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ICT in education can improve students' achievements in rural China: The role of parents, educators and authorities

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Abstract

Based on a quasi-natural experiment of the Three Links Project (TLP) implemented in rural China, we explore the impact of ICT in education on students' achievements. By using the difference-in-differences (DID) method, we find that TLP implementations result in a 3.4340-point increase in students' test scores and cognitive and noncognitive ability scores increased by 0.1631 and 0.0405 points, respectively. Results of mechanism tests show that this positive effect is explained by the improvement of teachers' efforts and enthusiasm, the increase of parental involvement in education, and positive student responses. Moreover, heterogeneity analysis results suggest that TLP implementations have a greater positive effect on achievements of some disadvantaged students, such as girls, non-only children, and those from relatively low-income families. This study highlights the benefits of ICT in education and reveals the positive role of parents, educators, and authorities in promoting student achievement and human capital accumulation. Furthermore, our findings complement the research field on educational inequity and have some insights for China and other developing countries.

Keywords: ICT in education; Students' achievements; Three Links Project; Human capital accumulation; Rural China

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1. Introduction

As a new generation, students are familiar with Information and Communication Technology (ICT) from an early age. ICT applications have gradually become an important component of high-quality education (Li & Ranieri, 2013; Luo et al., 2020). However, due to differences in economic and technological levels, there is a large gap between developing and developed countries in ICT in education. The latest report from the Program for International Student Assessment (PISA) showed that the computer-student ratio in developed countries such as the UK and the US has reached 1.25, however, in some developing countries, such as Brazil, Morocco, Turkey, and Vietnam, this ratio is about 0.25, which is only one-fifth of developed countries (OECD, 2020).

As a developing country, China is not much better off. The PISA investigated Beijing, Shanghai, Jiangsu, and Zhejiang, which are the most developed regions in China, and the report suggests that the average computer-student ratio is above 0.5 slightly (OECD, 2020). The situation in rural areas is even worse. As represented in Table 1, in 2006, the computer-student ratios in rural primary schools, junior middle schools, and senior high schools were only 0.03, 0.05, and 0.08, respectively. In recent years, with the adoption of several initiatives including ICT in education in rural and distant locations, the situation has improved recently (Li & Ranieri, 2013), but the gap between urban and rural areas remains obvious.

Considering the disadvantages of ICT in education in rural China, the resulting digital divide may have a negative impact on student achievements (e.g., Jonassen & Kwon, 2001; Li & Ranieri, 2013; Machin et al., 2007; Subrahmanyam et al., 2001). Since educational and labor market outcomes in adulthood are largely pre-determined by the academic performances in childhood (Heckman et al., 2006), the potential influencing factors that affect student achievements have drawn a lot of interest from scholars. In addition to the digital divide mentioned above, other factors that were considered to be significant for student achievement, including family background (Avvisati et al., 2014; Zhao & Chen, 2022), school characteristics (Fan et al., 2020; Pop-Eleches & Urquiola, 2013), teacher characteristics (Chen & Zhao, 2022; Duflo et al., 2011; Gong et al., 2018), and socioeconomic conditions (Hannum & Meiyan, 2006; Malamud et al., 2019). In this paper, by regarding the Three Links Project (TLP) implemented in China as a quasi-natural experiment, we are aimed to identify the causal effect of ICT in education on student achievements in rural China.

Our study falls into the broad research field involving the impact of ICT in education on students. Some scholars found the advantages of ICT in education. Higher Internet self-efficacy, which is associated with better academic achievements and more cognitive capacities, is present among students who use the Internet at school (Bai et al., 2016; Li & Ranieri, 2013; Zhao & Xu, 2010). Moreover, ICT in education may foster student enthusiasm, boost classroom interaction,

Table 1
Comparison of computer-student ratios between urban and rural schools in China.

	Primary schools			Junior middle schools			Senior high schools		
	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
2006	0.0377	0.0752	0.0311	0.0537	0.0769	0.0493	0.1058	0.1503	0.0846
2010	0.0414	0.0719	0.0345	0.0635	0.0779	0.0599	0.1093	0.1479	0.0882
2015	0.0846	0.1011	0.0769	0.1265	0.1407	0.1194	0.1587	0.1961	0.1265
2019	0.1342	0.1333	0.1348	0.1857	0.1996	0.1774	0.2400	0.2928	0.1897

and interest, as well as promote digital skills (Straker & Pollock, 2005; Pagani et al., 2016). More importantly, students' horizons can be expanded by the Internet's wealth of knowledge and information, which can help increase learning effectiveness (Jonassen & Kwon, 2001). The PISA recently showed that high-speed Internet access in schools is linked to greater results, even after completely accounting for socioeconomic background (OECD, 2020).

However, some studies considered the potential negative effects of the ICT and Internet use on students' academic preforms, such as Internet addiction, reducing social interaction, lack of active participation in extracurricular activities, and decreasing classroom attention (Livingstone, 2012; McDool et al., 2020; Subrahmanyam et al., 2001). Besides, some scholars found that even an increase in information technology or applications for teaching did not help much in improving students' performance (Angrist & Lavy, 2002; Rouse & Krueger, 2004). While there are a number of reasons for the heterogeneity of results, the findings are consistent for disadvantaged students. For example, Jackson et al. (2006) found that computer use significantly improved the reading achievements of students from low-income families in the US. Coincidentally, based on a sample of students from most remote school districts in Michigan, Hampton et al. (2021) drew a similar conclusion. In Chinese cases, Yang et al. (2013) indicated that using computers in school was good for improving academic performances of students from poor communities. Another evidence from rural China concluded that using ICT in the classroom helped pupils perform better in English (Bai et al., 2016).

Although the impact of ICT in education on student achievements has received some scholarly attention, there are few studies evaluating the effectiveness of China's policies for ICT in education (Bai et al., 2016), especially causal effects and potential mechanisms. In fact, China has started putting the ICT in education construction initiative into practice since 2011.[3] This project required that each class in rural China must have access to ICT resources and technology by the year 2015. More importantly, it was carried out in batches, which provides us with an available quasi-natural experiment to identify the causal effect of ICT in education on students' achievement. In addition to the role of the authorities, we analyze potential mechanisms at the level of parents, teachers, and students. Thus, we seek to reveal how parents, educators, and authorities play a role in ICT in education to enhance student achievement and promote human capital accumulation.

In the following respects, we have some meaningful findings, which add to the body of literature already in existence. First, by using TLP implementation as a proxy for ICT in education in rural China, we adopt a difference-in-differences (DID) method to establish a causal link between ICT in education and students' achievement. Our empirical results provide evidence that TLP implementations significantly improve students' test scores, cognitive abilities, and non-cognitive abilities. This means that our findings support the positive outcomes of ICT in education (e.g., Li & Ranieri, 2013; Zhao & Xu, 2010; Straker & Pollock, 2005).

Second, we are also interested in potential mechanisms of ICT in education for student achievement. The results of mechanism analysis suggest that TLP implementations may work in three channels to enhance students' achievement: parents, teachers, and students. Specifically, we find that TLP implementations can improve teachers' efforts and enthusiasm, increase parental involvement in education, and bring positive student responses. Thus, based on the

[3] Website for information about the TLP: http://www.moe.gov.cn/srcsite/A16/s3342/201206/t20120626_139233.html.

distinctive Chinese context, our research framework is well represented in how parents, educators, and authorities promote human capital accumulation through ICT in education.

Third, heterogeneity analysis results show that the TLP have greater positive effects on the achievement of some disadvantaged students. With the advancement of ICT in education, China's education inequality and urban-rural digital divide may be alleviated. Taken together, our study complements the role of ICT in education on the human capital accumulation of disadvantaged students (Bai et al., 2016; Hampton et al., 2021), and expands the body of knowledge on reducing educational inequality (Agasisti et al., 2021; Asadullah et al., 2020; Hannum & Meiyan, 2006; Li & Ranieri, 2013; Machin et al., 2007). Also, this study may have implications for other developing countries to formulate relevant ICT in education public policies.

2. Research framework and mechanism analysis

In this section, we construct a theoretical framework about the mechanisms by which ICT in education affects student achievements at three levels: parents, teachers, and students.

2.1. Parental involvement in education

We consider that ICT in education may promote student achievements by increasing parental involvement in education. Not surprisingly, the ICT provides more opportunities and convenience for parental involvement in their children's education. On the one hand, ICT in education has a demonstration effect. Through ICT tools, parents can better understand more scientific models of family education and improve the effectiveness of family education. On the other hand, ICT in education creates better conditions for home-school contact, allowing parents to be more aware of their children's school performance and learning dynamics (del Carmen Ramírez-Rueda et al., 2021). Students' achievements are also improved through a more efficient model of home-school co-education (Chen & Zhao, 2022; Sheridan et al., 2012).

More specifically, the relatively low penetration of private computers and the Internet in rural China has led to difficulties in accessing ICT devices in home education. As a result, students are limited to traditional and inefficient learning tools at home (Zhao & Xu, 2010). However, the implementations of a range of programs for ICT in education could well compensate for this loss (Cleveland & Krashinsky, 1998), which may further have a spillover effect on parental involvement in education (Fan et al., 2020).

Many benefits of parental involvement in education have been widely acknowledged by prior research, such as social skills (Sheridan et al., 2012), attendances (Avvisati et al., 2014), and mental health (Wang & Sheikh-Khalil, 2014). It is clear that these factors are also closely related to student achievements (Chen & Zhao, 2022; De Paola & Gioia, 2017). Taken together, ICT in education may influence parental involvement in education, which in turn contributes to student achievement.

2.2. Teachers' efforts and enthusiasm

ICT in education provides teachers with a variety of pedagogical conveniences that can further promote their efforts and stimulate enthusiasm. First, ICT in education raises expectations for teachers' information technology skills and comprehensive quality (Bai et al., 2016; Livingstone, 2012; Peeraer & Van Petegem, 2011; Wang et al., 2019); therefore, it further

motivates teachers to put more efforts to improve their teaching skills and maintain good learning status (Qaddumi et al., 2021). Moreover, the high efficiency of ICT in education is likely to endogenously motivate teachers to take the initiative to use these electronic devices to enhance teaching quality and improve student academic performance (Bai et al., 2016; Siddiq et al., 2016). More importantly, teachers in rural schools may conclude their teaching methods through action and reflection to optimize teaching and create a more efficient classroom with ICT (Luo et al., 2020; Wang et al., 2019).

Second, ICT in education helps stimulate teachers' subjectivity and wisdom, and enhances sensual enthusiasm and creativity in rural schools. Teachers' enthusiasm has traditionally been defined as a lively and motivating teaching style that includes a range of behaviors that reflect a strong interest in the subject (Collins, 1978). The new teaching resources and equipment brought by ICT can reduce teachers' workload, decrease the time spent on simple and repetitive tasks (Peeraer & Van Petegem, 2011; Zhao & Xu, 2010), which is helpful for reducing burnout and promoting enthusiasm. Also, the new teaching concepts created by ICT in education can lead to a greater sense of achievements and self-efficacy for teachers (Wang et al., 2019), especially in rural schools where the ICT devices were lacking in the past.

Some studies have confirmed that teachers' efforts and enthusiasm for teaching helps correct students' learning attitudes (Frenzel et al., 2019; Meroni et al., 2015; Keller et al., 2016) and improve students' motivation, positivism, and vitality in learning (Chen & Zhao, 2022). Thus, we believe that by stimulating the efforts and enthusiasm of teachers, ICT in education may improve student achievements in rural schools.

2.3. Students' responses

There is no doubt that ICT in education can affect rural school students in several ways. ICT in education motivates students to study harder (Peeraer & Van Petegem, 2011). ICT in education provides new learning resources, opens up horizons and enriches students' academic knowledge (Bai et al., 2016; Wang et al., 2019). Therefore, students need to put more effort to acquire and master more knowledge (Straker & Pollock, 2005; Siddiq et al., 2016). In addition, ICT in education brings new learning experiences and more scientific learning models for students, which helps to stimulate interest in learning (Hampton et al., 2021; Voogt et al., 2013). Moreover, ICT in education may change students' learning abilities and attitudes in rural schools. One of the benefits of ICT in education is that it can better supervise students' learning (Wang et al., 2022), both at school and at home. Specifically, teachers can better help students shape good learning attitudes and correct bad habits through the use of these ICT teaching devices (Qaddumi et al., 2021). As ICT in education is promoted in rural schools, students' learning abilities and attitudes are improved (Bai et al., 2016; Wu et al., 2019).

In addition, ICT in education gives more children in rural schools hope and raises educational expectations (Wang et al., 2019). ICT in education further reduces the digital divide between urban and rural areas, allowing students in rural schools to enjoy better teaching resources, bridging the gap with urban schools through ICT educational devices (Li & Ranieri, 2013). Last, ICT in education may enhance students' sense of belonging at school. Some studies confirmed that students reporting a greater sense of belonging at school tend to display higher academic motivation, self-esteem, and achievements (Sirin & Rogers-Sirin, 2004). ICT in education may improve students' sense of belonging at school by better learning equipment and environment, higher quality campus management, a more outstanding disciplined climate, and more enthusiastic teachers (Dotterer et al., 2007).

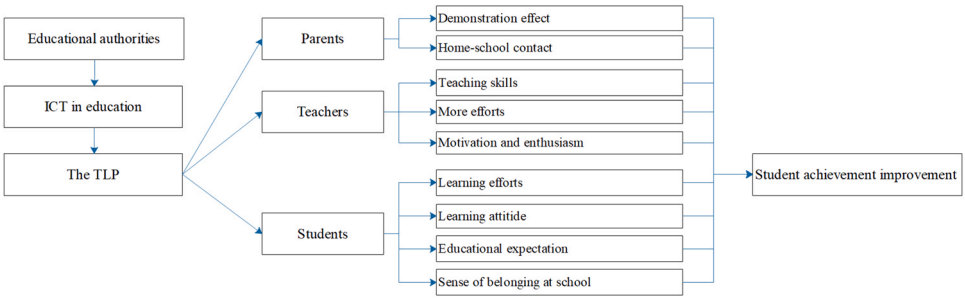

Fig. 1. Research framework.

Taken together, using the government-led TLP as a proxy for ICT in education, we construct an integrated research framework to observe how ICT in education influences the behaviors and responses of parents, teachers, and students. Moreover, we seek to analyze how parents, educators, and authorities come to play a role in student achievements and human capital accumulation through ICT in education. The research framework is shown in Fig. 1.

3. Institutional background

In recent years, the Chinese government has tried to promote some ICT reforms in education in rural schools. In 2003, the Ministry of Education, the National Development and Reform Commission, and the Ministry of Finance jointly implemented the "Project of Distance Education in Rural Schools" (PDERS), which aimed to provide some digital devices for primary and secondary schools in rural areas, such as digital satellite receiver, computer rooms, teaching CD-ROM players. By the end of 2007, this project had been basically completed. The total investment is about 11.1 billion, of which the central special funds and local funds were 5 billion and 6.1 billion, respectively, benefiting more than 100 million rural primary and secondary school students.

The TLP can be regarded as the continuation of PDERS. In 2011, the Chinese government issued the "Decade Plan for Development of ICT in education (2011–2020)," which stated the need to construct an educational information network covering all types of schools and educational institutions, further achieving broadband access to every school by 2020. Then, the Ministry of Education put forward the TLP, requiring three goals to be achieved by 2015. First, every classroom should be equipped with computers, the Internet, projectors, and other teaching digital equipment. Second, develop a wealth of quality teaching resources and deliver them to each classroom for general use in the teaching process. Third, ensure that all teachers and students in schools have their own online learning space.

During the implementation of TLP, all local governments were required to submit timelines for 2013, 2014, and 2015 to the Ministry of Education, which also regularly checked and monitored implementation processes. This top-down model ensures the achievements of the ICT goals of each pilot school (Meng & Su, 2021). More importantly, the TLP also emphasized that resources should be tilted to backward rural areas. Obviously, the TLP has become an important measure for China to improve ICT conditions in rural schools, alleviate the urban-rural digital divide, and promote educational equity (Becker, 2012; Zhao & Xu, 2010).

4. Methodology

4.1. Data

The data originates from two waves of the China Education Panel Survey (CEPS) conducted in the academic years of 2013–2014 and 2014–2015. The CEPS is a large-scale and nationally representative longitudinal survey undertaken by Renmin University of China, concentrating on junior middle school students. More crucially, the CEPS is China's first database that offers a plethora of information on schools, teachers, parents, and students, disclosing the impact of families, schools, and other socioeconomic status on student achievements (Chen & Zhao, 2022; Fan et al., 2020). We process the samples as follows. First, we keep only the tracking samples to accommodate the DID method.[4] Second, since the TLP targets rural schools, we eliminate all non-rural schools.[5] Third, considering that only two phases of data are available and 2013 is not the first year of TLP implementations. Therefore, in the DID framework, we remove samples that were already TLP pilots at the baseline wave.[6] That is, in fact, we evaluate the short-term effects of ICT in education, observing changes in student achievements one year after TLP implementations in rural schools.

4.2. Empirical model

As noted above, the TLP was issued by the Ministry of Education of China in 2011 and launched pilot construction in schools. Although the implementation time of the TLP varied in different schools, it was mainly concentrated between 2012 and 2015, which provided good conditions for the policy evaluation by adopting the DID approach. Specifically, we regard that the treatment group consists of rural schools that implemented the TLP. On the contrary, those rural schools that have never become TLP pilots as a control group, where students would not be affected. The empirical model is set up as follows:

$$ACH_{ist} = \alpha_0 + \alpha_1 TLP_{st} + \alpha_2 X_{ist} + \gamma_s + \rho_t + \delta_{ct} + \varepsilon_{ist} \tag{1}$$

Where ACH_{ist} indicates achievements of the student i at school s in the year t and TLP_{st} represents whether the school s has implemented the TLP in the year t. X_{ist} is a series of control variables which covers student, family, and school characteristics, and details are given below. γ_s and ρ_t are the school fixed effect (FE) and year FE, respectively. δ_{ct} is the year-by-county FE, which is used to capture time trends in different counties. High-dimensional FEs have been commonly seen in DID estimations to further mitigate potential endogeneity issues (e.g., Duflo et al., 2011; Zhao & Guo, 2022). ε_{ist} is a random error term. To control for serial correlation as well as heterogeneity of variables, we cluster the standard errors at the school level.

[4] They were 7th grade in the baseline wave and 8th grade in the second wave.

[5] The CEPS provides information on the location of schools with five options: (1) center of the city/town; (2) outskirts of the city/town; (3) rural-urban fringe zone of the city/town; (4) towns outside of the city/town; (5) rural areas. According to the focus area of Ministry of Education of China for TLP implementation, in the main specification, we remove the first two categories of non-rural schools by adopting a broad definition for rural schools.

[6] If we do not remove these samples, there would be a large number of observations from the treatment group in the base period, which may lead to unsatisfied parallel trends and invalid DID estimates (Sun & Abraham, 2021).

4.3. Variables

4.3.1. Students' achievements

Our explained variables are student achievements, measured by average scores, cognitive abilities, and noncognitive abilities, which are widely used in previous studies (e.g., Chen & Zhao, 2022; Duflo et al., 2011; Feng & Li, 2016; Gong et al., 2018). Specifically, *Average scores* is expressed by the average scores of three main subjects (including Chinese, Math, and English) in the most recent midterm exam (Chen & Zhao, 2022; Fan et al., 2020). *Cognitive abilities* is measured the standardized scores of the cognitive ability test[7] provided by the CEPS database (Cunha & Heckman, 2008; Fiorini, 2010). Moreover, according to existing literature (Cunha & Heckman, 2008; Gong et al., 2018; Romero et al., 2017; Zhao & Chen, 2022), *Noncognitive abilities* is a composite indicator consisting of confidence, openness, emotional stability, and agreeableness.

Adopting multiple variables to measure student achievements is motivated by two main considerations. First, three variables help to more accurately reflect the positive effect of ICT in education on students' achievements in rural schools. Second, the CEPS only provides results for one test and only includes three main subjects, and test papers were inconsistent from school to school, with differences in difficulty levels. Therefore, the explained variable *Average scores* is incomplete and contingent (Chen & Zhao, 2022). Conversely, using the cognitive ability scores would more objectively capture student achievement, as it was tested by the CEPS group by using the same questions.

4.3.2. The TLP

Although the TLP has been implemented in some schools since 2011, given that the CEPS has not announced the specific names of counties and schools, it is impossible to determine which rural schools in the sample are really affected by the policy. Fortunately, in the school leadership questionnaire, the respondents were asked whether the school has implemented the TLP since a certain year. According to the CEPS, we find that 24 rural schools in 14 counties are TLP pilots in the first wave,[8] and 6 schools in 4 counties are added in the second wave. Based on the DID method, the setting rule of our key explanatory variable is as follows. If a rural school becomes the TLP pilot in the second wave, it is set to 1, and 0 otherwise.

4.3.3. Control variables

We include a series of control variables. First, in terms of student characteristics, *Gender*, *Birth year*, *Only child*, *Hukou*, and *Self-rated health* are controlled for, because these determinants of student achievements that is routinely examined in the literature (Cunha & Heckman, 2008; Gong et al., 2018). From the perspective of family characteristics, *Self-rated wealthy*, *Basic living allowance*, *Schooling of father*, *Schooling of mother*, and *Occupation of father* are added in the control set, as household economic status and parental educational attainment are important factors that influence student achievements (Asadullah et al., 2020; Feng & Li, 2016). From the school characteristics, there are five variables, namely *Ranking of school*, *Appropriation per student*, *Teacher quality*, *Education of teachers*, and *Infrastructure of*

[7] Test questions included eleven types of three dimensions: language, graphics and space, as well as calculation and logic, and students were required to answer these questions intensively in class.

[8] As highlighted in Section 4, these observations were deleted.

Table 2
Descriptive statistics.

Variables	Full sample			Non-TLP schools	TLP schools	Diff. (T-test)
	N	Mean	SD	Mean	Mean	
Average scores	2006	70.7082	22.6670	70.2135	71.9273	-1.7138
Cognitive abilities	2006	-0.0521	0.8238	-0.1913	0.2908	-0.4821 ***
Noncognitive abilities	2006	3.0321	0.4754	3.0192	3.0638	-0.0446 *
TLP	2006	0.2886	0.4532			
Gender	2006	0.5189	0.4998	0.5123	0.5354	-0.0231
Birth year	2006	2000.32	0.8010	2000.3174	2000.3264	-0.0090
Only child	2006	0.6825	0.4656	0.7162	0.5993	0.1169 ***
Hukou	2006	0.2483	0.4321	0.2249	0.3057	-0.0808 ***
Self-rated health	2006	4.0543	0.8925	4.0224	4.1330	-0.1106 **
Self-rated wealthy	2006	2.6102	0.6629	2.5809	2.6822	-0.1013 ***
Basic living allowance	2006	0.2039	0.4030	0.2172	0.1710	0.0463 **
Schooling of father	2006	9.2423	2.4528	9.2032	9.3385	-0.1353
Schooling of mother	2006	8.2732	3.0009	8.3139	8.1727	0.1412
Occupation of father	2006	0.0763	0.2655	0.0757	0.0777	-0.0020
Ranking of school	2006	3.4227	0.8671	3.4043	3.4680	-0.0637
Appropriation per student	2006	6.5380	1.1592	6.5701	6.4588	0.1113 *
Teacher quality	2006	0.5635	0.2942	0.6052	0.4607	0.1445 ***
Education of teachers	2006	0.7024	0.2640	0.7121	0.6786	0.0335 **
Infrastructure of school	2006	5.9676	1.6591	5.7456	6.5147	-0.7691 ***

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively.

school. Since our core explanatory variable is at the school level, controlling for some school characteristics helps to further mitigate potential endogeneity (Fan et al., 2020; Zhao & Chen, 2022). The specific definitions can be seen in Appendix Table A1.

4.4. Descriptive statistics

The descriptive statistics of main variables mentioned above are shown in Table 2. Our final sample included 2006 students from rural schools, of which 575 students in the TLP pilot schools in the second wave, accounting for 28.86%. Additionally, Table 2 shows that the mean values of students' average scores, cognitive abilities, and noncognitive abilities were 70.7082, – 0.0521, and 3.0321, respectively. According to the T-test, we find that students in the TLP pilot rural schools had better achievement, particularly in cognitive abilities. More specifically, on average, students in TLP schools had higher cognitive ability scores than these in non-TLP schools by 0.4821. Thus, these statistics provide preliminary validation that TLP implementations contributed to improved students' achievements and illustrated the positive role of ICT in education.

5. Results

5.1. The effect of TLP implementations on students' achievement

Based on the quasi-natural experiment of TLP implementations, we employ the DID approach to examine the causal effect of ICT in education on students' achievement. The baseline results are shown in Table 3. It is clear that the coefficients on *TLP* keep significantly positive at

Table 3
The impact of TLP implementations on student achievement: DID estimations.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
TLP	3.4340 ***	0.1631 ***	0.0405 ***
	(0.1545)	(0.0075)	(0.0042)
Gender	-7.5943 ***	-0.0060	-0.0070
	(1.2418)	(0.0386)	(0.0205)
Birth year	2.8441 ***	0.1572 ***	-0.0008
	(0.6477)	(0.0368)	(0.0113)
Only child	1.0352	0.0382	-0.0251
	(1.2358)	(0.0442)	(0.0225)
Hukou	-0.4342	-0.0679	-0.0467 *
	(1.0720)	(0.0665)	(0.0263)
Self-rated health	-0.3257	0.0021	0.1048 ***
	(0.5509)	(0.0143)	(0.0127)
Self-rated wealthy	-0.0981	0.0214	0.0190
	(0.9301)	(0.0362)	(0.0166)
Basic living allowance	-2.3699 *	-0.0743	-0.0181
	(1.1565)	(0.0599)	(0.0380)
Schooling of father	0.4343 **	0.0079	0.0185 **
	(0.2026)	(0.0073)	(0.0064)
Schooling of mother	-0.1259	-0.0078	0.0096 *
	(0.2020)	(0.0091)	(0.0052)
Occupation of father	-0.8071	0.0011	-0.0025
	(1.0105)	(0.0757)	(0.0452)
Ranking of school	-1.1262 **	0.5855 ***	0.0475 ***
	(0.4656)	(0.0153)	(0.0086)
Appropriation per student	-4.5725 ***	0.0651 ***	0.0433 ***
	(0.0573)	(0.0033)	(0.0019)
Teacher quality	-18.3068 ***	0.1684 ***	0.0792 ***
	(0.6772)	(0.0327)	(0.0190)
Education of teachers	-12.8934 ***	-1.1662 ***	-0.3545 ***
	(0.8419)	(0.0230)	(0.0146)
Infrastructure of school	-0.0714	0.0545 ***	0.0251 ***
	(0.1155)	(0.0033)	(0.0025)
Year FE	Yes	Yes	Yes
School FE	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes
Adj. R-squared	0.4614	0.2924	0.1474
N	2006	2006	2006

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

the 1% level in all columns, implying that TLP implementations did help to improve student achievements in Chinese rural schools. These estimates are not only statistically significant, but are equally significant in an economic sense. In particular, in column (1), TLP implementations result in a 3.4340-point increase in the average scores, corresponding to an improvement of 4.86%, relative to the mean, 70.7082. By converting to standard deviations, the estimates indicate that the TLP increases average scores by 0.069 standard deviations. Moreover, in columns (2) and (3), the results suggest that the TLP results in an increase in the students'

Table 4
Parallel trend tests.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
TLP	5.9851 **	0.2765 ***	0.0767
	(2.4836)	(0.0660)	(0.0586)
TLP_1	2.9264	0.1301	0.0416
	(2.9045)	(0.0765)	(0.0693)
Control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
School FE	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes
N	2006	2006	2006

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

cognitive and noncognitive ability scores by 0.1631 and 0.0405 points, respectively, which is equivalent to 0.0897 and 0.0386 standard deviations.

These results are consistent with some previous studies that confirmed the positive effects of ICT in education (Bai et al., 2016; Li & Ranieri, 2013; Straker & Pollock, 2005; Pagani et al., 2016), especially vulnerable children in rural and remote areas (Bai et al., 2016; Hampton et al., 2021; Yang et al., 2013). Taken together, by using the case of TLP implemented in Chinese rural schools and multiple educational outcome variables, we further prove the advantages of ICT in education.

5.2. Parallel trend tests

The main prerequisites of employing DID models is to satisfy parallel trends. That is, prior to becoming a TLP school, where both the treatment and control groups' trends for students' achievements are staying consistent. In Table 4, we discover that the coefficients on *TLP_1* are insignificant in three columns, indicating that prior to TLP implementations, there were no differences in three explained variables between the treatment and control schools. Additionally, students in the treatment group, however, demonstrate a significant improvement in their achievements after their schools being TLP pilots. These results suggest that the parallel trend is satisfied and that it is perfectly appropriate to use DID methods in this paper.

5.3. Mechanism tests

5.3.1. Parental involvement in education

We construct five variables to measure parental involvement in education (Zhao & Chen, 2022), namely *Family education expenses*, *Home-school communication*, *Parental requirements in children's learning*, *Parent tutoring*, and *Parental educational expectations*. These variables include not only specific behaviors of parents in children's education, such as parental tutoring and home-school communications, but also subjective parental demands and expectations for their children's education. These variables are defined as shown in Panel A of Table A2 in the Appendix.

The results for TLP implementations and parental involvement in education are represented in Table 5. It is clear that the coefficients on *TLP* are significantly positive in columns (1), (2), and

Table 5
Mechanism tests: parental involvement in education.

	(1)	(2)	(3)	(4)	(5)
	Family education expenses	Home-school communication	Parental requirements in children's learning	Parent tutoring	Parental educational expectations
TLP	1.3794 ***	0.0407 ***	0.0035	0.0008	0.3362 ***
	(0.0533)	(0.0074)	(0.0038)	(0.0043)	(0.0096)
Control variables	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes	Yes	Yes
N	1560	1994	1970	1975	1995

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

Table 6
Mechanism tests: teachers' efforts and enthusiasm.

	(1)	(2)	(3)	(4)
	Hours of correcting homework or test papers	Class hours	Responsibility	Patience
TLP	0.0085 **	0.3354 ***	0.1201 ***	-0.0068
	(0.0034)	(0.0025)	(0.0093)	(0.0100)
Control variables	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes	Yes
N	2006	1648	1994	1994

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

(5), indicating that the government-led ICT in education program has affected the thinking consciousness of families, resulting in more education expenses as well as stricter academic requirements for their children (Wang et al., 2022). In addition, the results imply that the TLP increase the frequency of home-school contact. Table A3 reports the results between these mechanism variables that are shown to be effective in Table 5 and student achievements. We find that home-school communications and parental educational expectations are significantly and positively related to student achievement. However, there is no association between family education expenditures and three explained variables, suggesting that the TLP may not enhance children's education outcomes by increasing family education expenditures. Our findings provided evidence that ICT in education made up for the disadvantages of rural households in human capital accumulation and had a positive spillover effect on parental involvement in education.

5.3.2. Teachers' efforts and enthusiasm

We measure teachers' efforts and enthusiasm in two ways. The first is teachers' effort in teaching, including *Hours of correcting homework or test papers* and *Class hours*. The second category is the patience and responsibility of teachers as rated by parents (Chen & Zhao, 2022; Cordero & Gil-Izquierdo, 2018). In Panel B of Table A2 in the Appendix, for these four variables, the precise definitions are provided. The results are reported in Table 6. In the first two columns, we find that TLP implementations allow teachers to spend more time correcting homework or test papers, and the impact on their class hours is also significant. These results indicate that ICT in education makes teachers tend to make more efforts in teaching, which is consistent with some previous studies (Luo et al., 2020; Siddiq et al., 2016). We further investigate the impact of TLP implementations on teachers' responsibility and patience. The results suggest that the coefficient on *TLP* is significantly positive in column (3), while insignificant in column (4). Although ICT in education makes teachers more responsible, it may also have a potential negative impact on their patience; after all, the new pedagogical concepts that ICT brings may require teachers to learn more and adapt gradually (Livingstone, 2012; Zhao & Xu, 2010).

In addition, to test the mechanisms completely, we further show the results for the effect of mechanism variables on student achievements in Table A4. We can see that all coefficients are positive, although some are not significant at the 10% level; however, this does not affect our conclusions that teachers' efforts and enthusiasm is an important way for ICT in education to enhance student achievements in rural China.

Table 7
Mechanism tests: students' efforts, learning attitude, expectations, and sense of belonging.

	(1)	(2)	(3)	(4)	(5)	(6)
	Weekend learning	Cram school on weekends	Learning attitude	Responsiveness	Self education expectation	Liking the school
TLP	0.1141 ***	0.0056 **	-0.0035	0.0207 ***	0.2266 ***	0.1089 ***
	(0.0032)	(0.0025)	(0.0077)	(0.0069)	(0.0078)	(0.0068)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2006	2006	1995	1996	1990	1989

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

5.3.3. Students' responses

According to CEPS questionnaires, we select several variables to measure students' responses. First, two variables are used to reflect children's efforts, namely *Weekend learning* and *Cram school on weekends*. Second, students' attitude toward learning also include *Learning attitude* and *Responsiveness*. Third, students' expectation was expressed in terms of future educational expectations. Last, sense of belonging at school is expressed in terms of how much students like the school. These variables were defined as shown in Panel C of Appendix Table A2 and regression results are represented in Table 7.

Specifically, we find that the coefficient of TLP is significantly positive in all columns except column (3), suggesting that with the advancement of ICT in education, students are working harder and spending more time on their studies. Also, the ICT improves student responsiveness for learning and does raise students' educational expectations in rural schools. These estimates are similar to the findings in previous literature (Bai et al., 2016; Wang et al., 2019). In addition, we find that ICT in education led to a significant increase of 0.1089 points in students' overall liking of the school. As we analyze earlier, ICT in education makes up for the lack of digital resources at home for rural students, giving them a stronger sense of belonging to the school (Bai et al., 2016). In Appendix Table A5, all mechanism variables were significantly and positively correlated with the three measures of student achievements (De Paola & Gioia, 2017), except for the two variables for student efforts, which were not significantly correlated with average scores. Basically, we confirm that ICT in education could contribute to student achievements in rural China by bringing positive student responses such as efforts, expectations, and sense of belonging at school.

5.4. Heterogeneity effects

In this subsection, we explore heterogeneity effects of TLP implementations on student achievements and further examine whether ICT in education could be of greater benefits to disadvantaged students.

First, we analyze the heterogeneity effect by gender. In rural China, gender discrimination and son preference within families persists (Murphy et al., 2011; Zhao & Chen, 2022), which leads to boys having access to more resources for family human capital investments. In Panel A of Table 8, although the TLP estimates are all positive and significant in columns (1)-(5), we

Table 8
Heterogeneity effects.

	(1)	(2)	(3)	(4)	(5)	
	Average scores		Cognitive abilities		Noncognitive abilities	
Panel A. Gender	Girls	Boys	Girls	Boys	Girls	Boys
TLP	4.3287 ***	1.5254 ***	0.2329 ***	0.1026 ***	0.1404 ***	-0.0336 ***
	(0.6480)	(0.4088)	(0.0261)	(0.0149)	(0.0153)	(0.0101)
N	1041	965	1041	965	1041	965
Panel B. Only child	Only child	Non-only child	Only child	Non-only child	Only child	Non-only child
TLP	-1.5610	3.9983 ***	0.1462 ***	0.3541 ***	0.0252 ***	0.2318 ***
	(2.3148)	(0.1516)	(0.0051)	(0.0930)	(0.0029)	(0.0551)
N	498	1508	498	1508	498	1508
Panel C. Household income	Relatively low	Relatively high	Relatively low	Relatively high	Relatively low	Relatively high
TLP	4.2034 ***	-4.8122 ***	0.1646 ***	0.0077	0.0414 ***	0.0538 ***
	(0.7367)	(0.5693)	(0.0268)	(0.0176)	(0.0117)	(0.0088)
N	695	1311	695	1311	695	1311

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. All regressions include baseline control variables, year FE, school FE, and year-by-county FE. Standard errors clustered at the school level are reported in parentheses.

find that positive effects of the TLP on girls' average scores and cognitive abilities is much greater. The ICT increases students' access to the Internet in education, which may increase the risk of Internet addiction in boys with relatively poor self-control (Livingstone, 2012; McDool et al., 2020). Therefore, these results suggest that ICT in education is more conducive to enhancing achievements of girls, a vulnerable group in rural China.

Second, we explore the only-child heterogeneity effect. According to the quantitative-qualitative trade-off theory in household human capital investment, as the number of children in the family increases, the dilution effect of family education resources becomes more pronounced, with fewer resources allocated to each child (Becker & Lewis, 1973). As shown in Panel B of Table 8, the effect of TLP implementations on non-only children is more pronounced, both in terms of average scores and cognitive and noncognitive abilities. These findings indicate that although non-only children may get fewer educational resources from their families, ICT in education may effectively compensate students with siblings in rural China.

Last, we consider the heterogeneity effect of household economic status. We divide the sample into two groups based on self-rated wealth.[9] As presented in Panel C of Table 8, we find that in terms of noncognitive abilities, the impact of TLP implementations is similar for two groups; however, for average scores and cognitive abilities, the TLP has a significantly positive effect on students from relatively low-income families. Also, these results imply a compensatory effect of TLP implementations on the human capital of relatively disadvantaged students, reflecting the need for universal access to ICT in education in rural schools.

5.5. Robustness checks

We further confirm the reliability of the baseline results by some robustness tests in Appendix Fig. A1 and Tables A6–A8. First, in placebo tests, we firstly randomly select TLP pilots from all rural schools as the treatment group. Then, 2013 and 2014, one year is randomly selected as the period being the TLP pilots. By repeating 500 times in Fig. A1. Clearly, the distribution of estimates from random assignments is centered around zero, suggesting that randomly constructed TLP school pilots have no effect on student achievements.

Second, we redefine rural schools in Table A6. In columns (1)-(3), we remove schools in rural-urban fringe zone of the city/town; in columns (4)-(6), we retain only students who attended schools located in rural areas. Results show that these estimates are quite similar to the baseline results.

Third, we consider two interfering factors: school construction activities and reclassification. If there were other policy changes during the same period that the TLP was implemented, the estimates capture the effects of other confounding factors that bias the empirical results (Hallam et al., 2004; Zhao & Wu, & Guo, 2022; Gong et al., 2018). we retain students in schools without major construction activities[10] in columns (1)-(3) of Appendix Table A7. Moreover, we keep a sample of random assignment in columns (4)-(6). Although about half of samples are removed, coefficients of *TLP* remain robust. These results tell us that school construction activities and reclassification do not have a shock on the effect of TLP implementations.

[9] Specifically, "very poor" and "somewhat poor" were regarded as relatively low income, while "moderate", "somewhat rich" and "very rich" are defined as relatively high income.

[10] These major construction activities refer to relocation, expansions, and new constructions.

Lastly, we conduct robustness checks by adding other control variables and the results are reported in Appendix Table A8. Specifically, we control for class FE in Panel A; add some teacher characteristics variables in Panel B[11]; birth year FE and self-rated health FE are included in Panel C. Clearly, coefficients on *TLP* are significantly positive in all columns and Panels, indicating that the conclusion that ICT in education enhances student achievements remained unchanged.

6. Conclusions and policy implications

Although some studies explored the impact of Internet use or ICT in education on student human capital (Bai et al., 2016; Hampton et al., 2021; Yang et al., 2013), causal effects and potential mechanisms are of little concern. Fortunately, the TLP implemented in batches provided us with a good quasi-natural experiment to help identify the causal relationship between ICT in education and students' achievement in rural China.

The findings can be summarized as follows. First, by using the DID methods, we find that TLP implementations are conducive to improving student achievement, indicating that ICT in education could promote student human capital accumulation in rural China. More specifically, TLP implementations increase average test scores by 3.434 points, and the cognitive and non-cognitive ability scores by 0.1631 and 0.0405 points, respectively. Second, we explore several mechanisms in three aspects: teachers, parents, and students, finding that the positive effect of TLP implementations can be explained by increasing teachers' efforts and enthusiasm, improving parental involvement in education, and positive student responses. Third, results of heterogeneous effects show that TLP implementations had a greater positive impact on the achievements of vulnerable students, including girls, non-only children, and those from relatively low-income families.

This study has made a few contributions to the literature. Undoubtedly, our findings support the benefits of ICT in education, which are similar to previous conclusions that emphasized that more ICT should be applied to schools instead of home (Fairlie & Kalil, 2017; Li & Ranieri, 2013; Malamud et al., 2019). Besides, our results based on rural China show that ICT in education has a greater effect on disadvantaged students, suggesting the potential of ICT to mitigate educational inequality and promote human capital accumulation (Bai et al., 2016; Hampton et al., 2021). More importantly, we construct an integrated framework that includes parents, educators, authorities, and students to provide some insight into the subsequent analysis of some key issues, such as the role of ICT in education and educational inequality in China and other developing countries (Becker, 2012; Hannum & Meiyan, 2006; Machin et al., 2007).

Our study has some policy implications. For educational authorities, investment in ICT in education should continue to be increased to improve the computer-student ratio and to further narrow the digital divide in rural China, especially those in less developed and remote areas (Bai et al., 2016). Our China-based study suggests that strengthening educational infrastructure is effective in improving educational inequality and promoting human capital development in backward areas. Thus, this paper may be supportive for those countries to increase the investment in ICT in education to make the basic education more efficient and improve human capital (Asadullah et al., 2020), which provides a new direction for related education policies.

[11] Teacher characteristics variables include gender, age, education, years of teaching experience, and title.

In addition, in terms of educators, based on ICT in education, there is a need to continuously improve teaching methods and enhance teaching enthusiasm to improve student achievement, as demonstrated by our mechanism tests. Thus, it is necessary to improve teachers' technology skills and gradually incorporate more efficient ICT tools in their classes (Meroni et al., 2015). After adapting to ICT teaching and learning, teachers should continue to innovate ICT usages, such as the online interaction and home-school connection, to enhance teaching and learning, especially in the post-COVID-19 era. These measures motivate teachers to actively use these electronic devices to improve students' achievement (Bai et al., 2016; Siddiq et al., 2016).

Last, from a parental perspective, in addition to actively using ICT in education opportunities to strengthen connections with teachers and other parents in the class, it is also important to actively guide and monitor children's use of electronic devices to avoid the potential negative effects of the Internet (Fairlie & Kalil, 2017; Livingstone, 2012). Further, learning digital skills is better suited for teachers and schools to increase the involvement of their children's education through ICT in education.

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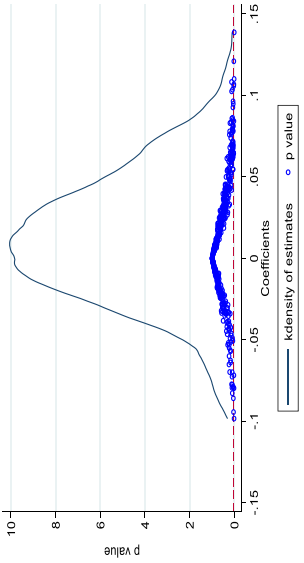
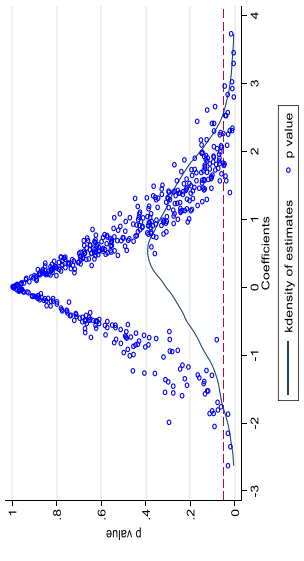
Appendix A

See Fig. A1 and Tables A1–A8.



(a) Average scores



(b) Cognitive abilities

(c) Noncognitive abilities

Fig. A1. Placebo tests.

Table A1
Definitions of main variables.

Variables	Definitions
Average scores	Average scores of three subjects, Chinese, Math, and English, on the most recent midterm
Cognitive abilities	Standardized scores of students' cognitive abilities based on the 3PL model
Noncognitive abilities	A composite indicator for average scores across dimensions, including confidence, openness, emotional stability, and agreeableness. Each dimension is assigned an integer from 1 to 4, with larger values indicating higher noncognitive ability scores
TLP	= 1 if the school has implemented TLP in 2014; 0 otherwise
Gender	Girl = 1; boy = 0
Birth year	Year
Only child	Yes = 1; no = 0
Hukou	Urban = 1; rural = 0
Self-rated health	Very poor = 1; not very good = 2; moderate = 3; good = 4; very good = 5
Self-rated wealthy	Very poor = 1; somewhat poor = 2; moderate = 3; somewhat rich = 4; very rich = 5
Basic living allowance	= 1 if the family receives basic living allowance; 0 otherwise
Schooling of father	Unschooled = 0; primary school = 6; junior middle school = 9; (vocationally) high school= 12 junior college = 15; bachelor's degree = 16; master's degree = 19
Schooling of mother	Unschooled = 0; primary school = 6; junior middle school = 9; (vocationally) high school= 12 junior college = 15; bachelor's degree = 16
Occupation of father	= 1 if the occupation is civil servant, manager, technician, and professional (e.g., lawyer and doctors); 0 otherwise (e.g., farmers)
Ranking of school	Near the bottom = 1; below average = 2; average = 3; above average = 4; among the best = 5
Appropriation per student	The fiscal appropriation per student this year
Teacher quality	Percentage of teachers with first-class or higher titles in the school
Education of teachers	Proportion of teachers with a bachelor's degree or higher
Infrastructure of school	Sum scores across dimensions: playground with circular track, laboratory, computer classroom, library, music room, student activity room, student dining room, and gymnasium.

Table A2
Definitions of mechanism variables.

Variables	Definitions
Panel A. Parental education involvement	
Family education expenses	Total household education expenditure every semester (1000 yuan)
Home-school communication	Times of parents contacting the teacher this semester. Never = 1; once = 2; two to four times = 3; five times or more = 4
Parental requirements in children's learning	Average scores across dimension: homework and examination, behavior at school, attendances at school every day.
Parent tutoring	Did the family members help with children's homework last week? Need but no one helped = 1; yes, one or two days = 2; yes, three or four days = 3; yes, almost every day = 4.
Parental educational expectations	1 = junior middle school; 2 = (vocationally) high school; 3 = college/bachelor's degree; 4 = master's degree; 5 = doctoral degree
Panel B. Teachers' efforts and enthusiasm	
Hours of correcting homework or test papers	Hours for homeroom teachers to correct homework or test papers last week
Class hours	Total class hours of homeroom teachers last week
Responsibility	Parents' comments. Not responsible at all = 1; not so responsible = 2; moderate = 3;somewhat responsible = 4; very responsible = 5

(*continued on next page*)

Table A2 (*continued*)

Variables	Definitions
Patience	Parents' comments. Not patient at all = 1; not so patient = 2; moderate = 3;somewhat patient = 4; very patient = 5
Panel C. Students' response	
Weekend learning	= 1 if the child has more than two hours of study time on the weekend; 0 otherwise
Cram school on weekends	= 1 if the child attends cram school on weekends; 0 otherwise
Learning attitude	Parents' comments. Not serious at all = 1; somewhat not serious = 2; moderate = 3;somewhat serious = 4; very serious = 5
Responsiveness	Parents' comments for quick responses of their children. Not fit at all = 1; somewhat not fit = 2; somewhat fit = 3; exactly fit = 4
Self education expectation	1 = junior middle school; 2 = (vocationally) high school; 3 = college/bachelor's degree; 4 = master's degree; 5 = doctoral degree
Liking the school	Strongly dislike = 1; somewhat dislike = 2; somewhat like = 3; like very much = 4

Table A3
Parental education involvement and student achievement.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
Family education expenses	-0.0862	0.0027	-0.0020
	(0.0668)	(0.0028)	(0.0022)
Home-school communication	0.6067	0.0667 **	0.0422 ***
	(0.4498)	(0.0268)	(0.0108)
Parental educational expectations	4.3396 ***	0.1002 ***	0.0476 ***
	(0.7382)	(0.0121)	(0.0075)

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. All regressions include baseline control variables, year FE, school FE, and year-by-county FE. Standard errors clustered at the school level are reported in parentheses.

Table A4
Teachers' efforts and enthusiasm and student achievement.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
Hours of correcting homework or test papers	3.4885	0.2999 **	0.0527
	(4.9152)	(0.1091)	(0.0328)
Class hours	17.3497 *	0.2922	0.2144 ***
	(8.8567)	(0.2457)	(0.0476)
Responsibility	3.4141 ***	0.1204 ***	0.0973 ***
	(0.8003)	(0.0253)	(0.0170)

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. All regressions include baseline control variables, year FE, school FE, and year-by-county FE. Standard errors clustered at the school level are reported in parentheses.

Table A5
Students' responses and achievement.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
Weekend learning	0.5290	0.3379 ***	0.0406 **
	(1.3312)	(0.0773)	(0.0171)
Cram school on weekends	-2.8488	0.2468 ***	0.0805 **
	(2.4857)	(0.0749)	(0.0321)
Responsiveness	2.4515 ***	0.0937 ***	0.2694 ***
	(0.4769)	(0.0228)	(0.0124)
Self education expectation	7.7249 ***	0.1786 ***	0.0935 ***
	(1.0024)	(0.0242)	(0.0143)
Liking the school	2.3154 ***	0.0406 *	0.1930 ***
	(0.3782)	(0.0213)	(0.0157)

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. All regressions include baseline control variables, year FE, school FE, and year-by-county FE. Standard errors clustered at the school level are reported in parentheses.

Table A6
Robustness checks: redefining rural schools.

	(1)	(2)	(3)	(4)	(5)	(6)
	Average scores	Cognitive abilities	Noncognitive abilities	Average scores	Cognitive abilities	Noncognitive abilities
TLP	3.2810 ***	0.1569 ***	0.0399 ***	1.6851 *	0.6054 ***	0.1571 ***
	(0.1533)	(0.0079)	(0.0045)	(0.9623)	(0.0227)	(0.0224)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1719	1719	1719	1082	1082	1082

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

Table A7
Robustness checks: interfering factors.

	(1)	(2)	(3)	(4)	(5)	(6)
	Construction activities			Reclassification		
	Average scores	Cognitive abilities	Noncognitive abilities	Average scores	Cognitive abilities	Noncognitive abilities
TLP	4.7782 ***	0.6487 ***	0.2334 ***	5.9003 ***	0.3118 ***	0.0786 ***
	(0.7591)	(0.0370)	(0.0175)	(0.3518)	(0.0153)	(0.0100)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
School FE	Yes	Yes	Yes	Yes	Yes	Yes
Year-by-county FE	Yes	Yes	Yes	Yes	Yes	Yes
N	1116	1116	1116	1369	1369	1369

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. Standard errors clustered at the school level are reported in parentheses.

Table A8
Robustness checks: adding other variable variables.

	(1)	(2)	(3)
	Average scores	Cognitive abilities	Noncognitive abilities
Panel A. Class FE			
TLP	3.5661 ***	0.1604 ***	0.0432 ***
	(0.1559)	(0.0079)	(0.0048)
Panel B. Homeroom teacher characteristics			
TLP	5.4907 ***	0.1646 ***	0.1415 ***
	(1.1957)	(0.0460)	(0.0115)
Panel C. Birth year FE and self-rated health FE			
TLP	3.7161 ***	0.1681 ***	0.0454 ***
	(0.2042)	(0.0087)	(0.0049)

Note: Significant levels of 1%, 5%, and 10% are indicated by ***, **, and *, respectively. All regressions include baseline control variables, year FE, school FE, and year-by-county FE. Standard errors clustered at the school level are reported in parentheses.

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