects of early education programs (Behrman, Cheng, & Todd, 2004).[3]

Given the differential returns to life-cycle skill investments as reflected in the Heckman Curve (Carneiro & Heckman, 2003), a full understanding of the effects of preschool programs may help policy makers to allocate educational resources efficiently. If attending a preschool program also generates positive effects on other peers in society, ignoring such effects may underestimate the value of preschool programs. This could be quite important for both developed countries like the US, where the share of four-year-olds enrolled in state-funded preschools is only approximately 34% in 2019 (Gray-Lobe, Pathak, & Walters, 2022), and developing countries like China, where early childhood education remains less invested. Furthermore, given the limited early childhood education resources, it is attractive to understand the trade-off between expanding preschool enrollments and prolonging preschool duration.

In this paper, we attempt to enrich this literature by investigating the external effects of attending a preschool program on children's middle school classmates. In particular, we offer the first piece of evidence on the dosage effects of attending a preschool program from the perspective of preschool externalities in middle school period. As will be described in Section 2, there are two kinds of preschool programs in China, kindergartens that offer a three-year preschool education and pre-primary classes that are typically one-year programs. In 2009, 74.0% of children were enrolled in one-year preschool programs and only 50.9% of them were enrolled in three-year preschool programs (State Council, 2010). The difference in preschool program length provides us an opportunity to examine the external effects of classmates with different preschool experiences.

Given that preschool programs may have long-lasting effects on the formation of attendees' personality traits (e.g., perseverance, self-confidence, conscientiousness, self-discipline and agreeableness) and behaviors, as found in previous studies, exposure to more classmates with a preschool experience may affect middle school students' outcomes via at least three channels. First, classes with more preschool attendees may have a more suitable atmosphere for learning, thus helping foster positive inter-student interactions. Second, teachers may teach more effectively in classes with more well-behaved and self-disciplined students, thereby generating positive teacher-student interactions.[4] In contrast, teachers may be disturbed more frequently in classes with more unruly children, hence hindering the learning effectiveness of their classmates. Third, parents may respond to the characteristics of their children's classmates. For example, parents may devote more effort and time to parenting as a response to the rising competition in classes with more preschool attendees, generating positive family-class interactions. Therefore, one would expect to observe a positive relationship between the share of classmates with a preschool experience and the outcomes of middle school students in the class.

We use data from the China Education Panel Survey (CEPS), a nationally representative sample of Chinese middle school students, to examine whether and how exposure to more classmates with a preschool experience affects students' cognitive and noncognitive outcomes. The estimation of such effects is subject to two major threats that may confront causal identification (Manski, 1993, 2000).[5] One is selection bias. This kind of bias could arise if parents choose a middle school for their children based on their preferences. For example, wealthy/educated parents may have a stronger motivation to invest in their children via transferring them to better schools as well as sending them to a preschool. To address this kind of school sorting, we include school fixed effects in the regressions, as in the literature (e.g., Fruehwirth & Gagete-Miranda, 2019; Lavy, Daniele Paserman, & Schlosser, 2012). Selection bias could also arise if students within a school are grouped based on certain observable or unobservable characteristics such as ability and family

[1] A great deal of recent evidence from developed countries indicates that early education programs can have substantial impacts on children's own skill development, labor market outcomes and behaviors (e.g., Anders, Barr, & Smith, 2022; Bailey, Sun, & Timpe, 2021; Baker, Gruber, & Milligan, 2015; Cappelen, List, Samek, & Tungodden, 2020; Carneiro & Ginja, 2014; Conti, Heckman, & Pinto, 2016; Cornelissen & Dustmann, 2019; Gelber & Isen, 2013; Gray-Lobe et al., 2022; Heckman et al., 2013). For surveys on earlier studies, see Currie (2001), Almond and Currie (2011) and Duncan and Magnuson (2013).

[2] Neidell and Waldfogel (2010), to our knowledge, is the first study to look at the external effects of preschool programs. Using a sample of American kindergartners, they find statistically significant spill-over effects of preschool on math and reading outcomes of kindergartners in the same class, but statistically insignificant effects on behavioral and social outcomes. More recently, Williams (2019) exploits the district and time variation in access to a state preschool program in South Carolina, and finds that the program not only benefits its targeted students but also increases the math and reading scores of the program-ineligible students. The two studies focus on the short-term external effects of preschool programs on a narrow range of peers' cognitive outcomes, but miss the mid- and long- term external benefits of preschool programs.

[3] One of a few exceptions, for example, is delivered by Behrman et al. (2004), who show that the duration of exposure to preschool programs affects test score of children with at least 7 months' exposure, and the positive effects increase with longer duration.

[4] Many studies have shown that students' outcomes may be affected by peer characteristics such as immigrants, repeaters, gender, test scores, and personality traits via the social interactions between peers in classroom (Golsteyn, Non, & Zölitz, 2021; Gong et al., 2021; Hu, 2018; Huang & Zhu, 2020; Lavy & Schlosser, 2011; Lu & Anderson, 2015; Ohinata & van Ours, 2013; Xu et al., 2020). For example, using the data from a Dutch business school, Golsteyn et al. (2021) show that students exposed to more persistent peers achieve higher grades.

[5] As demonstrated by Manski (2000), members of the same group tend to behave similarly because of three effects: (1) endogenous peer effects, occurring when an individual's propensity to behave in some way varies with the behavior of the group, (2) contextual peer effects, occurring when an individual's propensity to behave in some way varies with exogenous characteristics of the group members (e.g., socioeconomic composition of the group), and (3) correlated effects, occurring when individuals in the same group tend to behave similarly because they have similar individual characteristics or face similar institutional environments (i.e., non-peer effect reasons for the correlations within the group such as endogenous peer group selection and correlated unobservables of peers). The reflection problem arises because endogenous peer effects and contextual peer effects are hard to disentangle.

socioeconomic background. Middle school students, who are in the second stage of compulsory education, are required by law to be randomly assigned to classes at the beginning of grade 7. Once assigned, students are usually not allowed to transfer to other classes throughout the subsequent middle school years. Thus, students in the same class take the same courses and participate in other activities together. Utilizing this random class assignment rule, we can mitigate the bias from potential class sorting.[6]

The other is reflection problem, which could occur when a student's and his/her classmates' outcomes are simultaneously determined. Although a distinction between endogenous and contextual peer effects is valuable because of their different policy implications, it is often difficult to disentangle the two effects.[7] One strategy to address the reflection problem is to use preexisting variables as measures of peer outcomes (Carrell & Hoekstra, 2010). In the context of the present study, a student's preschool experience is largely exogenous to the peers' outcomes as long as the peers' outcomes do not cause the student's enrollment in a preschool program. This assumption may be reasonable because a student's enrollment in a preschool program is predetermined several years ago, therefore, the reflection problem is less likely to be a concern.[8] Nevertheless, we also follow the strategy used in the literature (e.g., Eisenberg, Golberstein, & Whitlock, 2014; Huang & Zhu, 2020) to mitigate potential reflection problem. We include a set of average characteristics of classmates and/or preschool attendees to control for the contextual effects.

It is worth noting that a recent study of Wang (2021) conducted a work similar to ours. Using the same CEPS data, Wang (2021) finds significant effects of peers' enrollment in preschool on students' cognitive and noncognitive outcomes. Nevertheless, our work rather differs from that of Wang (2021) in at least three aspects. First, we explicitly distinguish the differences in preschool program duration among children in our specifications and quantify separately the external effects of classmates with different preschool experiences, while Wang (2021) does not. Our evidence indicates that ignoring this distinction may underestimate the external effects of preschool programs. To the best of our knowledge, our work is the first to shed light on the dosage effects of attending a preschool program from the perspective of externalities.

Second, we offer two possible mechanisms that may drive the external effects besides the inter-student interactions emphasized in Wang (2021), and quantify the relative explanatory power of each mechanism, enriching our understanding of how children develop. Instead of looking at the relationship between class environment and preschool attendees, we provide direct evidence on the effects of exposure to preschool attendees on the behaviors of students, teachers and parents. We show that the external effects may be driven via teachers' positive responses to high-quality students in their classes. Moreover, we demonstrate that family-class interactions play an important role in education production. Based on the decomposition approach proposed by Heckman, Pinto, and Savelyev (2013) and Gelbach (2016), we show that at least 7% of the explanatory power can be attributed to the latter two mechanisms.

Finally, we impose one more sample restriction than Wang (2021) to ensure the validity of the random class assignment setting. Specifically, we utilize the information from the head teacher questionnaire, and exclude the grades if the head teacher reports that students are grouped according to their test scores. In the comparison analyses, we follow Wang (2021) sample restriction procedures to generate replication samples which are nearly equivalent to that used in Wang (2021). The statistical tests indicate that ignoring this condition may lead to a violation of the random class assignment assumption.

Our estimation results demonstrate that students with a three-year preschool experience have sizable and positive external effects on cognitive outcomes of their fellow middle school classmates. On average, a 10% increase in the share of preschool attendees raises students' academic achievement and cognitive score by 0.049 and 0.067 standard deviations, respectively. Exposure to classmates with a three-year preschool experience is also conducive to improving middle school students' mental health. These results are robust to a series of sensitivity tests. However, we do not find evidence that exposure to classmates with a shorter preschool duration has statistically significant positive effects on middle school students' outcomes. The findings suggest that it may be more efficient to prioritize prolonging preschool duration given the limited early education resources.

We provide evidence of three potential mechanisms driving the external effects. Students in a class with more preschool attendees are more likely to benefit from the improved interactions among students, between teachers and students, and between family and class. We also show that the external effects vary across groups. Girls tend to benefit more in the achievement of cognitive outcomes than boys, and boys benefit more in the relief of mental stress. Students with educated parents and preschool attendees also benefit more than their counterparts.

The rest of the paper proceeds as follows. Section 2 introduces the early childhood education system in China. Section 3 describes the data and variables. Section 4 discusses the specifications and identification strategy. Section 5 reports the results of random assignment tests, baseline estimations and robustness checks. Section 6 discusses the possible mechanisms. Section 7 reports the heterogeneous effects. Section 8 concludes.

2. Preschool education in China

As an important part of elementary education system, preschool education in China provides early care and education service for

[6] A series of statistical tests suggest that the random class assignment of students in practice works well. Several recent studies also take this random assignment rule to explore the determinants of the development of middle school students in China (Gong et al., 2018, 2021; Hu, 2018; Huang & Zhu, 2020; Xu et al., 2020). For example, two recent studies by Huang and Zhu (2020) and Xu et al. (2020) examine the effect of peer ability on the cognitive or non-cognitive outcomes of the student, where students who were retained during their primary school are treated as low-ability peers.

[7] As pointed out in Manski (2000), endogenous peer effects have social multiplier effects, while contextual peer effects (and correlated effects) do not have such effects.

[8] In the earlier version of this paper, we also conduct a test similar to Carrell and Hoekstra (2010), and find no evidence that one's own preschool experience is affected by his/her classmates' average preschool experience.

preschool-age children who are typically 3-6 years old. Kindergarten is the dominant type of preschool education, and it typically offers three years of early care and education services for 3- to 6-year-olds. According to the *Regulations for Kindergarten Work* (hereafter, *Regulations*) initially issued in 1981 and revised by the Ministry of Education in 1996 and 2016, kindergartens should promote children's holistic development in connection to behaviors, habits, psychological quality, manners and self-care ability via daily games and outdoor physical activities. Kindergarten education should maintain close contact with primary school education, and focus on the connections between the two stages of education. The *Regulations* state that preschool-age children can be enrolled into stand-alone kindergartens. However, in some areas where stand-alone kindergartens are not available, preschool-age children can either only attend one-year preschool programs or not go to preschool. Pre-primary class (Xue Qian Ban, in Chinese) is the major form of one-year preschool programs which are often attached to a primary school. Unlike kindergartens, pre-primary classes usually provide subject-focused education to meet the demands of 5- to 6-year-olds.

The Chinese government has increasingly recognized the importance of early childhood care and education in the development of children's ability, and introduced a series of policies to promote and guide the provision of preschool education. Among others, the *Outlines of National Medium- and Long-Term Program for Education Reform and Development 2010–2020* (hereafter, the *Outlines*), issued by the State Council in 2010, is probably the most important guideline documentation, which gives priority to early childhood education and sets a clear goal for the development of preschool education.[9] Since then, the preschool education has experienced a rapid expansion. Between 2009 and 2019, the number of preschools doubled from 138,209 to 281,174, the gross enrollment ratio of preschool education grew from 50.9% to 83.4%, and the proportion of preschool education expenditure to GDP ballooned from 0.07% to 0.41%.

Despite the significant progress in preschool education over the past two decades, preschool education remains less developed in terms of accessibility and quality. Currently, preschool education in China remains not compulsory. Most preschool education programs, either publically funded or privately run, charge fees. Preschool education expenses impose a relatively heavy burden on low-income families. In particular, low-income families in rural areas are often ineligible for public preschool subsidies. Some children from low-income families may either not attend preschool programs or only attend pre-primary classes when they are 5 or 6 years old. Even in 2020, ten years after the implementation of the *Outlines*, a considerable proportion of preschool-age children could not access three-year preschool programs. According to the data from the CFPS 2020, 29.6% of 3-year-old children were not enrolled into preschool programs and 31.1% of the new enrollments were above 3 years old, indicating substantial differences in exposure to preschool programs among children. A recent study by Zhang (2017) shows that the effects of attending a preschool vary with the age of preschool entrance, providing evidence of the dosage effects on children's own development. In this paper, we examine the dosage effects of attending a preschool program from the perspective of externalities.

In addition, public preschool funding is unevenly distributed across preschools, resulting in significant disparities in preschool quality. One is the disparity between publicly-funded preschools and privately-run preschools. Publicly-funded preschools in economically developed areas usually enjoy more and better educational resources. Privately-run preschools, particularly those in less developed areas, are usually of relatively inferior quality in terms of physical environment, teacher-student ratio and teacher quality. They mainly serve children who are unable to access public preschools because of household registration issues, financial concerns, or family socioeconomic backgrounds. Although the *Regulations* requires minimum standards for preschool facilities and instructional quality, many privately-run preschools cannot meet the official requirements in practice. The other is the disparity between rural preschools and urban preschools. Although the implementation of the *Outlines* has greatly improved the accessibility of preschools in rural areas, the urban-rural gaps in preschool quality remain large. For example, in 2020, the proportion of teachers with a college degree or above in rural preschools is 75.6%, less than urban preschools (87.8%), and the expenditure per student in rural preschools is about CNY 9257, much lower than the national average (CNY 12956).

3. Data and variables

3.1. Data

The data we use come from the China Education Panel Survey (CEPS), which is a nationally representative longitudinal survey of Chinese middle school students conducted by Renmin University of China. The survey employs a stratified and multistage sampling design in which four middle schools in a given county (or district) and four classes of grades 7 and 9 within each school (i.e., two classes for each grade) are chosen.[10] The baseline survey was conducted in the 2013–2014 academic year, starting with grades 7 and 9, with approximately 20,000 students from 438 classes of 112 schools in 28 counties/districts in China. According to the CEPS technical documentation, less than 5% of the schools have surveyed only one class for each grade. We keep the schools with four classes. The

[9] According to the *Outlines*, by 2020, one-year preschool programs will be universal, two-year preschool education will be basically universal, and three-year preschool education will be universal where conditions permit. For details, please see the website of Ministry of Education of China. (http://www.moe.gov.cn/jyb_xwfb/s6052/moe_838/201008/t20100802_93704.html, accessed on October 30, 2021)

[10] For the detailed sampling method and process used in the CEPS, please see the technical documentation available online. (http://ceps.ruc.edu.cn/xmwd/dcsc.htm, accessed on May 7, 2021)

data include rich information on the students, their parents, head teachers, and school principals.

Although students in the compulsory education stages are regularly required to be assigned randomly to classes, some schools may not strictly comply with the random class assignment rule in practice.[11] In the CEPS survey, principals and head teachers are requested to report whether students in the school are randomly assigned to classes. We make use of these information to obtain our sample. First, each principal is requested to answer the questions of "whether students are randomly or evenly assigned into classes when they are enrolled into school?" and "whether students are allowed to change their classes during the subsequent middle school period?" We exclude the school from the sample if the principal responds "yes" to either of the questions. Second, each head teacher is also requested to answer the question of "whether students in the grade are assigned by test scores?" We exclude the entire grade from the sample if any of the head teachers in the grade responds "yes" to the question.[12] Accordingly, our sample consists of 6783 students in grades 7 and 9 across 196 classes in 62 schools.

3.2. Variables

The school administration offices are requested to provide students' test scores of three compulsory core subjects (i.e., Chinese, math, and English). Our primary cognitive outcome is students' *academic achievement*, defined as the average of the three core subject test scores. Students from the same grade in the same school usually use the same syllabus and take the same exams. Therefore, this measure is consistent and comparable across students, conditional on the school and grade fixed effects. For the sake of interpretation and comparison with other studies, we standardize each of the raw subject test scores to have a mean of zero and a standard deviation of one by school and grade.

The CEPS also designed and conducted an independent cognitive test for each student based on the three-parameter logistic item response theory. We standardize the raw scores obtained in the cognitive test to construct a variable of *cognitive score* with a mean of zero and a standard deviation of one, as an alternative measure for cognitive outcome.

In the CEPS, students are requested to report their mental health status. Specifically, each student is asked whether having the following feelings during the past seven days: (1) blue; (2) depressed; (3) unhappy; (4) life is meaningless; and (5) sad. The responses range from 1 ("never") to 5 ("always"). We define five mental health indicators (i.e., *feeling blue, feeling depressed, feeling unhappy, meaningless life, and feeling sad*) based on students' responses to these questions. The indicators equal 1 if the corresponding response is "sometimes," "often," or "always," and 0, otherwise. We use these mental stress indicators to measure students' non-cognitive outcomes.[13] We report the effects on each of the five indicators, and calculate the average effect based on the approach proposed by Kling, Liebman, and Katz (2007).[14] Following the strategy adopted in prior studies (e.g., Huang, Li, Pan, & Ren, 2020; Xu, Zhang, & Zhou, 2020), we also create an index of *mental stress* that combine five indicators, to measure non-cognitive outcomes. By design, *mental stress* is positively correlated with the five indicators, and larger *mental stress* denotes worse mental health status. Using a composite index as the dependent variable helps address the potential issue of false positives from the multiple hypothesis inference (Deming, 2009; Xu et al., 2020). Furthermore, a composite index is conducive to reduce measurement errors and improve statistical power (Deming, 2009; Kling et al., 2007).

Our key independent variable is *preschool share*, defined as the share of classmates with a three-year preschool experience. As described in Section 2, the duration of preschool programs in China ranges from one to three years. To examine the dosage effects of attending a preschool program, we also include another variable of *shorter preschool share* in some specifications. The variable of *shorter preschool share* is defined as the share of classmates with a one- or two-year preschool experience. The CEPS does not explicitly report the duration of students' preschool education. We adopt a two-step procedure to impute students' preschool education duration. First, we identify whether a student has a preschool experience according to their response to the question of "Have you ever gone to a kindergarten/preschool since you were three years old?" For students with a preschool experience, we then impute their preschool

[11] As documented in *Article 22* of *the Compulsory Education Law of the People's Republic of China*, "And the schools shall not divide the classes into key and non-key classes." *Article 57* of the Law further regulates that "a school shall be ordered to make rectification within a time limit by the administrative department for education of the people's government at the county level" and "if the circumstances are serious, the person directly in charge and the other persons directly responsible shall be punished according to law" if *Article 22* is violated. (For the details of the *Law*, see http://old.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_2803/200907/49979.html, accessed on May 7, 2021)

[12] As will be shown later, the second sample restriction seems quite important for the validity of random class assignment assumption.

[13] The concept of non-cognitive outcome is extensively mentioned in the literature, however its measurement remains inconclusive (e.g., Heckman & Kautz, 2012). Perhaps depending on the data available to researchers, prior studies have used a wide range of non-cognitive measures, such as Big Five personality inventory (Borghans, Duckworth, Heckman, & Ter Weel, 2008; Huang et al., 2020), Behavior Problem index (Cunha & Heckman, 2008; Heckman et al., 2013), Emotional Disorder index (Akee, Copeland, Costello, & Simeonova, 2018; Gong et al., 2018; Gong et al., 2021), Rotter Internal-External Locus of Control Scale (Heckman, Stixrud, & Urzua, 2006; Rotter, 1966), and Rosenberg Self-Esteem Scale (Heckman et al., 2006; Rosenberg, 1965). The Big Five personality inventory, developed by Goldberg (1990), is probably the most extensively used non-cognitive outcome measure, which includes five dimensions (Openness to Experience, Conscientiousness, Extraversion, Agreeableness, and Neuroticism). The Behavior Problem index is often used to measure behavioral and attitudinal factors that affect academic success. The Emotional Disorder Index is often constructed from "Any Diagnostic and Statistical Manual of Mental Disorders". The Rotter Internal-External Locus of Control Scale is used to measure the degree of control individuals feel they possess over their life. The Rosenberg Self-Esteem Scale is used to measure the degree of approval or disapproval towards himself.

[14] Following Kling et al. (2007), we define the average effect size of preschool share on a set of K outcomes in category t as $AES = \frac{1}{K}\sum_{k=1}^{K}\frac{e_{kt}}{\sigma_{kt}}$, where K is the number of outcomes in category t (e.g., K = 5 in mental health), e_{kt} is the estimated effect for outcome k in category t, and σ_{kt} is the standard deviation of outcome k in category t.

education duration based on the ages at which the students were enrolled into kindergartens and primary schools.

Table 1 reports the summary statistics of the outcome variables. Each variable has a sufficient variation for identification. Columns (4)–(6) report the differences in the cognitive or non-cognitive outcomes of students with different preschool experiences. First, students with a preschool experience achieve higher scores in the cognitive and subject tests than their counterparts without, which is consistent with the findings in previous studies (e.g., Luo et al., 2012; Rao, Sun, Zhou, & Zhang, 2012). Second, students with a preschool experience have a better mental health status than those without. Finally, students with a three-year preschool experience are more likely to have higher cognitive ability and better mental health status than their counterparts with a shorter preschool duration.

The definitions and summary statistics of a series of control variables used in the analysis are reported in Table 2. On average, 52.5% of students in the sample have ever participated in a three-year preschool program in their early childhood, and 29.6% of students have ever participated in a one- or two-year preschool program. Both *preschool share* and *shorter preschool share* have large standard deviations of 0.199 and 0.125, respectively, indicating inequality in the opportunity to access preschool programs among classes.[15]

4. Estimation strategy

To quantify the external effects of preschool programs, we estimate Eq. (1) wherein individual outcomes are determined by the preschool share, school and grade fixed effects, a set of individual predetermined characteristics, teachers' characteristics, and class characteristics.

$$y_{icgs} = \alpha + \beta^{*}preschool\ share_{-icgs} + \delta X_{igcs} + \tau_g + \omega_s + \varepsilon_{icgs} \tag{1}$$

where y_{icgs} denotes the outcome measures of student i in class c, grade g and school s. X_{icgs} denotes a vector of predetermined student characteristics (i.e., his/her age, ethnicity status, number of siblings, gender, preschool experience, Hukou type, left-behind status, individual's current and early family background, and parents' education level) and teachers' characteristics (i.e., teachers' average age, the share of teachers with a college degree or above, and teachers' average professional title). To control for the unobserved factors that vary uniformly across grades (e.g., different examinations across grades within the same school), we include the grade fixed effects (τ_g) into Eq. (1). ε_{ics} is the error term.

Preschool share denotes the share of classmates with a three-year preschool experience. The coefficient of interest is β, which captures the external effects of attending a three-year preschool program on middle school students' outcomes. As noted earlier, to examine the dosage effects of attending a preschool program from the perspective of externalities, we also include a variable of *shorter preschool share* in some specifications.

Estimation of the coefficient β may suffer from the potential reflection problem and selection bias. We include into Eq. (1) three sets of peer characteristics to mitigate the potential reflection problem. We first include a set of average characteristics of classmates, such as class size, gender composition, and current and early family socioeconomic background, to control for any contextual effects from these characteristics.[16] To control for any effects driven by other peer quality, we further include a variable of classmates' quality into the regressions, where students' quality is identified according to the response to the question of "How did your academic record rank in your class when you were in grade 6?" In some specifications, we also control for a set of average characteristics of preschool attendees, as in Huang and Zhu (2020).

Including the school fixed effects (ω_s) into Eq. (1) can easily control for the selection bias from potential sorting into schools. As noted in Introduction, however, selection bias may also occur as long as students are not randomly grouped within schools. As discussed in Section 3, we make use of the random class assignment rule required by the *Compulsory Education Law of PRC* to address the selection bias from potential class sorting.

5. Results

In this section, we first conduct several tests to verify the key identification assumption before presenting the main estimation results. We also offer a series of sensitivity tests after presenting the baseline results.

5.1. Testing for the random class assignment

As discussed, our identification of the external effects largely relies on the assumption that students in each school are randomly assigned to classes. We employ two strategies to verify the validity of this random class assignment assumption. First, we adopt the

[15] Following Huang et al. (2020), we plot the distributions of preschool share and shorter preschool share in Figure 1. The figure shows that there are large differences in the distribution of two variables even if the school and grade fixed effects are controlled for.

[16] The survey does not contain information on family's income and wealth. However, families are requested to report family's relative socioeconomic status in child's preschool period and current relative socioeconomic status of the family, ranging from "very rich" to "very poor". Families with a self-reported socioeconomic status of "very rich" and "relatively rich" are defined as a better family background. We use this information to construct measures of classmates' family background.

Table 1
Summary statistics of the outcome variables.

Variables	Students with 3 Years preschool experience	Students with 1–2 Years preschool experience	Students without preschool experience	Differences		
				(1)–(3)	(2)–(3)	(1)–(2)
	(1)	(2)	(3)	(4)	(5)	(6)
Raw Cognitive Score	11.311	9.896	9.071	2.240***	0.825***	1.415***
	(3.704)	(3.650)	(3.740)			
Raw Average Subject Score	87.957	78.796	76.117	11.840***	2.680***	9.160***
	(24.448)	(24.899)	(24.676)			
Chinese Score	87.568	81.847	79.905	7.663***	1.942***	5.721***
	(19.427)	(20.386)	(20.499)			
Math Score	87.137	76.768	73.358	13.779***	3.410***	10.369***
	(30.755)	(31.795)	(32.063)			
English Score	89.166	77.774	75.086	14.079***	2.688**	11.392***
	(29.612)	(30.053)	(29.503)			
Mental Stress	−0.079	−0.028	0.159	−0.238***	−0.186***	−0.052*
	(0.993)	(0.955)	(1.012)			
N	3559	2006	1218	–	–	–

Notes: The sample covers 6783 students in total, among which 3559 students attended a three-year preschool, 2006 students attended a one-year preschool, and 1218 students did not attend preschool. Columns (1)–(3) report the means and standard deviations (in parentheses) of the variables. Column (4) reports the differences of the means in columns (1) and (3), column (5) reports the differences of the means in columns (2) and (3), and column (6) reports the differences of the means in columns (1) and (2).
*** *** $p<0.01$, ** $p<0.05$, * $p<0.1$

approach used by Gong, Lu, and Song (2018) to regress the *preschool share* and *shorter preschool share* variables on a set of predetermined student characteristics, respectively.[17] If students are randomly assigned to classes within schools, there will be no systematic correlation between the two variables and the observed student characteristics. Finding statistically significant coefficients is an indicator that students may be grouped on the basis of their observed characteristics, hence violating the random class assignment assumption. As shown in Table 3, most of the coefficients become statistically insignificant and all are small in magnitude once the school and grade fixed effects are controlled for, and the *F*-statistics are also small and statistically insignificant. The results suggest that we cannot reject the null hypothesis that there is no systematic correlation between the dependent variables and the predetermined variables conditional on the school and grade fixed effects.

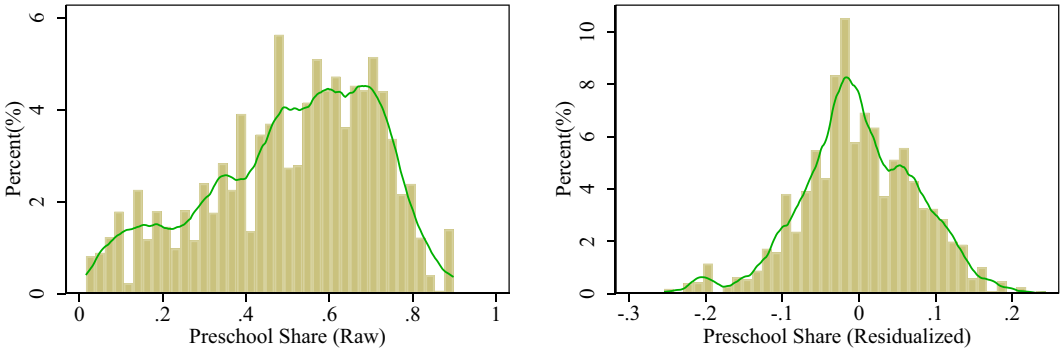
Second, we examine whether the actual within-school variations in the preschool shares stem from a random process. Following Mouganie and Wang (2020), we randomly designate a student as a preschool attendee using a binomial distribution function with a probability *p* equal to the average share of preschool attendees in the school, and then calculate the within-school standard deviation of the share of preschool attendees. We repeat this process 1000 times to obtain a 95% confidence interval of within-school standard deviations. The Monte Carlo simulation results summarized in Fig. 2 show that the actual standard deviation in the preschool share of 55 schools (out of 62 schools in total) ranges within the 95% confidence interval, offering further supportive evidence for the randomization setting.[18]

One may be also concerned about the potential selection in the assignment of teachers within schools. For example, if high-quality teachers are assigned to the classes with a higher preschool share, the external effects may be overestimated. To address this concern, we regress the *preschool share* and *shorter preschool share* variables on a set of teachers' predetermined characteristics, respectively. Finding significant correlations between teachers' characteristics and the two variables is an indicator that there may be class sorting of teachers. As shown in Table 4, the coefficients of teachers' characteristics and the *F*-statistics of the regression are all statistically insignificant and small in magnitude once the school and grade fixed effects are controlled for. We do not find evidence against the random class assignment of teachers.

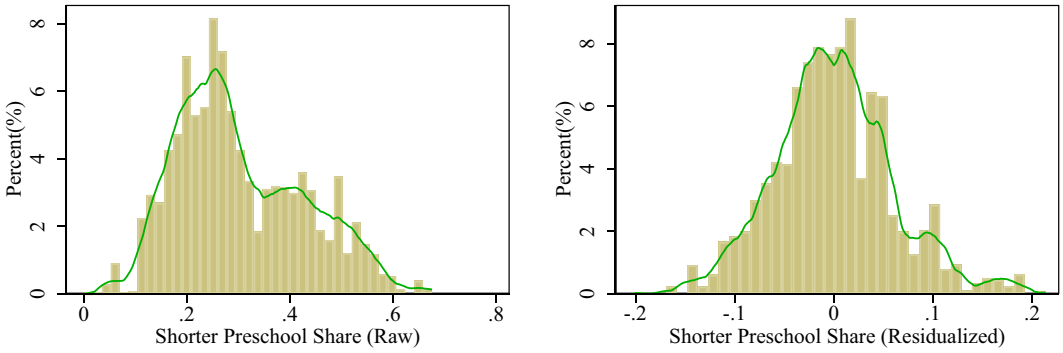
5.2. Baseline estimates

We first look at whether exposure to more classmates with a preschool experience affects students' cognitive outcomes. Panel A of Table 5 presents the results using *academic achievement* as the dependent variable. Regression in column (1) only includes the *preschool share* variable, grade fixed effects and school fixed effects.[19] The coefficient of the *preschool share* variable is positive and statistically significant at the 1% level, suggesting that an increase in the share of classmates with a three-year preschool experience helps to improve students' academic achievement. Column (2) of Table 5 controls for a set of students' individual characteristics that may

[17] We also adopt the alternative approach used extensively in the literature (Carrell & Hoekstra, 2010; Lavy & Schlosser, 2011; Lavy et al. 2012a) to examine the random assignment assumption. The results are in line with that reported here.
[18] In the sample of Wang (2021), the actual standard deviation of the preschool share almost in one-fourth of schools is outside the 95% confidence interval, indicating that the variation of preschool share in the sample might not be consistent with a random process.
[19] We use an alternative specification which controls for the grade-by-school fixed effects, instead of the grade- and school- fixed effects. The results are similar to those reported in Table 5.



A. Distribution of Preschool Share



B. Distribution of Shorter Preschool Share

Fig. 1. Distributions of preschool shares.
Notes: Fig. A plots the distributions of the Preschool Share without (left) and with (right) residualization. Fig. B plots the distributions of the Shorter Preschool Share without (left) and with (right) residualization. The lines denote the corresponding fitted kernel density. We regress the *preschool share* and *shorter preschool share* on school and grade fixed effects, respectively, to obtain the residuals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

affect the academic outcome. The coefficient of interest decreases from 0.614 in column (1) to 0.431 in column (2), but remains statistically significant at the 5% level. In the regression of column (3), we further include a set of teachers' predetermined characteristics. If teachers and classes are randomly paired, as discussed in Section 5.1, one would expect to observe no dramatic change in the coefficient of the *preschool share* variable when controlling for teachers' characteristics. As expected, we show that the inclusion of teachers' characteristics does not alter the coefficient of interest a lot.

As described in Section 2, perhaps because of limited preschool education resources, not all children in China can be enrolled to stand-alone kindergartens. Many children can only access one-year pre-primary classes at their ages of 5 or 6. In the CEPS sample, about 40 % of preschool attendees actually participated in a shorter preschool program. If attending a preschool program does help improve children's own cognitive and non-cognitive outcomes, children with a longer preschool education exposure may benefit more than those with a shorter preschool duration. A few prior studies confirm that children enrolled in a preschool program at earlier ages of 2 or 3 have better academic performance than those enrolled at older ages (e.g., Domitrovich et al., 2013; Lee, 2011; Loeb, Bridges, Bassok, Fuller, & Rumberger, 2007; Zhang, 2017). This finding is also reflected in the preliminary statistics in Table A1 of the Appendix. For example, children with a three-year preschool experience tend to have higher academic ranks in grade 6 and are less likely to be a repeater in primary education.

To test whether the above external effect of attending a preschool program varies with preschool education duration, we include an additional variable of *shorter preschool share* into the regression. As shown in column (4) of Table 5, the *preschool share* and *shorter preschool share* variables have an expected positive coefficient. However, the coefficient of the *shorter preschool share* variable is

Table 2
Summary Statistics of the Variables.

Variables	Definitions	Mean	S·D
Panel A. Class Characteristics			
Preschool Share	Share of classmates with a three-year preschool experience	0.517	0.199
Shorter Preschool Share	Share of classmates with a 1–2 years preschool experience	0.301	0.125
Class Size	Number of students in class	47.338	13.596
Gender Composition	Share of male students in class	0.509	0.080
Classmates' Early Family Background	Share of classmates who lived in a rich family in the preschool period	0.103	0.085
Classmates' Current Family Background	Share of classmates who live in a rich family in the middle school period	0.141	0.106
Classmates' Quality	Average of classmates' relative academic rank in grade 6	13.973	4.032
Panel B. Teachers' Characteristics			
Teacher's Age	Teachers' average age	37.894	6.893
Teacher's Education	Share of teachers having an education level of college or above	0.516	0.500
Teacher's Title	Teachers' average professional title (0: no professional title; 5: principal senior-level)	2.769	0.867
Panel C. Individual Characteristics			
Age	Student's age	13.973	1.346
Ethnicity	Whether being a Han Chinese	0.893	0.309
Only Child	Whether being only child	0.527	0.499
Gender	Whether being male	0.491	0.500
Preschool Attendee	Whether having a preschool experience	0.820	0.384
Hukou Type	Whether having an urban Hukou	0.556	0.497
Left-behind Status	Whether currently being a left-behind child	0.079	0.270
Own Early Family Background	Whether student's family was rich in the preschool period	0.110	0.313
Own Current Family Background	Whether student's family was rich in the middle school period	0.145	0.352
Educated Parents	Whether both parents have a college education or above	0.145	0.352
Local	Whether having a local Hukou	0.813	0.390
Repeater	Whether student repeated a grade in primary school	0.094	0.292
High Ability	Whether academic rank in 6th grade being in the top ten	0.444	0.497
Express Clearly	Whether being able to express oneself clearly in primary school	0.792	0.406
Response Quickly	Whether being able to give quick responses in primary school	0.768	0.422
Fast Learner	Whether being a fast learner in primary school	0.750	0.433
Curious	Whether being curious about new stuff in primary school	0.876	0.330

Notes: The means and standard deviations (in parentheses) of the variables are reported.

statistically insignificant at the 10% level, while that of the *preschool share* variable remains statistically significant. In particular, the magnitude of the coefficient of the *shorter preschool share* variable is less than one-third of that of the *preschool share* variable after controlling for a full set of students' and teachers' characteristics. In Table A2 of the Appendix, we also estimate the effects of exposure to preschool attendees in a class on test score of each subject, and calculate the average effect based on the approach proposed by Kling et al. (2007). It is seen that the average effect remains similar to that reported in Table 5, although the separate effect on English score is statistically insignificant.

Panel B of Table 5 presents the results using an alternative cognitive measure – *cognitive score* – as dependent variable. Regressions in columns (1)–(3) of Panel B show that the coefficients of the *preschool share* variable are positive and statistically significant although the magnitude of the effects has a slight decline from 0.831 to 0.704 after controlling for students' individual characteristics and teachers' characteristics. Column (4) of Panel B further explores the effects of having classmates with different preschool education durations. We show that the coefficient of the *preschool share* variable is not sensitive to the inclusion of the *shorter preschool share* variable and remains statistically significant. Furthermore, the effect of the *shorter preschool share* variable is very small in magnitude and has a negative and statistically insignificant sign, indicating again that exposure to classmates with a shorter preschool duration tends to have no significant effect on students' cognitive outcomes.

We next examine the external effects of preschool attendees on students' mental health status. The results are presented in Table 6. Columns (1)–(5) look at the effects of exposure to more preschool attendees in a class on students' mental health, where five separate mental health indicators are used as the dependent variable, respectively. The coefficients of the *preschool share* variable range from −0.033 to −0.214, and most of them are statistically significant at the 5% level. On the contrary, the coefficients of the *shorter preschool share* variable have inconsistent signs and most of them are statistically insignificant at the 10% level. Based on the approach of Kling et al. (2007), column (6) reports the average effects across the five variables, and the pattern of the average effects is consistent with those reported in columns (1)–(5). In column (7), we use the composite index of *mental stress* as the dependent variable. We show that the pattern of the results remains. Exposure to more classmates with a longer preschool duration tends to have a healthier mental status. However, we do not find strong evidence that exposure to classmates with a shorter preschool duration has such effects. On average, a 10-percentage increase in the *preschool share* variable helps decrease *mental stress* by about 0.054 standard deviations.

Table 3
Tests for random class assignment of students.

Variables	Shorter preschool share		Preschool share	
	(1)	(2)	(3)	(4)
Age	0.013**	0.000	−0.026***	−0.002
	(0.005)	(0.001)	(0.007)	(0.002)
Ethnicity	−0.009	−0.002	0.117***	−0.002
	(0.017)	(0.003)	(0.025)	(0.004)
Number of Siblings	−0.016**	0.002	0.055***	0.003
	(0.007)	(0.002)	(0.011)	(0.002)
Gender	−0.002	−0.001	−0.001	0.000
	(0.003)	(0.001)	(0.004)	(0.001)
Preschool Attendee	−0.008	−0.002	0.064***	0.005
	(0.006)	(0.002)	(0.009)	(0.003)
Hukou Type	−0.037***	−0.002	0.057***	0.001
	(0.010)	(0.002)	(0.013)	(0.004)
Left-behind Status	0.051***	−0.000	−0.107***	−0.005
	(0.013)	(0.003)	(0.020)	(0.005)
Own Early Family Background	−0.019***	−0.005*	0.030***	0.003
	(0.007)	(0.003)	(0.009)	(0.004)
Own Current Family Background	−0.003	0.004*	0.026***	0.000
	(0.006)	(0.002)	(0.009)	(0.003)
Educated Parents	−0.031***	−0.002	0.059***	0.002
	(0.008)	(0.003)	(0.010)	(0.004)
Local	0.013	−0.009**	−0.030**	0.010**
	(0.010)	(0.003)	(0.013)	(0.005)
Repeater	0.032***	0.004	−0.074***	−0.006
	(0.011)	(0.002)	(0.015)	(0.004)
High Ability	−0.000	−0.001	0.004	0.003
	(0.004)	(0.002)	(0.006)	(0.002)
Express Clearly	0.009*	0.002	−0.013**	−0.003
	(0.005)	(0.002)	(0.006)	(0.002)
Response Quickly	0.001	−0.000	0.014**	0.002
	(0.005)	(0.002)	(0.006)	(0.002)
Fast Learner	−0.011**	0.001	0.019***	−0.001
	(0.005)	(0.002)	(0.006)	(0.002)
Curious	−0.000	0.000	−0.009	−0.001
	(0.005)	(0.002)	(0.007)	(0.002)
Test for joint significance				
F-statistics	6.18	1.42	18.53	1.14
p-value	0.00	0.13	0.00	0.32
Grade fixed effects	–	Yes	–	Yes
School fixed effects	–	Yes	–	Yes

Notes: Standard errors (in parentheses) are clustered at the class level. OLS estimation is applied for the regressions. School fixed effects and grade fixed effects are included for the regression in columns (2) and (4).
*** p<0.01, ** p<0.05, * p<0.1.

5.3. Robustness tests

We conduct several robustness tests to check the baseline estimates. First, we check whether the effects are mainly driven by the unmeasured characteristics of classmates. For example, the effects may simply be a reflection of peers' family backgrounds, given that families with better economic conditions are more likely to invest in their children. Class size and gender composition are also found to be correlated with the outcomes in previous studies (e.g., Angrist & Lavy, 1999; Gong, Lu, & Song, 2021; Lavy & Schlosser, 2011). If so, the estimates are actually a combination of endogenous peer effects and contextual peer effects, as noted in footnote 5. To mitigate the reflection problem, we further control for a set of average characteristics of classmates/preschool attendees, as in Eisenberg et al. (2014) and Huang and Zhu (2020). Regressions in Panel A of Table 7 include five additional variables, i.e., classmates' current and early family conditions, classmates' quality, class size and gender composition. Panel B of Table 7 further controls for a set of average characteristics of preschool attendees, i.e., gender composition, average early and current family backgrounds, and the share of educated parents. If the contextual effects are dominant, the estimated effects should dramatically decrease in magnitude once we control for the contextual characteristics. However, it can be seen that the coefficients of interest do not change a lot in comparison with the corresponding baseline estimates, indicating that the baseline results are not sensitive to the inclusion of the potential contextual characteristics.

Second, given that migrant and private schools are quite different from public schools, we examine whether the effects are robust to the exclusion of these two types of schools. Migrant schools stem from the schooling demand of migrant children who are typically

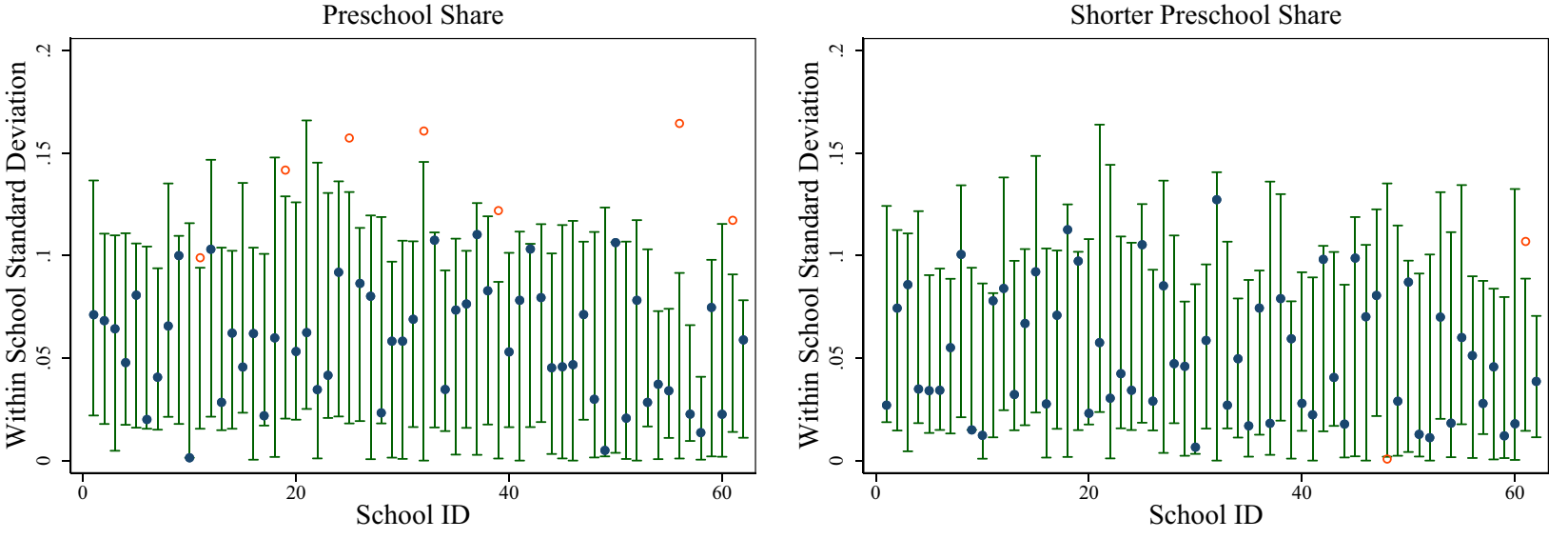


Fig. 2. Monte Carlo simulations of preschool share.

Notes: The figure presents the Monte Carlo simulations for the within-school standard deviations in the proportions of students with a (shorter) preschool experience relative to all students. Vertical bars represent simulated 95% confidence intervals for within-school standard deviations in the Preschool Share and Shorter Preschool Share variables. Scattered points represent actual within-school standard deviations for each school. Filled circles indicate that the actual standard deviation is within the simulated 95% confidence interval, whereas hollow circles indicate schools with standard deviations outside the simulated confidence interval.

Table 4
Tests for random class assignment of teachers.

Variables	Shorter preschool share		Preschool share	
	(1)	(2)	(1)	(2)
Teacher's Age	−0.000	0.001	−0.002	−0.001
	(0.002)	(0.001)	(0.003)	(0.001)
Teacher's Education	−0.032*	0.016	0.078***	−0.021
	(0.018)	(0.012)	(0.028)	(0.014)
Teacher's Title	−0.036***	−0.004	0.100***	0.005
	(0.012)	(0.011)	(0.018)	(0.013)
Test for joint significance				
F-statistics	5.82	0.71	21.80	0.80
p-value	0.00	0.55	0.00	0.49
Grade fixed effects	–	Yes	–	Yes
School fixed effects	–	Yes	–	Yes
N	6783	6783	6783	6783
R-squared	0.073	0.769	0.190	0.860

Note: Standard errors (in parentheses) are clustered at the class level. OLS estimation is applied for the regressions. School fixed effects and grade fixed effects are included for the regression in columns (2) and (4).
*** p<0.01, ** p<0.05, * p<0.1.

Table 5
Effects of exposure to preschool attendees on cognitive outcomes.

	(1)	(2)	(3)	(4)
	Dependent Variable: Academic Achievement			
Preschool Share	0.614***	0.431**	0.422**	0.492**
	(0.221)	(0.184)	(0.175)	(0.227)
Shorter Preschool Share	–	–	–	0.144
				(0.265)
Students' Characteristics	–	Yes	Yes	Yes
Teachers' Characteristics	–	–	Yes	Yes
N	6783	6783	6783	6783
R-squared	0.006	0.253	0.254	0.254
	Dependent Variable: Cognitive Score			
Preschool Share	0.831***	0.685***	0.704***	0.669**
	(0.274)	(0.247)	(0.247)	(0.314)
Shorter Preschool Share	–	–	–	−0.072
				(0.331)
Students' Characteristics	–	Yes	Yes	Yes
Teachers' Characteristics	–	–	Yes	Yes
N	6783	6783	6783	6783
R-squared	0.280	0.342	0.342	0.342

Notes: Standard errors (in parentheses) are clustered at the class level. School fixed effects and grade fixed effects are also included in each regression. Preschool Share is defined as the share of classmates with a three-year preschool experience. Shorter Preschool Share is defined as the share of classmates with a one- or two-year preschool experience. Variables of students' Characteristics and teachers' characteristics are listed in Table 2.
*** p < 0.01, ** p < 0.05, * p < 0.1.

excluded from the urban public education system.[20] Students from migrant schools typically have a poorer family background and perform worse in terms of test scores than their counterparts from public schools (Chen & Feng, 2013, 2017; Chen, Huang, Rozelle, Shi, & Zhang, 2014; Wang, Luo, Zhang, & Rozelle, 2017). In contrast, enrollments in private schools may be highly selective because of the expensive tuition (Schulte, 2017). The inclusion of students from these two types of schools may bias the estimates. Panel C of Table 7 suggests that the baseline estimates are robust to the exclusion of migrant and private schools from the sample.

5.4. Comparisons with prior studies

The results presented above suggest that a higher share of classmates with a three-year preschool experience tends to improve the subject scores of the students in the class, while exposure to more classmates with a shorter preschool duration does not. On average, given a 10-percentage increase in the *preschool share*, the external effects range from 0.04 to 0.06 standard deviations. The magnitudes of the effects are comparable to those reported in previous studies, which use the same data and investigate the external effects of other

[20] Migrant children usually refer to those who live in cities with their migrant parents but have a Hukou registered in their hometown (Wang, Zhang, Ni, Zhang, & Zhang, 2019).

Table 6
Effects of exposure to preschool attendees on non-cognitive outcomes.

	Dependent variable						Dependent variable
	Feeling blue	Feeling unhappy	Feeling sad	Feeling depressed	Meaningless life	AES	Mental stress
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Preschool Share	−0.214*	−0.033	−0.201**	−0.213***	−0.203**	−0.392**	−0.543**
	(0.110)	(0.116)	(0.088)	(0.075)	(0.080)	(0.154)	(0.227)
Shorter Preschool Share	−0.124	0.031	−0.134	−0.141	−0.258***	−0.258	−0.428
	(0.121)	(0.141)	(0.109)	(0.095)	(0.096)	(0.190)	(0.279)
N	6783	6783	6783	6783	6783	6783	6783
R-squared	0.062	0.054	0.048	0.055	0.042	–	0.081

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (6) presents the average effect size (AES) of preschool shares on five mental health indicators in columns (1)–(5) based on the approach proposed by Kling et al. (2007). Column (7) reports the effects of preschool shares on non-cognitive outcome measuring as a composite index of mental stress.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7
Robustness checks.

Variables	Academic achievement		Cognitive score		Mental stress	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Controlling for Class Characteristics						
Preschool Share	0.337**	0.391*	0.568**	0.517	−0.313*	−0.537**
	(0.161)	(0.212)	(0.260)	(0.323)	(0.173)	(0.243)
Shorter Preschool Share	–	0.111	–	−0.104	–	−0.458
		(0.252)		(0.329)		(0.289)
N	6783	6783	6783	6783	6783	6783
R-squared	0.256	0.256	0.345	0.345	0.081	0.082
Panel B: Controlling for Peers' Contextual Characteristics						
Preschool Share	0.348**	0.403*	0.535**	0.496	−0.316*	−0.541**
	(0.164)	(0.213)	(0.251)	(0.318)	(0.174)	(0.250)
Shorter Preschool Share	–	0.113	–	−0.079	–	−0.464
		(0.250)		(0.332)		(0.281)
N	6783	6783	6783	6783	6783	6783
R-squared	0.257	0.257	0.346	0.346	0.082	0.082
Panel C: Subsample Excluding Migrant and Private Schools						
Preschool Share	0.415**	0.449**	0.755***	0.712**	−0.370**	−0.514**
	(0.171)	(0.219)	(0.251)	(0.316)	(0.176)	(0.231)
Shorter Preschool Share	–	0.071	–	−0.091	–	−0.299
		(0.254)		(0.329)		(0.274)
N	6359	6359	6359	6359	6359	6359
R-squared	0.262	0.262	0.345	0.345	0.078	0.079

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Regressions in Panel A also include a set of class characteristics listed in Table 2. Regressions in Panel B include a set of average characteristics of preschool attendees, including gender composition, average early and current family background, and the share of educated parents. Regressions in Panel C use a subsample that only covers students from public schools.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

peer characteristics (e.g., Gong et al., 2021; Hu, 2018; Huang & Zhu, 2020). In terms of the effects on students' academic achievement, Huang and Zhu (2020), for example, report that a 10-percentage increase in the share of repeaters in a class results in a decrease of academic achievement by 0.12 standard deviations. However, given that the two studies have used the same data to investigate a similar topic, our results seem much lower than that of Wang (2021) who reports an external effect of 0.1 standard deviations on students' academic achievement.

It's worth noting that a simple comparison between Wang (2021) and ours may not be informative for two reasons. One is that the two studies use different measurements of the key independent variable. Wang (2021) defines the preschool share as the share of classmates with a preschool experience without distinguishing the preschool program duration. The other is that the sample and sample restrictions used in this study are different from those in Wang (2021). We use the cross-sectional sample from the CEPS 2013–2014 wave in most of our analyses, while Wang (2021) uses a pooled sample from the 2013–2014 and 2014–2015 waves.

To make a meaningful comparison between Wang (2021) and ours, we then attempt to use the same CEPS waves and the sample

restrictions used in Wang (2021) to generate a replication sample.[21] Table 8 provides a comparative analysis using the replication sample. As a benchmark, column (1) of Table 8 simply copies the result of column (3) of Table 3 in Wang (2021). The regression in column (2) uses the preschool share measure same as that in Wang (2021) and repeats the estimation using our replication sample. The coefficient of interest remains statistically significant at the 5% level, but its magnitude is lower than that reported in Wang (2021). Regression in column (3) uses the *preschool share*, instead of *Wang's preschool share*, as the key independent variable. The coefficient of interest increases from 0.701 to 0.888, and remains statistically significant. In column (4), we break down *Wang's preschool share* into two shares, *preschool share* and *shorter preschool share*. We observe a similar pattern, as found in Table 5. An increase in the *preschool share* has statistically significant effects on students' academic achievement, however an increase in *shorter preschool share* does not have such effects. Consistent with the findings in Table 5, the evidence above suggests that exposure to classmates with a shorter preschool duration does not seem to have a significant effect on students' academic achievement. If students attending a shorter preschool program are less capable than those attending a three-year preschool program, as indicated in Table A1, equivalently treating students with different preschool durations may underestimate the effects.

As mentioned earlier, we have also utilized the information from the head teacher questionnaire to ensure that students in the sample are randomly grouped into classes. In columns (5) and (6), we further refine the replication sample by excluding the grades that may violate the random class assignment assumption. The coefficient of *Wang's preschool share* decreases dramatically from 0.701 to 0.126, and becomes statistically insignificant. The coefficient of the *preschool share* variable has also a large decrease but remains marginally significant. Importantly, the effect is very close to those reported in Table 5. The results provide a piece of evidence that estimations without fully controlling for potential class sorting may lead to an overestimation of the effect.

6. Mechanisms

Our baseline estimates suggest that exposure to more preschool attendees in a class tends to improve students' outcomes. If preschool programs do improve children's behaviors, as found in prior studies, one would expect that classes with more preschool attendees would have a more suitable environment for learning and teaching. In this section, we investigate three potential mechanisms through which preschool attendees affect students' cognitive and non-cognitive outcomes, and quantify the relative power of each mechanism.

6.1. Inter-student interaction: Effects on Students' behaviors and attitudes

We first look at whether the effects are driven by the inter-student interactions in classrooms. Intuitively, peers could affect the learning behaviors and attitudes of their classmates, either via their behaviors or via their academic performance (Carrell & Hoekstra, 2010). In the context of the present study, for example, students in classes with more preschool attendees may be less distracted because preschool attendees are more likely to be well-behaved and self-disciplined. Furthermore, given that preschool attendees typically perform better in academics, students in classes with more preschool attendees can learn from more classmates with better academic performance.

The CEPS covers a set of questions regarding students' learning behaviors and their prospects for future achievements. Using these information, we first define five behavior variables (*late for class, TV time, game time, learning effort,* and *homework time*) and three attitude variables (*college prospect, career prospect,* and *self-confidence*). *Late for class* is a dummy variable that equals 1 if the student's response to the item "I am always late for school" is "strongly agree" or "comparatively agree." *TV time* denotes the time that the student spent in watching TV on the last weekdays. *Game time* denotes the time that the student spent on Internet surfing or computer games last weekdays. *Learning effort* is a dummy variable that equals 1 if parents believe their child is "very hardworking" or "relatively hardworking." *Homework time* denotes the time that the student spent on homework in the last week. *College prospect* is a dummy variable that equals 1 if the student believes that he/she will receive an education level of at least junior college. *Career prospect* is a dummy variable that equals 1 if the student believes that he/she will engage in an occupation that requires high-skilled experience and/or a college degree. *Self-confidence* is a dummy variable that equals 1 if the student's response to the question of "Are you confident in your future?" is "somewhat confident" or "very confident." Based on the above two categories of variables, we also construct two composite indices of *learning behaviors* and *attitudes*. Similar to the construction of the *mental stress* variable, both indices have a mean of zero and a standard deviation of one.[22]

Table 9 summarizes the results using the above two composite indices as the dependent variable, respectively. We find that the coefficients of the *preschool share* variable are positive and statistically significant regardless of the inclusion of the *shorter preschool share*. In addition, although the coefficients of the *shorter preschool share variable* have a positive sign, neither of them is statistically significant. In Tables A3 and A4 of the Appendix, we also use the five behavior indicators and three attitude indicators as the dependent variable, respectively, and compute the average effects of each category. The pattern of the results is basically consistent with that found in Table 9.

[21] It is worth noting that the size of our replication sample is not perfectly equivalent to that of Wang (2021) since we are unable to obtain the data cleaning codes used in Wang (2021).

[22] The *learning behaviors* index is by design negatively correlated with the first three variables but positively correlated with the last two variables of the category. The *attitude* index is by design positively correlated with the three variables of the category.

Table 8
Comparisons with the findings in Wang (2021).

	Dependent variable: subject score					
	Wang (2021)	Replication sample of Wang (2021)			Sample with more restrictions	
	(1)	(2)	(3)	(4)	(5)	(6)
Wang's Preschool Share	1.010**	0.701**	–	–	0.126	–
	(0.435)	(0.292)			(0.346)	
Preschool Share	–	–	0.888***	0.959***	–	0.516*
			(0.242)	(0.298)		(0.272)
Shorter Preschool Share	–	–	–	0.166	–	–
				(0.298)		
Observations	36,309	35,279	35,279	35,279	28,127	28,127
R-squared	0.094	0.081	0.083	0.083	0.092	0.092

Notes: Student control variables include student's age, gender, number of siblings, parental education, and dummy variables indicating race, hukou status, whether attended kindergarten. Teacher control variables include teacher's gender, marital status, years of experience, and years of education. Peers' family socioeconomic background is measured by peers' parental education and peers' family income status. All specifications include student and teacher control variables, peers' family socioeconomic background, school fixed effects, wave fixed effects and subject fixed effects. Columns (5)–(6) further include additional classmates' variables such as class size and gender composition, and a set of average characteristics of preschool attendees (i.e., gender composition, average family background, the share of parental education).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9
Mechanism: effects on students' behaviors and attitudes.

Variables	Dependent variable			
	Learning behaviors		Attitudes	
	(1)	(2)	(3)	(4)
Preschool Share	0.385**	0.569***	0.319**	0.474***
	(0.166)	(0.185)	(0.138)	(0.181)
Shorter Preschool Share	–	0.377	–	0.323
		(0.240)		(0.238)
N	6407	6407	6783	6783
R-squared	0.171	0.171	0.160	0.161

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

6.2. *Teacher-student interaction: Effects on Teachers' behaviors*

Prior studies have demonstrated that teachers may behave differently towards students with different characteristics (see Dee, 2005; Fairlie, Hoffmann, & Oreopoulos, 2014; Gong et al., 2018; Lavy & Schlosser, 2011), although the evidence remains limited and varies across contexts (Feld & Zölitz, 2017). For example, Gong et al. (2018) find that female teachers are less likely to criticize girls than boys, and are more likely to question and praise girls than boys.

We then turn to examine whether teachers positively respond to classes with more preschool attendees in terms of their teaching behaviors. We use the information from both the parents and teacher questionnaires. Specifically, parents are requested to answer three questions: (1) "Is the teacher responsible for the child?" (2) "Is the teacher patient with the child?" and (3) "How many times has this child's teacher contacted the parents this semester?" In the teacher questionnaire, teachers are requested to answer the question of "How many hours did you spend on correcting homework and/or test papers last week?" Based on these responses, we construct four separate variables (i.e., *being responsible*, *being patient, contacting parents*, and *time spent on correcting homework*).[23] We also construct a standardized index of *teachers' behaviors* that combine the four dimensions. The composite index is by design positively correlated to each of the variables.

We first look at the estimation results using the above four behavior and attitude variables as the dependent variable, and calculate the corresponding average effects. The results are presented in columns (1)–(5) of Table 10. We find that teachers are more likely to be responsible for and patient with students,[24] contact parents more frequently and may devote more time to correcting homework if they

[23] *Being responsible* is a dummy variable that equals 1 if a parent's response to the item "Is the teacher responsible for the child" is "somewhat responsible" or "very responsible"; 0, otherwise. *Being patient* is a dummy variable that equals 1 if a parent's response to the item "Is the teacher patient to the child" is "somewhat patient" or "very patient"; 0, otherwise. *Contacting parents* is a dummy variable that equals 1 if a parent's response to the item "How many times has this child's teacher contacted the parents this semester" is more than twice; 0, otherwise. *Time spent on correcting homework* denotes the time that the teacher spent on correcting homework and/or test papers last week.

[24] It is worth to noting that these two characteristics are not fully predetermined and are constructed according to parents' responses. Finding statistically significant effects on these two variables are not contradictable to our balance test.

teach a class with more three-year preschool attendees. On the contrary, no strong evidence is observed that exposure to more students with a shorter preschool duration helps improve teachers' teaching behaviors. This pattern is also confirmed by the average effects reported in column (5) of Table 10, and the results in column (6) of Table 10 where the composite *teachers' behaviors* index is used as the dependent variable.

6.3. Family-class interaction: Effects on Parents' behaviors

As pointed out by Cunha and Heckman (2007), skill formation may be affected through the positive interactions between various kinds of skill investments. A growing body of literature on parenting economics has emphasized the role of parenting styles and parent-child interactions in child development (see e.g., Doepke, Sorrenti, & Zilibotti, 2019; Doepke & Zilibotti, 2017; Seror, 2022). Parents may adjust their behaviors in response to the class learning of their child. For example, parents may devote more effort to their child at home if they believe that their child's learning in class is efficient, thus generating a complementation effect. Alternatively, if parents devote less effort to their child in response to efficient class learning, there will be a substitution effect. Either of the effects would lead to a family-class interaction.

Owing to data limitations, we do not have direct measures for family-class interaction. Instead, we look at whether parents' behaviors respond to the class peers of their child. In the CEPS, parents are requested to answer a series of questions regarding their behaviors and the effort spent on their child. Specifically, the questions are as follows: (1) "Do you know the parents of the child's friends?" (2) "Do you contact the teacher this semester?" (3) "Do you attend the parent meeting this semester?" (4) "Could you meet the requirement if the teachers ask you to check homework?" (5) "How much time do you spend directly on this child every day on average?" To a certain extent, these behaviors can capture parents' efforts devoted to their child because all of these activities cost parents' time.

Again, we first construct five separate variables (*familiar with other parents*, *attending parent meeting*, *contacting teachers, checking homework, time spent on child*) based on the responses to the above questions.[25] We also construct a standardized index of *parents' behaviors* that combines all the above five dimensions. The composite index is, by design, positively correlated to each of the variables.

From Table 11, on the one hand, we observe that all the coefficients of the *preschool share* variable have an expected sign and most are statistically significant. On the other hand, most coefficients of the *shorter preschool share* variable are statistically insignificant and the signs of the coefficients exhibit a mixed pattern. The average effects in column (6) and the results in column (7), where the composite index is used as the dependent variable, further confirm the pattern. Parents tend to respond positively to the quality of class peers of their child. However, such kind of positive responses can be only observed for parents whose children are assigned to a class having more students with a longer preschool duration.

6.4. Relative explanatory powers of mechanisms

The results above have revealed three possible channels through which exposure to classmates with a longer preschool duration in classes affects students' cognitive and non-cognitive outcomes. We then attempt to quantify the relative importance of each mechanism. To do so, we follow the decomposition approach proposed by Heckman et al. (2013) and Gelbach (2016).

Let m^j_{icgs} denote the mechanism variable j, and $\widehat{\beta^j}$ denote the estimated coefficient of preschool share obtained from the corresponding regression of m^j_{icgs} on preschool share and a set of variables included in Eq. (1). Next, we estimate Eq. (2), which combines Eq. (1) with all the mechanism variables, to obtain the estimated coefficients of $\widehat{\theta^j}$.

$$y_{icgs} = \alpha_2 + \beta_2 * \text{Preschool share}_{-icgs} + \sum_j \theta^j m^j_{icgs} + \delta X_{igcs} + \tau_g + \omega_s + \varepsilon_{icgs} \quad (2)$$

Using the estimated coefficients of $\widehat{\theta^j}$ and $\widehat{\beta^j}$, we can easily obtain mechanism j's component, $\widehat{\theta^j}\widehat{\beta^j}$. The explanatory power of mechanism j can therefore be described as $\widehat{\theta^j}\widehat{\beta^j}/\widehat{\beta}$, where $\widehat{\beta}$ is the estimated coefficient obtained from the estimation of Eq. (1).

Fig. 3 presents the distributions that decompose the external effects of exposure to preschool attendees in a class on different outcomes into each of the above mechanisms and other factors. The total explanatory powers of the three mechanisms vary across outcomes. Approximately 60% of the effect on academic achievement, 20% of the effect on cognitive score and 40% of the effect on mental stress can be explained by the three channels. It can also be seen that the decomposition distributions differ for different outcomes. The inter-student interaction channel plays an important role in explaining the external effects on academic achievement and cognitive score, accounting for about two-thirds of the total explanatory powers. The other two channels together can explain 19% of the external effect on students' mental stress.

[25] *Familiar with other parents* is a dummy variable that equals 1 if a parent's response to the item "Do you know the parents of the child's friends" is "Yes"; 0, otherwise. *Attending parent meeting* is a dummy variable that equals 1 if a parent's response to the item "Do you attend the parent meeting this semester" is "Yes"; 0, otherwise. *Contacting Teachers* is a dummy variable that equals 1 if a parent's response to the item "Do you contact the teacher this semester" is "Yes"; 0, otherwise. *Checking homework* is a dummy variable that equals 1 if a parent's response to the item "Could you meet the requirement if the teachers ask you to check homework?" is "completely" or "mostly"; 0, otherwise. *Time spent on child* denotes the time that the parent spent on child every day on average.

Table 10
Mechanism: effects on teachers' behaviors.

Variables	Dependent variable					Dependent variable
	Being patient	Being responsible	Contacting parents	Time Spent on correcting homework	AES	Teachers' behaviors
	(1)	(2)	(3)	(4)	(5)	(6)
Preschool Share	0.160*	0.122*	0.276**	0.481*	0.656***	0.610***
	(0.086)	(0.071)	(0.115)	(0.278)	(0.232)	(0.228)
Shorter Preschool Share	0.059	−0.004	0.127	0.204	0.236	0.177
	(0.092)	(0.084)	(0.161)	(0.322)	(0.270)	(0.258)
N	6783	6783	6783	6783	6783	6783
R-squared	0.097	0.088	0.088	0.560	–	0.120

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (5) presents the average effect size (AES) of preschool shares on four indicators in columns (1)–(4) based on the approach proposed by Kling et al. (2007). Column (6) reports the effects of preschool shares on teachers' behaviors using a composite index as dependent variable.
*** p<0.01, ** p<0.05, * p<0.1.

Table 11
Mechanism: effects on parents' behaviors.

Variables	Dependent variable					AES	Dependent variable
	Familiar with other parents	Attending parent meeting	Checking homework	Time spent on child	Contacting teachers		Parents' behaviors
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Preschool Share	0.183*	0.090	0.402***	0.409**	0.187**	0.491***	0.791***
	(0.111)	(0.086)	(0.119)	(0.181)	(0.089)	(0.140)	(0.226)
Shorter Preschool Share	0.124	−0.073	0.067	0.488**	0.039	0.203	0.316
	(0.129)	(0.102)	(0.140)	(0.196)	(0.109)	(0.160)	(0.258)
N	6783	6783	6783	6783	6783	6783	6783
R-squared	0.067	0.321	0.190	0.096	0.092	–	0.217

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (6) presents the average effect size (AES) of preschool shares on the five parents' behavior indicators in columns (1)–(5) based on the approach proposed by Kling et al. (2007). Column (7) reports the effects of preschool shares on parents' behaviors using a composite index as dependent variable.
*** p<0.01, ** p<0.05, * p<0.1.

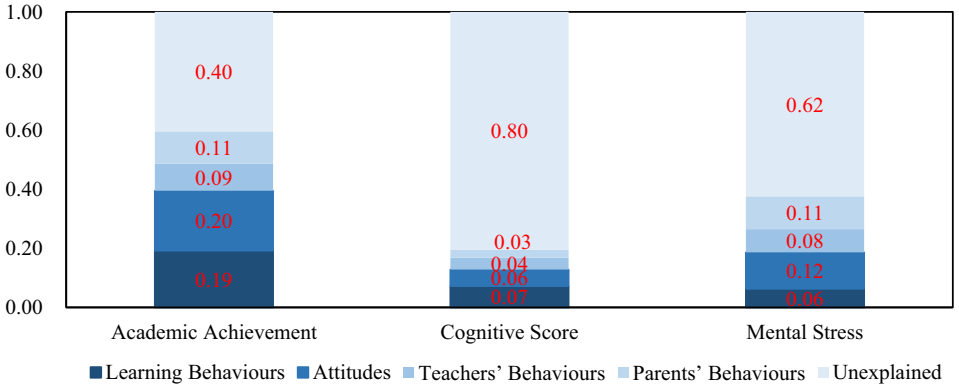


Fig. 3. Explanatory powers of mechanisms.
Notes: The figure presents the distributions that decomposes the external effects of exposure to preschool attendees in a class on different outcomes into each of the mechanisms and other factors. The effect on academic achievement can be explained by students' learning behaviors (19.2%), students' attitudes (20.3%), teachers' behaviors (9.1%), parents' behaviors (10.9%), and other factors. The effect on cognitive score can be explained by students' learning behaviors (7.2%), students' attitudes (5.6%), teachers' behaviors (4.1%), parents' behaviors (2.7%), and other factors. The effect on mental stress can be explained by students' learning behaviors (6.3%), students' attitudes (12.3%), teachers' behaviors (7.9%), parents' behaviors (11.1%), and other factors.

7. Heterogeneity in the effects

The baseline estimations present the linear-in-means effects of exposure to more classmates with a preschool experience. To shed light on potential heterogeneity, we test whether the effects vary across students with different characteristics. Doing so may also help improve our understanding of the potential mechanisms driving the linear-in-means results.

7.1. Do boys benefit more or less than girls?

Many prior studies have revealed that boys and girls may behave differently towards class peer composition (Black, Devereux, & Salvanes, 2013; Carrell & Hoekstra, 2010; Lavy, Silva, & Weinhardt, 2012). For example, Carrell and Hoekstra (2010) show that disruptive students in classrooms tend to affect primarily boys' academic achievement. On the other hand, Cai, Lu, Pan, and Zhong (2019) find that females perform worse than males in the competitive and high-stakes national college entrance examination.[26] Given that children with a preschool experience are better-behaved and perform better in academics, an increase in the preschool share may decrease disruptive peers and increase the degree of competition among students. To examine the potential gender heterogeneity of the effects, we report the external effects of exposure to more preschool attendees for the male and female subsamples.

As shown in Panel A of Table 12, the effects of exposure to classmates with a three-year preschool experience on *academic achievement* and *cognitive score* are statistically significant for girls, but insignificant and smaller in magnitude for boys. The finding suggests that girls' learning behaviors benefit more than boys from less disruptive peers in class. On the contrary, exposure to classmates with a three-year preschool experience tends to have a larger effect on boys' mental stress. One possible reason for this finding is that boys may receive less criticism from teachers and parents for their less disruptive behaviors in a class with less disruptive peers.

The results also reveal that neither of the coefficients of the *shorter preschool share* variable for both subsamples is statistically significant at the 10% level and the effects on *academic achievement* and *cognitive score* for boys and girls have mixed signs. The finding again confirms that students do not benefit from exposure to classmates with a shorter preschool duration.

7.2. Do children from disadvantaged families benefit more or less?

We have shown that parents behave positively towards the quality of class peers of their child. Prior studies have found that children from disadvantaged families are more likely to be affected by their classmates (e.g., Carrell & Hoekstra, 2010; Gong et al., 2018; Lavy & Schlosser, 2011). Uneducated parents may have little sense of fostering their child's skills via their own parenting at home or/and be less capable to teach their child themselves because they have less knowledge. Therefore, students with uneducated parents are more likely to be from disadvantaged families. Previous evidence has also revealed that students may benefit from the exposure to classmates with educated parents (Liu, Mao, & Zhang, 2022). One would expect to observe larger effects among students with uneducated parents because their parents may learn more from other educated parents.

From Panel B of Table 12, we see that the effects of exposure to classmates with a three-year preschool experience on cognitive and non-cognitive outcomes are all statistically significant among students with uneducated parents. The magnitudes of the coefficients are close to the baseline estimates reported in Tables 5 and 6, indicating that the effects may be primarily driven by students with uneducated parents. However, probably because the subsample size is too small, we do not find such consistent effects among students with educated parents. On the one hand, neither the effects on academic achievement nor mental stress are statistically significant. On the other hand, students with educated parents benefit significantly from exposure to classmates with a three-year preschool experience.

7.3. Do low-ability students benefit more or less?

Prior studies have revealed that students with different qualities may respond differently to exposure to high-ability peers (see e.g., Burke & Sass, 2013; Feld & Zölitz, 2017). If preschool attendees do better in communicating with classmates and teachers and learning from them, and the parents of preschool attendees devote more effort to their children, one would expect to observe larger external effects among preschool attendees. Alternatively, if non-preschool attendees can learn more from high-quality peers, one would expect to observe larger external effects among non-preschool attendees. To examine the possible ability heterogeneity, we report the external effects for preschool attendees and non-preschool attendee subsamples.

The results in Panel C of Table 12 clearly show that the effects of exposure to classmates with a longer preschool duration are all statistically significant for preschool attendees, but insignificant and smaller in magnitude for non-preschool attendees. The findings are consistent with those reported in prior studies. For example, Burke and Sass (2013) show that low-ability students appear to benefit less from an increase in the average ability of their peer group.[27]

[26] Similar findings also appear in Gneezy, Niederle, and Rustichini (2003) who find that males are more effective than females in competitive environments.

[27] Feld and Zölitz (2017) find that low-ability students are harmed by high-ability peers although students benefit from high-ability peers on average.

Table 12
Heterogeneity of the external effects.

	Dependent variable:					
	Academic achievement	Cognitive score	Mental stress	Academic achievement	Cognitive score	Mental stress
	(1)	(2)	(3)	(5)	(6)	(7)
Panel A:	Boys			Girls		
Preschool Share	0.466	0.536	−0.621*	0.514**	0.744**	−0.409
	(0.310)	(0.347)	(0.326)	(0.215)	(0.330)	(0.248)
Shorter Preschool Share	−0.119	−0.306	−0.207	0.367	0.069	−0.499
	(0.364)	(0.392)	(0.405)	(0.267)	(0.347)	(0.325)
N	3331	3331	3331	3452	3452	3452
R-squared	0.208	0.358	0.073	0.252	0.346	0.116
Panel B:	Educated Parents			Uneducated Parents		
Preschool Share	0.369	1.407**	−0.181	0.519**	0.552*	−0.564**
	(0.412)	(0.613)	(0.639)	(0.240)	(0.326)	(0.221)
Shorter Preschool Share	0.193	−0.145	0.194	0.155	−0.044	−0.457
	(0.579)	(0.931)	(0.810)	(0.273)	(0.341)	(0.279)
N	983	983	983	5797	5797	5797
R-squared	0.279	0.262	0.133	0.259	0.339	0.081
Panel C:	Preschool Attendee			Non-Preschool Attendee		
Preschool Share	0.457*	0.640*	−0.531**	0.410	0.322	−0.053
	(0.241)	(0.344)	(0.251)	(0.430)	(0.389)	(0.394)
Shorter Preschool Share	0.176	−0.027	−0.383	−0.157	−0.587	−0.145
	(0.279)	(0.346)	(0.316)	(0.477)	(0.543)	(0.489)
N	5565	5565	5565	1218	1218	1218
R-squared	0.265	0.316	0.079	0.255	0.406	0.119

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

8. Conclusions

Early childhood education is viewed as an effective intervention that may have long-lasting impacts on child development. Despite the extensive evidence with respect to the private benefits of early education programs, evidence of the social benefits of these programs remains limited. This paper investigates the effects of attending a preschool program from the perspective of externalities with a focus on preschool dosage effects. We use the random class assignment rule embedded in the Chinese education system to mitigate the selection bias from potential class sorting. We show that exposure to classmates with a three-year preschool experience is conducive to the improvements of students' cognitive and non-cognitive outcomes, while exposure to classmates with a shorter preschool duration tends to have no such significant effects. We also demonstrate that a large part of the effects can be explained by three types of interactions. In addition, girls tend to benefit more in the achievement of cognitive outcomes but benefit less in the relief of mental stress than boys. Students with educated parents and preschool attendees are also found to benefit more than their counterparts.

Our study has implications for the allocation of public education resources. First, it presents evidence of the positive external benefits of attending a preschool. The economic value of preschool programs will be underestimated if these effects are ignored. Second, our finding on the preschool dosage effects implies that it may be more efficient to prioritize prolonging preschool duration given the limited early education resources.

Data availability

Data will be made available on request.

Appendix

Table A1
Average quality of students with different preschool durations.

Variables	Students with a 3-year preschool experience	Students with a 1–2 year preschool experience	Differences between (1) and (2)
	(1)	(2)	(3)

(*continued on next page*)

Table A1 (*continued*)

Variables	Students with a 3-year preschool experience	Students with a 1–2 year preschool experience	Differences between (1) and (2)
	(1)	(2)	(3)
Academic Rank in Grade 6	13.983	14.955	−0.972***
	(11.089)	(11.499)	
Repeater	0.049	0.113	−0.064***
	(0.216)	(0.317)	
N	3559	2006	

Notes: Columns (1)-(2) report the means and standard deviations (in parentheses) of student's average quality (measured as academic relative rank in grade 6 and whether is a grade-repeater in primary school). Column (3) reports the differences of the means in columns (1) and (2).
*** Significant at the 1% level.

Table A2
Effects of exposure to preschool attendees on students' subject score.

Variables	Dependent variable			AES
	Chinese score	Math score	English score	
	(1)	(2)	(3)	(4)
Preschool Share	0.485**	0.608**	0.080	0.509**
	(0.221)	(0.243)	(0.245)	(0.233)
Shorter Preschool Share	0.117	0.307	−0.092	0.149
	(0.268)	(0.295)	(0.287)	(0.272)
N	6783	6783	6783	6783
R-squared	0.212	0.181	0.240	

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (4) presents the average effect size (AES) of preschool shares on three academic achievement indicators in columns (1)–(3) based on the approach proposed by Kling et al. (2007).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A3
Effects of exposure to preschool attendees on students' behaviors.

Variables	Dependent variable			AES	Dependent variable		AES
	Late for class	TV Time	Game time		Learning effort	Homework time	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Preschool Share	−0.025	−1.378***	−0.302	−0.299**	0.090	0.762***	0.395**
	(0.044)	(0.423)	(0.452)	(0.132)	(0.110)	(0.286)	(0.172)
Shorter Preschool Share	−0.015	−1.017*	−0.183	−0.208	0.048	0.398	0.208
	(0.053)	(0.576)	(0.598)	(0.159)	(0.150)	(0.465)	(0.257)
N	6407	6407	6407	6407	6407	6407	6407
R-squared	0.038	0.135	0.096	–	0.145	0.185	–

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (4) presents the average effect size (AES) of preschool shares on three behaviors indicators in columns (1)–(3) based on the approach proposed by Kling et al. (2007). Column (7) reports the average effect size (AES) of preschool shares on two behaviors indicators in columns (5) and (6).
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table A4
Effects of exposure to preschool attendees on students' attitudes.

Variables	Dependent variable			AES
	College prospect	Career prospect	Self-confidence	
	(1)	(2)	(3)	(4)
Preschool Share	0.185***	0.048	0.068	0.323***
	(0.062)	(0.074)	(0.046)	(0.123)
Shorter Preschool Share	0.088	0.036	0.095	0.233
	(0.071)	(0.098)	(0.059)	(0.164)
N	6783	6783	6783	6783
R-squared	0.174	0.056	0.089	–

Notes: Standard errors (in parentheses) are clustered at the class level. A full set of students' and teachers' characteristics listed in Table 2, school fixed effects and grade fixed effects are also included in each regression. Column (4) presents the average effect size (AES) of preschool shares on three attitude indicators in columns (1)–(3).
*** p < 0.01, ** p < 0.05, * p < 0.1.

Table A5
Construction of composite standardized indices.

Index	Item definition	Scale/Units	Correlation Coef.
Mental Stress	whether the respondent has ever experienced feelings such as feeling blue in the past seven days.	1–5; 1 (never) to 5 (always)	0.823*
	whether the respondent has ever experienced feelings such as feeling depressed in the past seven days.		0.830*
	whether the respondent has ever experienced feelings such as feeling unhappy in the past seven days.		0.844*
	whether the respondent has ever experienced feelings such as feeling not enjoying life in the past seven days.		0.745*
	whether the respondent has ever experienced feelings such as feeling sad in the past seven days.		0.811*
Student' Behaviors	if a student's response to the item "I am always late for school" is "strongly agree" or "comparatively agree".	0–1; Yes = 1; Otherwise = 0	−0.209*
	if parents' evaluation on students' effort in learning is "very hardworking" or "relatively hardworking".		0.376*
	the time students spent watching TV last weekdays.	minute	−0.783*
	the time students spent surfing the Internet or playing games last weekdays.		−0.794*
	the time students spent on homework last week.		0.248*
Student' Attitudes	if a student's response to the highest level of education you expect yourself to receive is junior college or above.	0–1; Yes = 1; Otherwise = 0	0.776*
	if a student believes that his/her future career requires high-skilled experience and/or a college degree.		0.701*
	if a student's response to the item "Are you confident in your future" is "somewhat confident" or "very confident".		0.568*
Teachers' Behaviors	In parents' opinion, is the teacher responsible for the child.	0–1; Yes = 1; Otherwise = 0	0.909*
	In parents' opinion, is the teacher patient to the child.		0.906*
	if a parent's response to the item "How many times has this child's teacher contacted the parents this semester" is more than twice.		0.452*
	the time teachers spent correcting homework.	hour	0.168*
Parents' Behaviors	if parents' response to the item "Do you know the parents of the child's friends" is "Yes".	0–1; Yes = 1; Otherwise = 0	0.504*
	if parents' response to the item "Do you attend the parent meeting this semester" is "Yes".		0.675*
	if parents' response to the item "Do you contact the teacher this semester" is "Yes".		0.589*
	if parents' response to the item "Could you meet the requirement if the teachers ask you to check homework?" is "completely" or "mostly".		0.646*
	the time parents spent directly on this child every day on average.	hour	0.635*

Notes: The last column reports the relationship between the composite index with each underlying variable.
* *** $p<0.01$.

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