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A Two-Level Hierarchical Linear Model Analysis of the Effect of Teacher Factors, Student Factors, and Facility Conditions on Students' Cognitive Scores in Rural China

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Abstract: Based on the data from the China Education Panel Survey 2013–2014, this study uses a two-level hierarchical linear model to explore the impact of student factors, teacher factors, and facility conditions on students' cognitive scores and the model's heterogeneity. Additionally, under the Owen value method, the contribution of teacher and student factors to students' cognitive scores is much greater than that of facility conditions, and teacher-related factors contribute more to scores than student-related ones. Therefore, teacher and student resources should be given priority in allocating resources to rural education systems, and high-quality teachers, who can have positive impacts on students' cognitive scores, should be prioritized.

Keywords: input of rural educational resources; China Education Panel Survey Data (CEPS data); Hierarchical Linear Model (HLM); Shapley value method

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1. Introduction

Students' cognitive scores are a key index to measure educational quality. The analysis of the factors affecting students' scores in large-scale tests is an important part of the academic quality evaluation system worldwide and is also a hot issue in the research field. Each international cooperation organization will use a special chapter in the annual report to deeply analyze the factors affecting students' achievement in order to improve the rural educational resources allocation and enhance the quality of education [1]. Firstly, the systems and resources can vary widely, so a range of supply-demand imbalances is always possible. Priorities must be balanced among stakeholders, who can also vary widely and have conflicting values as well frequently [2]. Through a historical investigation of the two dimensions of quality and quantity, Wang, A. and Wang, X. [3] studied historical allocations of rural educational resources in China and established that teachers, students, and facility conditions have been insufficient in both quantity (supply) and quality. With time, the quality of both has been improved, and the gap was decreasing between the supplies to rural and urban schools; however, in the face of structural shortages, the policy preference errs toward more teacher resources, but teacher quality can still present a low level. Historically, early rural schools in the United States were mostly "one room, for all classes" and "one teacher per school"; teacher quality was generally at a high level but school buildings could be rudimentary, so facility conditions were not satisfactory. By the 1990s, the rural school merger movement had produced a batch of large schools; however, a considerable imbalance between need (demand) and the availability of teacher resources remained [4]. In Australia, micro-schools and central schools were set up in sparsely populated villages; the offices, classrooms, libraries, sports fields, computers, and teaching facilities at these schools were not worse than the facilities at standard schools, but there were only a few teachers, and they were only part-time [4]. Scientific understanding of the impact of teacher variables, student variables, and facility conditions and their specific components on students' achievement is the key to reducing the imbalance in the educational resources allocation generally faced by the above countries. Secondly, clarifying the influence of various factors (including student factors) on students' scores is helpful to improve the strategies and methods of teaching and learning and the key to improving the quality of education. In 2005, in order to improve the quality of primary and secondary education in Europe, the Council for Education, Culture of the European Commission, and the Danish Institute of Technology conducted a special study on the academic performance factors of the member countries participating in the three international education assessment programs [5] and a series of targeted teaching improvement recommendations for member states were put forward [5,6].

Most studies used simple traditional educational production functions to analyze the factors affecting students' scores in China, ignoring the heterogeneity between data, and only analyzed the correlation between possible factors and student achievement simply, without stating the contribution of each variable or a certain kind of variables to the variance of the dependent variable [7]. This study focuses on the student level and school level to analyze the impact of student variables, teacher variables, and facility conditions on student performance in order to provide a reference for the improvement of macro education policy and micro students' academic performance. The specific research questions are, first, to identify the influence of student variables, teacher variables, and facility conditions on student performance, respectively, and second, to compare which of student variables, teacher variables, and facility conditions have a greater impact on students' scores.

2. Literature Review and Research Hypothesis

2.1. The Influence of Student and Teaches Factors on Students' Cognitive Performance

The human resources that have an impact on students' performance include the number of teachers and management personnel at the school level (student–teacher ratio, part-time or full-time teacher), the quality (education background [8–10], title), the structure (gender [11,12], nation identity [13], teaching age [14], regular staff or not [15], age [16], and the major, subject). At the student level, students' gender [17,18], nation identity [19–21], only child or not [22] and learning factors such as self-education expectation [23], learning attitude, extracurricular reading and extracurricular learning [24], parents' educational background [25], educational expectations for their children [26], economic status [25] and peer influence [27] will also affect students' performance. Considering the research purposes of this paper and that primary and secondary school administrators almost also undertake daily teaching but that there is a large difference in the number of teachers between Han and ethnic minorities, family resources and peer influence are included in this study as control variables, the impact of managers' and teachers' students' nationalities structure on students' performance is not considered separately.

From the perspective of student factors, the empirical results showed that students' background factors had an important impact on their performance [28]. There was a positive correlation between being an only child and student performance, and it was shown that students from smaller families performed better because an only child obtained more family capital, and family capital had a significant positive effect on students' cognitive performance [29]. In terms of the students' scores of different genders and nationalities, there were consistently higher math scores among boys than girls; girls show higher language scores than boys [30], and students' scores of ethnic minorities were lower than those of Han students, but the gender and ethnicity correlations were not significant [29]. Based on the above findings, we propose the following hypothesis:

Hypothesis 1 (H1). *Among the student background factors, (a) girls, (b) only child, and (c) Han students will have higher cognitive scores than those of boys, non-only children, and ethnic minority students.*

In terms of the effect of students' learning factors, self-education expectations of primary and secondary school students could predict their performance significantly [1,31].

Regarding extracurricular tutoring, some studies predicted significantly higher scores among left-behind children who participated in extracurricular tutoring than those who did not [32]; however, other studies found that participating in shadow education did not improve students' achievement significantly, extracurricular math tutoring did not improve students' math performance, and students' scores were lower with Chinese tutoring [33–36]. Identified purchases of extracurricular books and numbers of family books positively correlated with students' academic performance significantly; each unit increase in the number of books improved a student's score by 1.13 times. Other studies have proved this conclusion through the intermediary effect: a family's number of books significantly affected children's self-education expectations through parental expectations for children's education and the frequency of parent–child communication [37]; families with large book collections were more likely to participate in shadow education to improve their children's scores [38]. However, several studies questioned this as a blanket conclusion; if the family book collection was small or mainly novels and magazines, it would not have a positive impact on students' performance [1]. Based on these findings, we proposed the following hypotheses:

Hypothesis 2 (H2). *Among student learning factors, (a) student self-education expectations and (b) learning attitude, (c) large family book collections, and (d) participation in shadow education will improve students' cognitive performance.*

Most empirical studies established that the number of full-time teachers played a key role in the output efficiency and quality of compulsory education [39]. Some studies have shown that reducing the teacher–student ratio has a positive impact on students' academic performance [40], whereas others have shown that reducing the teacher–student ratio cannot improve students' academic performance effectively [41]. Some studies have even drawn neutral conclusions through meta-analysis and comparison of relevant studies in developing countries and the United States: of the 30 studies, eight studies supported the positive correlation between teacher–student ratio and student achievement significantly, and eight supported the opposite conclusion [42]. Zhang et al. [1] took the number of teaching subjects as the measuring standard of the number of teachers. Through large-scale test data, we found that full-time teachers are conducive to improving students' performance. The impact of the number of teachers on students' performance has not been unanimously established. Considering that the low teacher–student ratio makes it difficult to take care of each student and is simultaneously conducive to improving students' performance, the following assumptions to be verified are proposed:

Hypothesis 3 (H3). *Among teacher factors, (a) teacher–student ratio and (b) number of classes taught concurrently will correlate negatively with students' cognitive performance.*

Regarding the impact of teacher's quality on student achievement, several studies have compared relevant studies in countries with different levels of development using meta-analysis. In studies in Latin American countries, it was found that 35 of 63 items confirmed that teacher quality had a positive impact on student achievement [42]; 45.6% of similar studies have the same view [43]. More studies have shown that the quality of teachers had a greater influence on the student performance than other factors associated with schools; when one standard unit of teacher quality was raised nationwide, students' performance scores were increased by 0.1 standard points [28]. Jiang [44] and Deng [7] took education as the standard to measure teachers' quality. Through empirical research, it was concluded that the educational background of teachers had a significantly positive correlation with students' achievement. Yang [45] supplemented this result using an education production function based on large-scale data, highlighting that only when teachers' academic qualifications matched with their teaching subjects would they have a positive and significant impact on the class average. However, some studies believed that the academic qualifications of teachers had a significant negative impact on the performance of students [46]. At the same time, the professional title is also a key factor for Chinese scholars to measure the quality of teachers. Some studies found that the promotion of teachers' professional titles had a positive impact on students' performance [31], but others found that teachers with high professional titles have job burnout, which was not conducive to improving students' performance [37]. Thus, this study is the first to propose the following assumptions to be tested:

Hypothesis 4 (H4). *Among teacher factors, teachers' educational background is positively correlated with students' cognitive performance.*

Hypothesis 5 (H5). *Among teacher factors, teachers' professional title is negatively correlated with students' cognitive performance.*

From the empirical results, the teacher structure had a significant impact on students' performance [47]. Teachers' teaching age had an important positive impact on students' performance [48]; this result was confirmed by 40.3% of similar studies in Latin American countries [43], and some scholars also added that the rationality of this result should be based on the length of the subject taught by teachers. For example, the influence of teaching age and the years of teaching mathematics subjects on students' mathematics performance showed an inverted U-shape, and the inflection points appear in eight and six years, respectively. At the same time, the teaching age of Chinese teachers had a positive and significant impact on students' Chinese performance. However, some studies have shown that there was an uncertain relationship between teachers' teaching age and students' performance. It was generally believed that the proportion of female teachers had a significant positive correlation with students' performance. For every 1% increase in the proportion, students' mathematics performance will increase by 10.0124 points [45]. However, some studies have shown that teachers' gender had no significant impact on improving students' performance [31]. In terms of teacher identity, it was generally believed that a higher proportion of public teachers was conducive to improving the quality of education, and a higher proportion of substitute teachers may hinder the improvement of education quality [49], which was the basis for China to eliminate private and other informal teachers and increase the proportion of formal teachers. In terms of major, it was generally believed that a normal teacher can grasp the knowledge and skills of education better and be able to teach students according to the rules of education and the characteristics of students, which would be helpful for the improvement of students' grades. 47.3% of the studies in Latin America supported this result [31], but some of them supported the opposite conclusion. Therefore, we made the following assumptions to be verified. If the conclusion was the opposite, it could be regarded as the opposite evidence:

Hypothesis 6 (H6). *Among teacher factors, (a) normal (consistent) major, (b) female gender, and (c) senior-level teaching experience will have significant positive correlations with students' cognitive performance.*

Hypothesis 7 (H7). *Among teacher factors, the informal status will have a negative correlation with students' cognitive achievement.*

2.2. The Contribution of Facility Conditions to Students' Cognitive Performance

Facility conditions usually refer to the capital embodied in material products, which were measured by its quantity and quality [26]. The facility conditions in education include the school building area per student, class size, educational equipment, number of books per student, and low-value consumables [50–52]. Currently, most rural schools in China are small. Results following a 2014 plan to comprehensively improve the weak compulsory education schools in poor areas and standardized school construction showed no obvious effects of average school area or average school building area per student on student cognitive performance. Therefore, we do not consider these school factors in this study.

As early as the 1980s, based on large-scale survey data, numerous scholars found that class size had a negative effect on student performance [53], and some scholars showed that factor of class size ranked 106 in a list of 138 factors that affected students' performance based on a meta-analysis of more than 800 studies, However, in Hanushek's [10] meta-analysis of 227 studies, findings from 72% of the studies showed no significant correlation between class size and student achievement. Numerous scholars in China believed that class size had a positive impact on student performance, and the data proved that among all the factors affecting student's performance, class size ranks first for explaining 7.5% of the variation in student performance, which was attributed to the selection of high-quality educational resources by collectivism culture behind the large class size. In short, findings are inconsistent on the role of class size in student achievement, and we proposed the following hypothesis to test in this study:

Hypothesis 8 (H8). *Low class size will positively correlate with students' cognitive achievement.*

Jiang [44] conducted an empirical study of 328 countries in China and found a significant correlation between teaching equipment conditions and students' achievement, Hanushek [42] compared school performance between developing and developed countries, he found that teaching equipment in developing countries had a greater impact on student achievement than it did in developed countries. As for the impact of books per student on their performance, 76.5% of studies in Latin American countries have confirmed a positive correlation; furthermore, Chinese scholars confirmed this result. However, a scholar found a marginal contribution of school real estate for buildings, laboratories, and other facility conditions to student academic achievement because students did not particularly use these facilities. Given these contradictory findings, we proposed the following hypotheses:

Hypothesis 9 (H9). *Among school factors, (a) number of books per student and (b) teaching equipment will have positive correlations with student achievement.*

Hypothesis 10 (H10). *School real estate will have a negative correlation with student achievement.*

3. Research Methodology

3.1. Data Source and Sample Distribution

The data used in this paper came from the CEPS during the 2013–2014 academic years. The CEPS is a large-scale national tracking project designed and implemented by the China Survey and Data Center of Renmin University. The project uses probability proportional sampling with average population education level and proportion of the floating population as stratified variables. For this study, we selected 28 county-level units from the whole country randomly and from counties, we randomly selected 112 schools and 438 classes with about 20,000 students to determine the impacts of family, school, community, and macro-social structure on individual student performance. The variable cog3pl used to measure students' ability represents the standardized total score of students' cognitive ability test estimated by the three-parameter IRT (Item Response Theory) model Table 1 presents the descriptive statistics for the study variables.

Table 1. Study Descriptive Statistics.

Variable Name	Level	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Student gender	1	17,664	0.49	0.50	0.00	1.00
Student nationality	1	17,664	0.09	0.28	0.00	1.00
Only child or not	1	17,664	0.56	0.50	0.00	1.00

Table 1. *Cont.*

Variable Name	Level	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Self-education expectation	1	17,664	1.61	0.55	0.00	2.00
Learning attitude	1	17,664	3.31	0.67	1.00	4.00
Logic cram school	1	17,664	0.34	0.47	0.00	1.00
Art cram school	1	17,664	0.30	0.46	0.00	1.00
Language cram school	1	17,664	0.15	0.36	0.00	1.00
Extracurricular reading amount	1	17,664	3.17	1.21	1.00	5.00
Teacher gender	2	419	3.15	0.85	0.00	4.00
Teachers' educational background	2	419	0.33	0.47	0.00	1.00
Teachers' major	2	419	3.77	0.47	2.00	4.00
Teaching experience	2	419	2.42	1.01	0.00	4.00
Teacher identity	2	419	4.37	0.88	4.00	8.00
Part-time teachers	2	419	0.89	0.51	0.00	3.50
Professional title	2	419	0.58	0.81	0.00	3.00
Books per student	2	112	96.55	362.49	4.18	5102.04
Teaching equipment	2	112	3.55	0.89	1.00	4.00
Class sizes	2	112	49.68	8.95	25.00	70.00
Laboratory	2	112	2.62	0.51	1.00	3.00
Computer classroom	2	112	2.58	0.56	1.00	3.00
Music room	2	112	2.40	0.64	1.00	3.00
Student activity room	2	112	1.97	0.70	1.00	3.00
Psychology consultation room	2	112	2.21	0.61	1.00	3.00
Faculty–student ratio	2	112	28.06	103.14	1.11	814.00

3.2. Research Variables and Analytical Framework

Research Variables

Based on the literature review, we used students' standardized cognitive ability scores as the outcome variable. The school-level teacher factors input variables are student–teacher ratio (H3a) and teaching more than one class concurrently (H3b) and teacher teachers' educational background (H4), professional title (H5), major (H6a), gender (H6b), teaching experience (H6c), and status (H7). The school-level facility conditions are class size (H8), books per student (H9a), teaching equipment (H9b), and real estate (laboratories, rooms for computers, music, student activities, and counseling; H10). The student-level student background factors are gender (H1a), only-child status (H1b), and nationality (H1c), and student learning factors are self-education expectations (H2a), learning attitude (H2b), number of books in the family home (H2c), and shadow education participation (H2d). Control variables are parents' education background, family socioeconomic status, peer influences, and parents' education expectations for their children. Table 2 presents the sources for and descriptions of the study variable data, and Figure 1 graphically displays the analysis model framework.

Table 2. Variable Descriptions.

Variable Name	Variable Description and Scoring Method
Result variables	
Standardized test scores	Standardized scores on students' cognitive ability test
Student level	
Gender	From the student questionnaire a01: 0 = male, 1 = female
Nationality	From the student questionnaire a03: 0 = Han, 1 = minority
Only-child or not	From the student questionnaire b01: 0 = an only child, 1 = non-only child

Table 2. *Cont.*

Variable Name	Variable Description and Scoring Method
Self-education expectation	From the student questionnaire c22: 1 = left school now, 2 = junior high school graduation, 3 = medium college graduation/technical school graduation, 4 = vocational high school graduation, 5 = common senior high school, 6 = college diploma, 7 = undergraduate graduation, 8 = postgraduate students, 9 = doctor degree, 10 = do not mind. In the econometric model, take "below undergraduate" in education expectation as the reference group, which is defined as 0, and "undergraduate and above" self-education expectation is defined as 1.
Learning attitude	From the student questionnaire a1201, 1202, and 1203: take a 4-point score: "complete disagreement" to "complete agreement" and forward scoring and calculate the mean.
Extracurricular learning	From the student questionnaire b19: to investigate the effects of different types of extracurricular tutoring on students' cognitive achievement, make the following code: "do not attend" is defined as 0; one or more participants in Mathematical Olympiad and general mathematics are classified as logic and coded as 1; one or more participants in Chinese composition and English are classified as language, and the code is 2; one or more participants in painting, calligraphy, musical instruments, dance, chess, and sports are classified as art, which is coded as 3; and the rest are treated as missing values.
Extracurricular reading	From the student questionnaire b12: do you have many books at home (excluding textbooks and magazines) as a reference. From few to many, take a 5-point score, forward scoring, and calculate the mean.
School level	
Teachers' gender	From the teacher (classroom teacher, Chinese, Mathematics, and English) questionnaire hrc01, chnb01, matb01, and engb01: 0 = male, 1 = female
Teachers' educational background	From the teacher (the classroom teacher, Chinese, Mathematics, and English teacher) questionnaire hrc04, chnb04, matb04, and engb04: 1 = education level of or under junior high school graduation, 2 = vocational high school/secondary specialized school/technical school graduation, 3 = high school graduation, 4 = college degree, 5 = undergraduate education (formal higher education), 7 = common senior high school, 6 = college diploma, 7 = graduate and above status.In the econometric model, take "under undergraduate status" defined as 0 and "undergraduate and above status" as 1.
Teachers' major	From the teacher (the classroom teacher, Chinese teacher, Mathematics teacher, and English teacher) questionnaire hrc05, chnb05, matb05, and engb05: 0 = yes, 1 = no.
Teachers' teaching age	From the teacher(classroom teacher, Chinese teacher, Mathematics teacher, and English teacher) questionnaire hrc07, chnb07, matb07, and engb07: 0 = not more than 10 years, 1 = 10 years and above
Formal teacher or not	From the teacher questionnaire hrc11, chnb11, matb11, and engb11: 0 = formal teacher, 1 = informal teacher
Whether teach concurrently	From the teacher questionnaire hra06, chnb06, and enga06: 0 = no, 1 = yes
Teachers' title	From the teacher questionnaire hrc12, chnb12, matb12, and engb12: 0 = no title, 1 = three-level title, 2 = second level title, 3 = first level title, 4 = senior title, 5 = high professional title. In the econometric model, 0 = non-senior title, 1 = senior title
Books per student	From the school questionnaire, pla17, plb0101b, plb0102b, and plb0103b are calculated by the number of books and students in the school.
Teaching equipment	From the school questionnaire pla15: whether the school is equipped with Class Access to ICTs to measure.
Class sizes	From school questionnaire pla14: measured by the average number of seats in each classroom.
Fixed assets	From the school questionnaire pla1201, pla1202, pla1204, pla1205, pla1206: 3-point score, 1 = no have, 2 = have, but the equipment needs to be improved, 3 = have, and equipment is well, and fixed assets are synthesized after obtaining the mean value.
Teacher–student ratio	From the school questionnaire plc0107

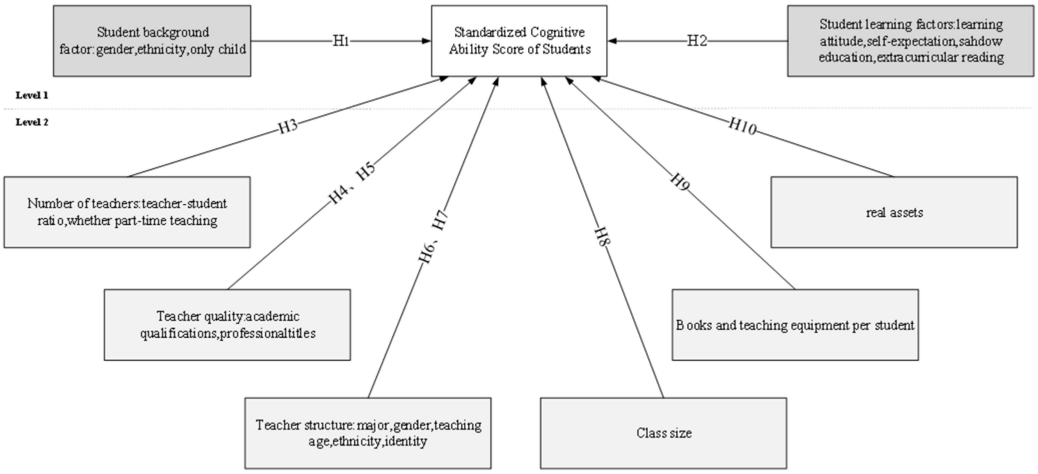

Figure 1. Study analysis framework.

3.3. Econometric Model

3.3.1. HLM

The HLM is a theory co-developed by Raudenbush and Bryk. It has been widely used in pedagogy and psychological research [30,54] and can address the effects of factors at various levels. Traditional multiple regression analysis can measure relationships between single-level variables, which reduces the effectiveness of multilevel data estimation, and the data for this study were nested. The overall level error item introduced in the two-layer horizontal HLM can fully utilize the information of each level [55]. The HLM is introduced in the research of modern educational production function. The first layer of data is student variables, and the second layer of data is school-level teacher variables and facility conditions. The data are divided into different levels, and the data size is different at different levels (for example, the number of teachers and students is not equal), so the modified data set is very suitable for the HLM. In this study, the method allows us to offer a more scientific breakdown of the contributions of teacher, student, and facility conditions to students' cognitive performance in rural schools in China.

Level 1:

$$\begin{aligned} \mathrm{cog3pl} &= \mathrm{b_{0j}} + \mathrm{b_{1j}SHO} + \mathrm{b_{2j}AR} + \mathrm{b_{3j}LO} + \mathrm{b_{4j}LA} + \mathrm{b_{5j}BOOS} + \\ &\quad \mathrm{b_{6j}SE} + \mathrm{b_{7j}PEO} + \mathrm{b_{8j}AT} + \varepsilon_{ij} \qquad \varepsilon_{ij} : \mathrm{N}(0,\sigma) \end{aligned} \tag{1}$$

Level 2:

$$\begin{aligned} \mathrm{b_{0j}} = &\ \mathrm{C_{00}} + \mathrm{C_{01}SJB} + \mathrm{C_{02}JXSB} + \mathrm{C_{03}JSGM} + \mathrm{C_{04}TEST} + \mathrm{C_{05}BEN} + \\ &\ \mathrm{C_{06}GJZC} + \mathrm{C_{07}WTE} + \mathrm{C_{08}SF} + \mathrm{C_{09}AGE} + \mathrm{C_{010}SYB} + \mathrm{C_{011}JXYJ} + \mathrm{u_{ij}} \\ \mathrm{b_{2j}} = &\ \mathrm{C_{02}} + \mu_{2j}; \mathrm{b_{3j}} = \mathrm{C_{03}} + \mu_{3j}; \mathrm{b_{4j}} = \mathrm{C_{04}} + \mu_{4j}; \mu_{ij} \sim \mathrm{N}(0,\tau) \end{aligned} \tag{2}$$

These two formulas combine to give a complete two-level model:

$$\begin{aligned} \mathrm{cog3pl} = &\ \mathrm{C_{02}AR} + \mathrm{C_{03}LO} + \mathrm{C_{04}LA} + \mathrm{b_{1j}SHO} + \mathrm{b_{5j}BOOS} + \mathrm{b_{6j}SE} + \mathrm{b_{7j}PEO} + \mathrm{b_{8j}AT} + \\ &\ \mathrm{C_{01}SJB} + \mathrm{C_{02}JXSB} + \mathrm{C_{03}JSGM} + \mathrm{C_{04}TEST} + \mathrm{C_{05}BEN} + \mathrm{C_{06}GJZC} + \mathrm{C_{07}WTE} + \mathrm{C_{08}SF} + \\ &\ \mathrm{C_{09}AGE} + \mathrm{C_{010}SYB} + \mathrm{C_{011}JXYJ} + \mu_{2j}\mathrm{AR} + + \mu_{3j}\mathrm{LO} + \mu_{4j}\mathrm{LA} + \varepsilon_{ij} + \mathrm{u_{ij}} \end{aligned} \tag{3}$$

In the above model, students are the first level, and schools are the second level; i represents students, j represents schools, and Y_{ij} represents the cognitive scores of the ith student in J school. SE is the student's gender, PEO is the student's nationality, DS represents only child status, AT is the student's learning attitude, LO indicates participation in logic classes, LA indicates participation in language classes, AR indicates participation in art classes, BOOS represents the number of books at the student's home, TEST is the teacher–student ratio, JZ represents whether the teacher teaches more than one class concurrently, BEN is teacher's educational experience, GJZC is teacher's title, WTE is teacher's gender, SF is teacher's major, AGE is teacher's teaching age, SYB is teacher's status, SJB is books per student, JXSB represents teaching equipment, JSGM represents class size, and JXYJ represents school real estate.

3.3.2. Shapley Method

The Shapley value method is an important method for calculating the contributions of individual variables to the variations in dependent variables by calculating the marginal contribution to decomposing R2 of each variable under the combinatorial game framework [56,57]. The benefit distribution of alliance members based on the Shapley value reflects the contribution of each alliance member to the overall alliance and avoids egalitarianism. The Shapley value method is fairer and more reasonable than other distribution methods based solely on resource input, resource allocation efficiency, or the combination of the two, and it also reflects the process of a game between allies [58]. For this paper, we used the Shapley value method to calculate the contribution values of each student, teacher, and facility conditions to students' cognitive performance, as follows.

Let R be a set of real numbers. Then, $N = \{1, 2, \ldots, n\}$ is a collection of players, the binary group (N, υ) represents the classical cooperative game, and υ is the eigen function of all subsets defined on N. Alliance S is a subset of N. All alliance sets are 2N and mark the classical cooperative game set as G(N). The Shapley value of (N, υ) is then

$$\phi(v) = \sum_{S \in 2^N, i \notin S} \frac{|S|!(n - |S| - 1)!}{n!} \times [v(S \cup \{i\}) - v(S)], \forall i \in N \tag{4}$$

where $|S|$ and $|N|$ represent the number of players in S and N.

Considering that the Shapley value method takes each participant in the alliance as the analysis object, it cannot consider any impacts of dividing the alliance. The Owen value is introduced to account for divisions of the alliance. A limited division of the alliance structure is $C = \{C_1, C_2, \cdots, C_M\}$, satisfying $U_{i-1}^{M} C_{>i} = N$ Then, the set of all alliance structures on N is CN, the feasible alliance is P(C), and the Owen value of this alliance division can be calculated as follows:

$$O\omega_i(C, v) = \sum_{R \subseteq M, p \notin R} \sum_{S \in C_P, i \notin S} \frac{|R|!(M - |R| - 1)!}{|M|!} \times \frac{|S|!(C_p - |S| - 1)!}{|C_p|!} \times [v(Q \cup S \cup \{i\}) - v(Q \cup S)] \tag{5}$$

where M is the subscript set of alliance structure, $R \subseteq M \backslash \{p\}$, $Q = \cup_{k \in R} C_k$, $\forall C_p \in C$, $\forall i \in C_p$.

4. Results

4.1. Analysis of Factors That Affect Student Scores without Model Parameter Estimates

In the HLM, null models are used to test whether cross-level effects exist. For this study, taking students' scores as the dependent variable, we construct null models without independent variables to test whether a multilevel linear model would be necessary. The chi-squared test of the null models indicates the significant effectiveness of the two-level model (χ^2 = 8421.21221, $p < 0.01$). The estimated within-group variance is 0.51135, the between-column variance is 0.23821, and the intraclass correlation coefficient is 0.3178, the latter indicating that 32% of the total variation in the students' cognitive scores comes from differences between classes. That class characteristics have a statistically significant impact on students' cognitive test scores, which makes these data suitable for analysis with multilevel models.

4.2. The Influence of Student and Teacher Factors on Students' Scores

Table 3 presents the HLM estimation results for the impacts of student and teacher factors on rural students' cognitive scores. Model 1 is the benchmark model that contains the control variables and the facility conditions input variables, and the results show that parents' educational background, education expectations for their children, economic status, and positive peer influence all have positive effects on students' scores, consistent with findings by Hu et al. [47].

Table 3. The Influence of student and teacher Factors on Students' Cognitive Scores.

Fixed Effect	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Whole Model
Student level							
Parent's educational background	0.0147 *** (0.002)	0.0140 *** (0.002)	0.0125 *** (0.002)	0.0147 *** (0.002)	0.0144 *** (0.002)	0.0144 *** (0.002)	0.0114 *** (0.002)
Family economic status	0.0353 *** (0.009)	0.0357 *** (0.009)	0.0316 *** (0.009)	0.0353 *** (0.009)	0.0346 *** (0.009)	0.0350 *** (0.009)	0.0313 *** (0.009)
Parent's educational expectation for their children	0.0578 *** (0.003)	0.0581 *** (0.003)	0.0306 *** (0.003)	0.0577 *** (0.003)	0.0577 *** (0.003)	0.0578 *** (0.003)	0.0306 *** (0.003)
Peer influence	0.0354 *** (0.003)	0.0369 *** (0.003)	0.0223 *** (0.003)	0.0353 *** (0.003)	0.0352 *** (0.003)	0.0352 *** (0.003)	0.0237 *** (0.003)
Student gender		0.0375 (0.001)					0.0520 (0.001)
Student nationality		0.0345 (0.01)					0.0294 (0.01)
Only child or not		0.02301 (0.02)					0.0182 (0.02)
Self-education expectation			0.0413 *** (0.004)				0.0421 *** (0.004)
Learning attitude			0.0155 *** (0.002)				0.0169 *** (0.002)
Logic cram school			0.0142 *** (0.002)				0.0148 *** (0.002)
language cram school			0.0191 *** (0.001)				0.0168 *** (0.001)
Art cram school			−0.0650 *** (0.007)				−0.0624 *** (0.007)
Extracurricular reading			0.0428 *** (0.005)				0.0423 *** (0.005)
Faculty–student ratio				−0.0004 *** (0.0002)			−0.0002 *** (0.0002)
Teaching two or more classes concurrently				−0.2227 *** (0.036)			−0.168 *** (0.036)
Proportion of teachers with senior title					0.112 * (0.022)		0.0888 * (0.022)
Proportion of teachers with a bachelor's degree or above					0.1300 ** (0.04)		0.0886 ** (0.04)
Proportion of female teachers						0.1211 *** (0.003)	0.0843 *** (0.003)

Table 3. *Cont.*

Fixed Effect	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Whole Model
Proportion of teachers with a normal profession						−0.0476 ** (0.03)	−0.0429 *** (0.03)
Proportion of teachers with more than 10 years of teaching experience						−0.0022 *** (0.001)	−0.0035 *** (0.03)
Proportion of formal teachers						−0.0709 *** (0.002)	−0.0353 *** (0.002)
Facility conditions variable	have	have	have	have	have	have	have
Random effect							
Level 1 variance	0.7013491	0.7013491	0.6909673	0.6915774	0.6915636	0.6915629	0.6904896
Level 2 variance	0.3799335	0.3675335	0.3376422	0.326925	0.3504121	0.3162254	0.260596
ICC	0.351373	0.343848	0.328251	0.320986	0.336296	0.313782	0.273998

Note: *, **, and *** are significant at the level of 0.9, 0.95, and 0.99, respectively; the same applies below.

For Model 2, we added student background factors to Model 1 and found higher scores for girls, minority students, and non-only children than the scores for boys, Han students, and only children. That is, H1a was supported, but H1b and H1c were rejected. In Model 3, we added student learning factors at the student level to Model 1 and found positive impacts of students' self-education expectations, learning attitudes, and the number of books in the family home on students' cognitive scores; each book in the home increased student score by 0.0428 standard deviation. For shadow education, students' participation in logic and language remedial classes had positive effects on cognitive scores, but participation in art remedial classes had a negative effect. In short, H2a, b, c, were all supported, H2d was partly rejected.

For Model 4, we added teacher–student ratio and teaching more than one class to Model 1 at the school level. Teacher–student ratio correlated negatively with students' scores; with each unit increase in the ratio, the score decreased by 0.0004 points. H3a was supported. Students' cognitive scores were also lower when teachers taught more classes, and therefore, H3b was supported. In Model 5, we added teacher education background and professional title to Model 1 at the school level. Each unit increase in teacher qualifications increased the average score by 0.13 points, and with each unit increase in teacher professional title, the average score increased by 0.11 points. That is, H4 was supported, but H5 was rejected. It is possible that there was a positive correlation between teachers' professional title and students' cognitive performance in this study because highly qualified rural teachers have been vetted and do not show obvious job burnout when they take their positions.

For Model 6, we added school-level teacher factors to Model 1 and found the following: Cognitive scores are higher among teachers with non-normal majors, which rejected H6a; scores were higher with female teachers, supporting H6b; and scores are higher among teachers with less than 10 years of teaching experience. The latter finding rejected H6c, and we propose that newer teachers have more recent teaching knowledge and newer skills than do teachers with longer experience, and newer teachers bring the latest education concepts and teaching enthusiasm; we argue that all of these factors can improve student scores. We also found that scores were higher with formal teachers than with temporary teachers, and this supported H7. Table 3 gives detailed statistics on the impacts of the various student and teacher factors on students' academic performance in rural schools in China.

4.3. The Influence of Facility Conditions

Table 4 presents the HLM estimation results for the impacts of facility conditions on students' cognitive scores in this study. Model 7 is a benchmark model that included the study control variables, teacher and student factors variables, and the control variables that showed positive effects on students' scores. In Model 8, we added the average number of books per student to Model 7 at the school level and found a negative correlation with student scores: with each unit increase in the average number of books per student, cognitive scores decreased by 0.00007 points. Thus, surprisingly, H9a was rejected. Model 9 is the result of adding teaching equipment to Model 7 at the school level, and this correlation was positive: with each unit increased in teaching equipment, student cognitive score increased by 0.0475 points, and H9b was supported. We propose that there was a significant negative impact of the average number of books per student on students' scores because the books available in rural schools might not be suitable for the students at a given school or that utilization rates are low.

Table 4. The Influence of facility conditions on Students' Cognitive Scores.

Fixed effect	**Model 7**	**Model 8**	**Model 9**	**Model 10**	**Model 11**
Student level					
Parent's educational background	0.0114 *** (0.002)	0.0114 *** (0.002)	0.0113 *** (0.002)	0.0114 *** (0.002)	0.0114 *** (0.002)
Family economic status	0.0318 *** (0.009)	0.0319 *** (0.009)	0.03147 *** (0.009)	0.0318 *** (0.009)	0.0315 *** (0.009)
Parent's educational expectation for their children	0.0307 *** (0.003)	0.0307 *** (0.003)	0.0307 *** (0.003)	0.0307 *** (0.003)	0.0307 *** (0.003)
Peer influence	0.0238 *** (0.002)	0.0238 *** (0.002)	0.0238 *** (0.002)	0.0238 *** (0.002)	0.0238 *** (0.002)
Average copies of books per student		−0.00007 *** (0.00002)			
Teaching equipment			0.0475 *** (0.001)		
Class size				−0.0009 *** (0.00002)	
Real estate					0.0176 *** (0.003)
Student and teacher variables	Have	Have	Have	Have	Have
Random effect					
Level 1 variance	0.6905276	0.6905311	0.690515	0.6905287	0.6904821
Level 2 variance	0.260931	0.2598987	0.2608355	0.2578693	0.260236
ICC	0.274243	0.2734538	0.274174	0.271813	0.273726

For Model 10, we added class size to Model 7 at the school level and found a negative correlation with student scores: each unit increase in class size decreased student cognitive score by 0.0008998 points, supporting H8. In Model 11, we added school real estate to Model 7 at the school level and found positive correlations with students' scores. H10 was rejected.

4.4. The Contributions of Student, Teacher Facors, and Facility Conditions to Students' Cognitive Scores

As we discuss earlier, we apply the Shapley and Owen value method [59] to analyze the contributions of student, teacher, and facility conditions to the cognitive scores of students at rural schools across China, and the results are shown in Table 5. The Shapley method results showed that student self-education expectation contributed the most to the students' cognitive scores, which is 15.88%. In addition, whether the teacher teaches classes concurrently explained more than 10%. Among the nonsignificant influences, student gender (background factor), and participation in art remedial classes explained less than 1.00% of students' cognitive scores. In the Owen value method, results showed that, consistent with the conclusion of Monk [1], the effect of teacher and student factors on students' scores (92.31%) is much higher than that of facility conditions (7.69%), teacher factors (59.69%), and student factors (32.72%), which corresponds to Darling–Hammond's research conclusion; however, Zhang et al. [60] concluded that the difference in student scores is primarily caused by individual student differences (81.9%), and the contribution of current assets (4.75%) is higher than that of fixed assets (2.94%).

Table 5. Shapley and Owen Value Method Results for Student and Teacher Factors versus Facility Conditions Contributions to Students' Cognitive Scores.

<table>
<tr><th>Variables Name</th><th>Shapley Value
R^2 (%)</th><th>Owen (Group 1)
R^2 (%)</th><th>Owen (Group 2)
R^2 (%)</th><th>Owen (Group 3)
R^2 (%)</th></tr>
<tr><td>Student nationality</td><td>1.81</td><td rowspan="17">92.31</td><td rowspan="7">32.72</td><td rowspan="17">92.31</td></tr>
<tr><td>Student gender</td><td>0.12</td></tr>
<tr><td>Teach two or more Extracurricular reading</td><td>6.86</td></tr>
<tr><td>Only child or not</td><td>3.08</td></tr>
<tr><td>Self-education expectation</td><td>15.88</td></tr>
<tr><td>Learning attitude</td><td>1.29</td></tr>
<tr><td>Logic cram school</td><td>1.74</td></tr>
<tr><td>Language cram school</td><td>1.07</td><td rowspan="10">59.59</td></tr>
<tr><td>Art cram school</td><td>0.87</td></tr>
<tr><td>Classes concurrently or not</td><td>14.32</td></tr>
<tr><td>Faculty–student ratio</td><td>5.74</td></tr>
<tr><td>Proportion of teachers with a bachelor's degree or above</td><td>4.7</td></tr>
<tr><td>Proportion of female teachers</td><td>7.93</td></tr>
<tr><td>Proportion of teachers with a normal profession</td><td>5.42</td></tr>
<tr><td>Proportion of teachers with more than 10 years</td><td>7.21</td></tr>
<tr><td>Proportion of formal teachers</td><td>6</td></tr>
<tr><td>Proportion of teachers with senior title</td><td>8.27</td></tr>
<tr><td>Average copies of books per student</td><td>1.17</td><td rowspan="4">7.69</td><td rowspan="4">7.69</td><td rowspan="3">4.75</td></tr>
<tr><td>Teaching equipment</td><td>2.33</td></tr>
<tr><td>Class size</td><td>1.25</td></tr>
<tr><td>Fixed assets</td><td>2.94</td><td>2.94</td></tr>
</table>

5. Limitations, Conclusions, and Recommendations

It is important to address the limitations of this study. Numerous student and school factors relevant to students' cognitive scores are not controlled. Principal leadership may influence the attitudes of teachers, which can influence students' achievement. Having more variables would allow a better analysis of the factors that matter for the learning of students. Furthermore, the HLM method does not imply causality. Causal inference usually requires one or a combination of close substitutes for the potential outcome, controlled random experiments, or statistical adjustments [61]. As this study did not apply any of these techniques, estimations indicate correlations and not causality. The third limitation is the use of only standardized scores on students' cognitive ability tests as an outcome. Evidence shows that factors affecting learning achievements may vary by learning domain, though the effect of several factors may be consistent across domains as well. This indicates that the findings of this study are to be interpreted within the scope of only cognitive achievements, as we do not assume that they are necessarily generalizable in relationship to other learning domains.

Despite its limitations, this study addressed the central questions of the contributions of student and teacher factors versus facility conditions to the academic performance of students at rural schools in China, we analyzed data from the initial (2013–2014) wave of the CEPS using a two-level horizontal linear model. We used the Shapley and Owen value method to identify which had the greatest impact on students' cognitive scores and confirmed a number of findings from the extant research. This has positive practical significance for the rational allocation of the country's limited education resources, controlling the dropout rate of students, and improving the quality of education. Based on the above research results, we offer a number of suggestions for better allocating scarce resources to rural education.

School performance will be optimized if student and teacher resources are prioritized at the school level. Teacher-level factors have the vast majority of the explanatory power in this study with regard to students' cognitive performance. A 2014 plan to improve the facility conditions of rural schools resulted in narrowing the gap between the rural schools and urban schools; some rural schools even have better facility conditions, but because of inadequate teacher and student resources, these facilities are being wasted and have no effects on students' academic performance. For example, almost every rural school is equipped with music, sports, art classrooms, and related equipment, but rural teachers are either unable or unwilling to incorporate these tools into daily learning; skilled art, music, and sports instructors are scarce in rural schools, and therefore, transferring more of this human capital to rural schools would allow for more efficiently and optimally using the school facilities.

At the student level, skilled teachers are needed who can consciously guide students' self-education expectations; high student self-education expectations are associated with student cognitive performance. At the school level, district leaders should attempt to decrease class sizes and student-teacher ratios at rural schools, and where possible reduce the numbers of teachers who must teach multiple classes concurrently given that class size, teacher–student ratios, and teaching only one class had positive impacts on student performance. Next, at the individual teacher level, teachers at rural schools should enter with higher, formal education and titles to reduce the impacts of temporary and nonprofessional teachers on student performance. Finally, in this study, teachers who were younger and female and who had non-normal majors showed greater positive impacts on students' cognitive performance, and thus, these teachers should be prioritized in staffing rural schools in China.

According to the research results, the level of material allocation is weaker than the impact of teacher and student factors on student performance, but in reality, educational decision-makers are more inclined to allocate material resources with obvious short-term effects, which results in the misplacement of educational resources between supply and demand. Therefore, policymakers of the education supply system should pay more attention to the human capital that has an important impact.

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