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IQ, grit, and academic achievement: Evidence from rural China

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A B S T R A C T

Promoting an educated labor force is critical for emerging economies. Educational achievement, in turn, depends heavily on general cognitive abilities as well as non-cognitive skills, such as grit. Current research, however, has not examined how cognition and grit may explain the academic performance of students in an economically disadvantaged context. Thus, this study examines how IQ and grit contribute to academic achievement gains for students in poor areas of rural China. Drawing on data from 2931 students in rural China, we measure general cognitive ability, using the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) and Raven's Standard Progressive Matrices (Raven IQ); non-cognitive ability, using the Short Grit Scale; and academic achievement, using a curricular-based mathematics exam. We find that IQ and grit each predict achievement gains for the average student. Grit is not positively associated with achievement gains among low-IQ students, however, suggesting that grit does not translate into academic achievement gains for students with delays in general cognitive ability.

1. Introduction

Promoting an educated labor force is critical for emerging economies, such as China (Khor et al., 2016). International research has demonstrated that academic outcomes determine future educational opportunities and predict later-life outcomes, such as employment and wages (Currie and Thomas, 2001; Zax and Rees, 2002). In China's less-developed rural areas, home to nearly three-quarters of the country's school-age population, however, educational attainment is low. Compared to 97 % of students from large cities, only 77 % of students from rural areas attend high school (Wang et al., 2018). Failure to attend high school has been shown to result in low acquisition of critical skills and high levels of unemployment (Khor et al., 2016; Zhang et al., 2013), which, in aggregate, have the potential to affect the nation's economic growth and social stability (Heckman and Yi, 2012; Yi et al., 2012).

The literature has established that academic achievement depends on general cognitive abilities, such as working memory, processing speed, and relational reasoning (Duncan et al., 2007; Fuchs et al., 2005; Geary, 2011; Passolunghi et al., 2007). Academic achievement in higher levels of schooling, where curricula requirements are extensive and complex, relies especially on such general cognitive abilities (Gathercole et al., 2004; Siegler et al., 2012). This is particularly true in China where, as early as junior high school, the academic curriculum, which is typically the same in both rural and urban areas within a province, is fast paced and demanding, requiring students to employ integrative thinking and higher levels of cognition to succeed (Wang, 2011; Yi et al., 2015).

Because general cognitive abilities are shaped early in life and can persist in later years due to social and economic circumstances, differences in general cognitive abilities can explain, at least in part, differences in academic achievement between economically advantaged and disadvantaged students (Duncan et al., 2007; Heckman et al., 2006; Manning and Patterson, 2006; Noble et al., 2007; Welsh et al., 2010). Recent research in rural China suggests that one possible explanation for the poor educational outcomes of China's rural students may be the persistent cognitive delays that begin in early childhood. Several recent studies of rural infants and toddlers have found that nearly half of rural children under age three are at risk for cognitive delays (Luo et al., 2017; Wang et al., 2018; Yue et al., 2017, 2019). These delays may be inhibiting academic achievement among China's rural students, contributing to the low skill levels in rural China overall.

In addition to general cognitive abilities, academic achievement also depends on non-cognitive skills, a catch phrase for character skills, social and emotional learning competencies, personality traits, and soft skills (Borghans et al., 2008; Brunello and Schlotter, 2011; Duckworth and Yeager, 2015; Duncan et al., 2007; Wolfe and Johnson, 1995). Among the various non-cognitive abilities that have been investigated by researchers, grit, defined as an individual's passion, perseverance, and hard work toward pursuing long-term goals, has been found to be

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positively associated with academic achievement among secondary school and college students (Duckworth, 2016; Duckworth et al., 2007; Eskreis-Winkler et al., 2014). In addition, although it is not correlated with IQ, grit has been shown to outperform IQ as a predictor of academic achievement in samples of high-achieving students (Duckworth et al., 2007; Duckworth and Seligman, 2005).

Although both cognitive ability and grit have been shown to play a key role in educational outcomes, current research has not examined how grit and IQ can explain the academic performance of students in an economically disadvantaged context, such as rural China. Further, few studies have examined the role of grit in predicting academic outcomes among students with low cognitive ability. Non-cognitive abilities may be more malleable than general cognitive abilities at later ages and levels of schooling (Cunha and Heckman, 2008; Heckman, 2007); if this is true for grit, strengthening the grit levels of cognitively delayed students may be one way to overcome the negative effects of low cognition on academic achievement. Although a recent study by Light and Nencka (2019) found that both high- and low-ability students were found to benefit from grit for their academic attainment, no studies have compared the relative importance of IQ and grit for cognitively disadvantaged students. Such research is particularly important for developing regions, such as rural China, where the development of greater levels of human capital is critical to economic growth and the transition to a skills-based economy.

This study examines the relationship between IQ, grit, and academic achievement among 2931 junior high school students in rural China. To meet this goal, we pursue three specific objectives. First, we describe the distribution of IQ and grit among rural students and identify the proportion of students with low IQ (i.e., cognitively delayed students). Second, we show the relationship between IQ and academic achievement as well as between grit and academic achievement. Third, we examine the correlations between grit, IQ and academic achievement and how the contributions of grit and IQ differ for students with and without cognitive delays.

2. Methods

2.1. Sampling

We collected data on first-year rural middle school (seventh-grade) students in two prefectures in two provinces in Northwest China. These two provinces are ranked in the bottom half of all provinces in China for GDP per capita, at $7640 and $1310 (National Bureau of Statistics of China, 2015). More than 45 % of the population in the first prefecture and more than 67 % of the population in the second prefecture are classified as rural (National Bureau of Statistics of China, 2015).

We created our sampling frame in three steps. First, we included all 19 counties within the two prefectures in the study. Second, we obtained a list of all 343 junior high schools in the 19 sample counties that had at least one seventh-grade class. We excluded junior high schools with 20 or fewer students in the seventh grade as well as schools typically not counted as rural schools, such as those located in the county seat. After applying the two exclusion criteria, we then randomly chose 160 schools to be included in our final sample. Third, we randomly selected one seventh-grade class in each school and randomly chose half of the students in each class for inclusion in our study. In total, our final sample included 2931 seventh-grade students from 160 schools. Ethical approval for this study was granted by the Stanford University Institutional Review Board (IRB) (Protocol ID 28344).

2.2. Data collection

The data presented in this study were collected between June and September 2016, in four blocks. In the first block, we assessed student academic achievement. All sample students were administered a 35-minute grade-appropriate mathematics test. Math items for each test were first selected according to regional curricular guidelines for junior high school students. The content validity of the selected items was then validated by local educational experts. Trained psychometricians further validated exam properties (e.g., reliability, fairness, unidimensionality) after analyzing extensive pilot data. During the examination, to prevent cheating, trained enumerators proctored the students. We also obtained the math scores of sample students at the start of seventh grade, which we use as a control variable in our subsequent analysis.

In the second block, we collected data on student and family characteristics. Students were administered a questionnaire regarding their gender (1 = female; 0 = male), boarding status (1 = student is boarding at school), father and mother's education level (1 = primary; 2 = junior high; 3 = high school; 4 = college or university), father and mother's migration status (1 = father or mother migrated to a city for work for more than six months in the past year), left-behind child status (1= both parents migrated) and family asset value (indicators of wealth in the family).[1] A summary of student and family characteristics is presented in Table 1.

In the third block, the research team collected data on the general cognitive abilities of sample students. We used two scales to evaluate cognition: the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) and the Raven's Standard Progressive Matrices (Raven's IQ test). The WISC-IV was designed as a tool for assessing the intelligence of children ages 6–16 (Zhang, 2009). Developed by American psychologist David Wechsler and first published in 1949, the WISC-IV is widely used in the United States and Asian countries, particularly East Asia (Prifitera et al., 2005). The fourth edition of the WISC IQ test was published in the United States in 2003 (Wechsler, 2003), and a Chinese version and IQ norms were published in 2008 (Zhang, 2009). We used this final Chinese version, which for which students are scored in four dimensions: similarities, digit span, coding, and matrix reasoning, which comprise the combined WISC IQ score used in our regression analysis.

We also measured the general cognitive ability of the sample students, using the Raven's IQ test (Zhang, 2009). The Raven's IQ test, designed by British psychologist John C. Raven, is a nonverbal (language-neutral) intelligence test comprised entirely of pictorial questions related to spatial reasoning and pattern matching. Raven's test of cognitive skills is a cross-cultural reasoning tool and one of the most-used tests in the world (Borghans et al., 2016). The test is divided into five parts, each of which is sorted into 12 questions according to difficulty. The total score on these 60 questions is calculated based on an established norm to assign a final IQ.

Choosing an appropriate norm is important to compensate for the Flynn effect, a phenomenon in which average IQs for populations rise over time (Liu and Lynn, 2013; Raven, 2000). The version of the test and the original norm that we use is drawn from a 1989 assessment of the Raven's IQ test (Zhang, 1989). We used an older version of this test because there is no newer version available for Chinese populations. Several recent studies in China have used this testing scale (Fan and Liu, 2016; Li et al., 2011; Li and Zheng, 2009). This test was initially normalized in China nearly 30 years ago; however, this is not unusual. For instance, studies conducted in Japan in the 1990s (e.g., Shigehisa

[1] To measure the household consumption asset index in our sample, we asked a series of questions related to whether the household owned certain household items, livestock, or small businesses; the material used to construct their home; and the size of their home. Most responses to household asset ownership variables in our data set were dichotomous; thus, we used polychoric principal component analysis (PCA; Kolenikov and Angeles, 2009) to construct a standard index for household wealth among our sample students, which we refer to as the *household asset index*. We did so because studies suggest that using household asset indicators and PCA to construct continuous measures for household wealth is more reliable than is self-reported income (for a review, see Kolenikov and Angeles (2009)). The household asset index is a standardized index that ranges from -1.49 to 3.02. Negative values indicate that the value of a family's household assets is below the average value for our sample.

Table 1
Variables, variable names and summary statistic for sample.

Variable	Definition	Obs.	Mean	Std. Dev.	Min	Max
IQ Scores	scores of IQ tests					
WISC IQ	WISC-IV test score	472	88.21	10.90	59.00	124.00
WISC Low IQ	1= IQ < 85; 0= IQ> = 85	472	0.40	0.49	0.00	1.00
Raven's IQ	Raven's test score	2459	88.61	15.35	39.66	127.11
Raven's Low IQ	1= IQ < 85; 0= IQ> = 85	2459	0.36	0.48	0.00	1.00
Grit score	grit scale score (1−5)	2459	3.39	0.58	1.00	5.00
Learning gains	Standardized math score	2931	−0.00	1.00	−2.40	2.97
Academic achievement at beginning of seventh-grade	Standardized math score	2931	0.00	1.00	−3.19	2.55
Gender	1=female; 0=male	2931	0.49	0.50	0.00	1.00
Boarding status	1=boarding; 0 = not boarding	2931	0.51	0.50	0.00	1.00
Household consumption asset index	numeric; Continuous variable of family assets	2931	−0.00	1.07	−1.49	3.02
Father migration status	1=father migrated; 0=father not migrated	2931	0.47	0.50	0.00	1.00
Mother migration status	1=mother migrated; 0=mother not migrated	2931	0.18	0.39	0.00	1.00
Left-behind child status	1=left behind; 0=live with parents	2931	0.13	0.33	0.00	1.00
Grit score		2459	3.39	0.58	1.00	5.00
Grit scale score =1	1=Yes	503	0.17	0.38	0.00	1.00
Grit scale score =2	1=Yes	621	0.21	0.41	0.00	1.00
Grit scale score =3	1=Yes	403	0.14	0.34	0.00	1.00
Grit scale score =4	1=Yes	506	0.17	0.38	0.00	1.00
Grit scale score =5	1=Yes	426	0.15	0.35	0.00	1.00
Father education level						
Primary	1=Yes	1369	0.47	0.50	0.00	1.00
Junior high	1=Yes	1331	0.45	0.50	0.00	1.00
High school	1=Yes	192	0.07	0.25	0.00	1.00
College or university	1=Yes	39	0.01	0.11	0.00	1.00
Mother education level						
Primary	1=Yes	2021	0.69	0.46	0.00	1.00
Junior high	1=Yes	770	0.26	0.44	0.00	1.00
High school	1=Yes	115	0.04	0.19	0.00	1.00
College or university	1=Yes	25	0.01	0.09	0.00	1.00

Note: Father/mother migration status is defined as migrating to a city for more than 6 months in the last year.

and Lynn, 1991) used norms established by Jensen and Munro in 1979. Nevertheless, we recognize the need to compensate for using a nearly 30-year-old norm in our application of Raven's IQ test. Because Raven's IQ test scores generally change at the same rate across cultures and time (Raven, 2000), we adjust our final scores by using the Flynn effect of 6.19, provided in a 2013 study of increasing scale norms from 1986 to 2012 (Liu and Lynn, 2013).

We used both the WISC-IV and Raven's IQ tests to collect data on the cognitive skills of students in the sample. The WISC-IV test assesses both fluid intelligence and crystallized intelligence, whereas the Raven's IQ test assesses fluid intelligence only. Because the WISC-IV test must be administered one-on-one and lasts approximately 45 min, whereas the Raven's IQ test can be administered to multiple students at one time, we chose to administer the WISC-IV test to three randomly selected students from each sample class. The Raven's IQ test was then administered to all other students in the sample. This means that, in this study, we have two independent measures of cognitive skills. For both IQ scales, students who score lower than 85 (1 standard deviation (SD) below the normal mean of 100, which is also the internationally recognized cutoff for low IQ) are considered cognitively delayed.

Finally, in the fourth block of the survey, we measured the grit of sample students, using the Short Grit Scale. The construct of grit was first introduced by Duckworth et al. (2007) and is defined as perseverance and passion for long-term goals. Grit entails working strenuously to overcome challenges and maintaining effort and interest despite failure, adversity, and plateaus in progress (Duckworth et al., 2007). The Grit Scale is a student self-assessment that contains 17 statements regarding student attitudes and behaviors toward long-term goals (e.g., "new ideas and projects sometimes distract me from previous ones"; "setbacks don't discourage me"; Duckworth, 2016), to which students are asked to respond on a 5-point Likert-type scale of always, often, sometimes, rarely, or never (1 = never, 5 = always). In this study, we used the Short Grit Scale, which contains eight statements. The Short Grit Scale has been demonstrated to have strong internal consistency, test-retest stability, consensual validity with informant-report versions, and high predictive validity (Duckworth and Quinn, 2009). Further studies have demonstrated the validity of this test for the age group of our sample (Park et al., 2018; Peña and Duckworth, 2018). Grit scores are calculated by averaging the eight items on the questionnaire.

2.3. Statistical analysis

Our analysis is comprised of three parts. First, we describe the distribution of IQ and grit across our sample. We also conduct *t*-tests to identify student and family characteristics that are associated with different levels of IQ and grit. The *t*-tests compare the mean Raven's IQ and grit scores of students for different individual and family factor groups (e.g., male vs. female, boarding vs. not boarding, father migrated vs. father not migrated) to identify specific personal and family traits that are more likely to correlate with students who are more vulnerable to cognitive delay or low grit.

Second, we examine the relationship between IQ and academic achievement as well as between grit and academic achievement, while controlling for student and family characteristics. To do so, we run an ordinary least squares (OLS) regression model using the following equation:

$$Y_{ij} = \alpha_0 + \beta IQ_{ij} + \gamma G_{ij} + \delta X_{ij} + \theta \tau_j + \varepsilon_{ij} \quad (1)$$

The dependent variable Y_{ij} indicates the academic achievement gain from the beginning to the end of seventh grade of student i in class j. Academic achievement is measured by standardized math test scores; IQ_{ij} is the cognitive skills of student i, presented as IQ test scores; and G_{ij} is a variable that represents the grit scores of student i. The coefficients β and γ measure the correlation between IQ_i, G_i, and student academic achievement.

The vector X_{ij} includes student individual and family characteristics. Student individual characteristics include gender (1 = female), boarding status (1 = boarding at school), and academic performance at the beginning of seventh grade (measured by standardized math test scores). The family characteristics include parental education level (dummy variables for whether the father/mother of the student has graduated from primary school, junior high school, high school, and college or university), and parental migration status (1 = the father/mother of the student migrated to a city for work for more than six months in the past year) as well as household consumption asset index.

We also include class-level dummy variables to completely control for variation in classroom characteristics (represented by τ_j in the equation). Because we randomly selected one seventh-grade class in each school, the class-level dummy variables are equal to the school-level dummy variables. Here, i represents each of the observations, and ε represents random error that exists in a normal distribution.

Third, we examine the contributions of grit and IQ to achievement gains for students with different levels of cognitive ability. To do so, we divide our sample students into two groups. The first group is low-IQ students, that is, students who have IQ scores below 85. The second group is normal-IQ students, who have IQ scores of 85 and above. We use Eq. (1) to identify the contributions of IQ and grit to academic achievement (controlling for student and family characteristics) for each group.

3. Results and discussion

3.1. Distribution of cognitive abilities and grit

According to our data, a relatively large share of students in our sample is cognitively delayed. Fig. 1 presents the distribution of WISC-IV scores in our sample. The mean WISC-IV for sample students is 88.2, and the share of students with low IQ (defined as IQ below 85) is 40 %. The distribution of Raven's IQ scores, shown in Fig. 2, is similar to the distribution of WISC-IV in our sample. The mean Raven's IQ score is 87.36, and among those students who took the Raven's IQ scale, 36 % scored below the cutoff for low IQ.

Both distributions of IQ scores (WISC-IV; Fig. 1 and Raven's IQ; Fig. 2) for sample students are skewed to the left of the distribution of a healthy population, indicating that a large proportion of sample students face cognitive delays. In a healthy population, by definition, about 15 % will score one or more SDs below the mean. Hence, our results show that the rates of low IQ are more than two times higher in rural China than in a healthy population. These rates, however, are only slightly lower than those in studies of infants and toddlers in rural China (Luo et al., 2017; Wang et al., 2019), including toddlers from the same region as students in our sample (Yue et al., 2017). Further, our results are almost identical to those found in a study of IQ among primary school students in 59 private schools for rural migrants in Beijing and Suzhou and 60 rural public schools in Henan and Anhui Provinces (Zhao et al., 2019). In Zhao et al.'s study, the percentage of left-behind rural students with Raven's IQ scores at 1 SD below the mean is 38 %. Together with the results from these previous studies, our findings suggest that this problem is not uncommon throughout rural China and that the students in our study sample may be suffering the long-term consequences of cognitive delays from early childhood.

Fig. 3 shows the distribution of grit scores for the students in our sample. The mean grit score among the students in our sample is 3.4 points. This is noticeably lower than the grit scores among junior high school-aged students in comparable populations of other countries. One study conducted with a sample of 1277 seventh- and eighth-grade students (who were mainly low-income and minority students) in the United States found a mean grit score of 3.60 (Park et al., 2018). In a study of grit among a broad sample of 14,762 students in Mexico, researchers found a mean score of 3.65 (Peña and Duckworth, 2018). In our sample, 71 % of students scored below 3.65 in grit, and 62 % of students scored below 3.60. In addition, 27 % of students scored lower than 1 SD below 3.65, and 20 % scored lower than 1 SD below 3.60. There are several reasons that these two studies can be considered comparable populations to ours. In both studies, the sample students are similar in age to our sample students. In addition, the majority of the students from the U.S. sample (Park et al., 2018) are low income, as is our sample. Finally, because the level of economic development in Mexico is comparable to that of China, and there likewise exists a large rural-urban divide in economic resources, the sample from Mexico can be considered similar to our sample.

From this analysis, it appears that, as in the case of cognition, the grit scores of students in our sample are lower than those of the other populations, including vulnerable populations. One possible reason for this finding is the combination of instructor-centered, passive, and rote learning; high levels of anxiety and a lack of social belonging; and a lack of academic and psychological support within China's rural school system (Sargent et al., 2011; Wang et al., 2015, 2016). In addition, recent studies have found that, among rural toddlers in China, more than 50 % have delayed social-emotional development (Wang et al., 2018). If rural junior high school students are indeed suffering from developmental delays in early childhood, in both cognition and social-emotional skills, they may be in greater need of academic and psychological support to maintain motivation and perseverance, as their social-emotional skill levels will likely be lower. Without systems of academic and psychological support, students may struggle to develop the ability to persevere over time, especially in the face of setbacks, causing them to develop lower levels of grit than do other populations.

Fig. 4 shows the distribution of grit scores for normal-IQ and low-IQ students. As seen in the figure, the variation in grit is similar between low-IQ students and students with a normal IQ. In other words, both subgroups of students have individuals with low grit.

3.2. Correlates of IQ and grit

As seen in Table 2, to help identify students who may be vulnerable to cognitive delay and low grit, we ran statistical tests of the differences in cognition scores (Raven's IQ) and grit scores among students of different characteristics and family backgrounds.[2] We find that two factors are significantly correlated with both IQ and grit: parental educational level and family wealth. Students whose fathers received more than nine years of schooling scored 1.32 points higher on Raven's IQ (10 % significance). Students whose mothers received more than nine years of schooling scored 1.03 points higher on Raven's IQ, but this difference is not statistically significant. Students with more educated parents also scored 0.06 points (educated father) and 0.08 points (educated mother) higher in grit (significant at 5 % and 1 %, respectively).[3]

We also find that students from less-wealthy families are more likely to exhibit lower IQ and lower grit compared to students from wealthier families. Students with family asset values in the bottom quartile scored lower than did students with family asset values in the top quartile by

[2] We use Raven's IQ for group comparison analysis because the sample size of the WISC-IV is much smaller and may not provide robust results.

[3] A large share of our sample students may have cognitive delays because less-educated rural parents are less likely to engage in interactive parenting practices with children from an early age. Indeed, two studies of infants and toddlers in rural China have found that mothers with educational attainment beyond middle school (i.e., more than nine years of education) are more likely to read, sing, and play with children, leading to lower rates of developmental delays (Luo et al., 2017; Yue et al., 2017). Unfortunately, as seen in Table 1, only less than 1 % of sample parents have more than a high school level of education. This also may explain the low levels of grit among students with less-educated parents; research indicates that parenting practices play an important role in the development of non-cognitive skills, which may contribute to the formation of grit as children grow (Kautz et al., 2014).

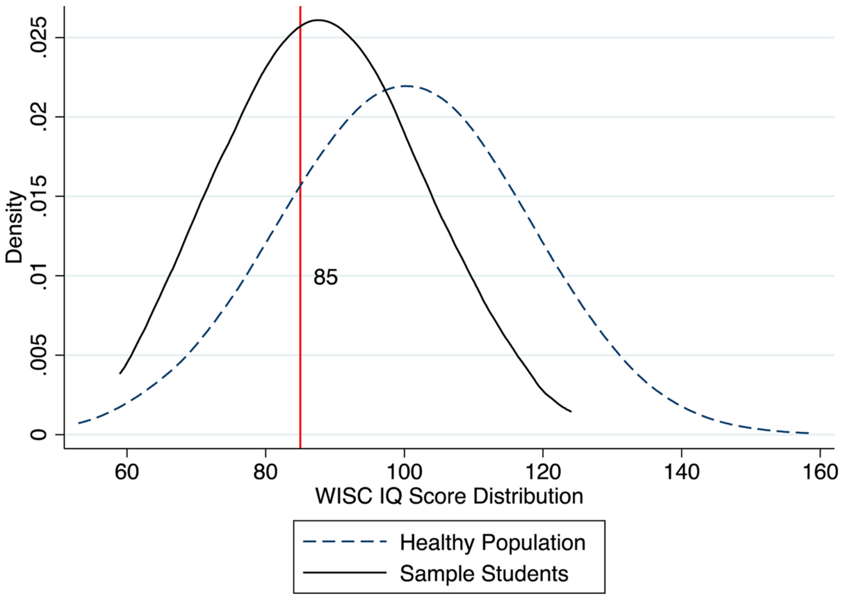

Fig. 1. Distribution of WISC IQ scores for sample students and a healthy population.
Note 1: The cutoff of low IQ is 85, visualized with a vertical red line. Using this cutoff, we calculated that across all school and counties, 189 of the 472 students surveyed were cognitively delayed, a population incidence of 40 %. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

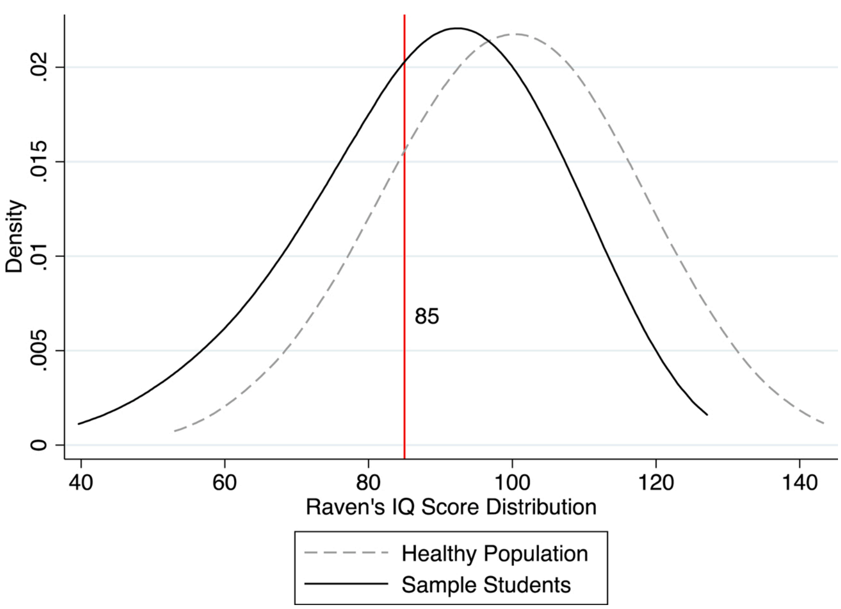

Fig. 2. Distribution of Raven's IQ scores for sample students and a healthy population.
Note 1: The cutoff of low IQ is 85, visualized with a vertical red line. Using this cutoff, we calculated that across all school and counties, 882 of the 2459 students we surveyed were cognitively delayed, a population incidence of 36 %. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

2.75 points on Raven's IQ (significant at 1 %). Students with low family asset values also scored 0.05 points less in grit (significant at 10 %). The relationship between family asset value and IQ in our sample is not surprising, given that poverty has been shown to affect the nature of a family's child-rearing environment and that poor environmental factors are closely associated with poor development outcomes of infants and toddlers during early childhood (Duncan and Brooks-Gunn, 2000; Parker et al., 1988). If the children in our sample are suffering from cognitive delays from early childhood due to persistent and ongoing poverty, the absence of resources could exacerbate these delays. Poverty also hinders the development of non-cognitive skills, leading students from poor households to develop lower levels of grit than that of their peers (Kautz et al., 2014; Phillips and Shonkoff, 2000).

We also find that certain factors are correlated with either IQ or grit but not both. Students boarding at school scored 1.49 points lower in terms of Raven's IQ than did students who live at home (significant at the 10 % level); however, there is no statistically significant difference in grit. In addition, although there is no gendered difference in IQ, girls tended to score 0.11 points higher in grit than did boys (significant at 1 %), which is similar to the findings of previous studies (Kannangara et al., 2018). Students whose father migrated scored 1.24 points lower than those whose father lived at home (significant at the 5 % level); however, there is no statistically significant difference in grit. Interestingly, we find that there is almost no significant difference in IQ and no statistically significant difference in grit scores between students whose mother or both parents migrated and students whose mother or both parents live at home.

3.3. IQ, grit, and gains in academic achievement

Table 3 presents the relationship between increases in IQ and academic achievement as well as between grit and academic achievement. The results of the analyses presented in Columns 1 through 4 do not control for individual and family characteristics. In Columns 5 through 8, however, the analysis does control for these characteristics.

The findings indicate that both the WISC-IV and Raven's IQ can

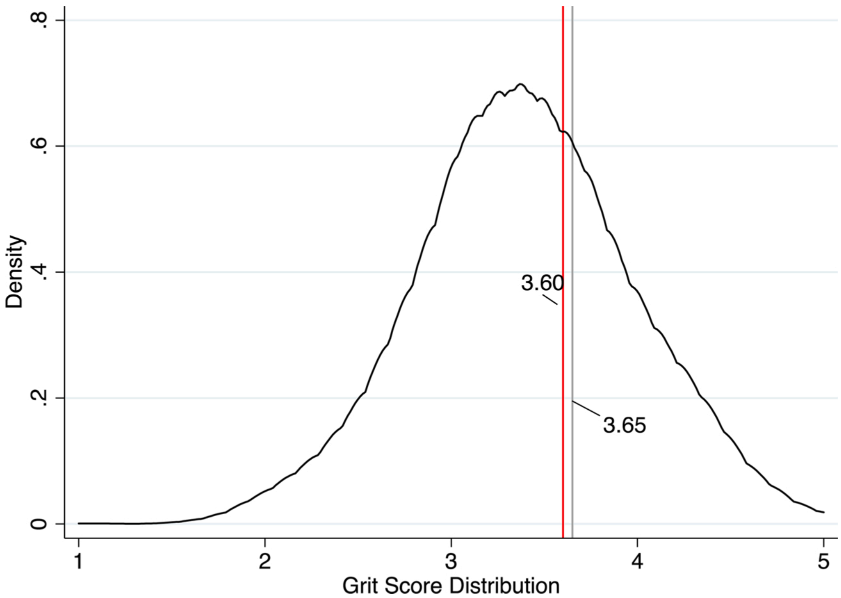

Fig. 3. Distribution of grit scores for sample students.
Note 1: Previous studies of grit in comparable populations have found mean grit scores of 3.60 and 3.65, visualized with a vertical red line and a vertical gray line, respectively. Using this cutoff, we found that 20 % of students scored lower than one standard deviation below 3.60 in grit, and 27 % scored lower than one standard deviation below 3.65. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

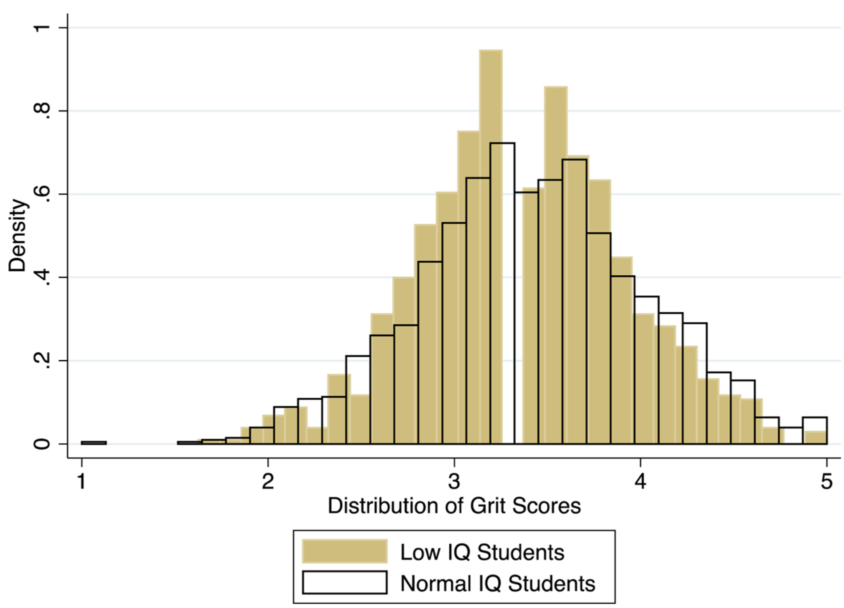

Fig. 4. Distribution of grit scores for low IQ students and students with normal IQ.

significantly predict academic achievement, regardless of whether student and family characteristics are controlled for. In our sample, a one-point increase in WISC-IV score corresponds to a 0.03-SD increase in academic achievement (Row 1, Columns 1 and 5; significant at 1 %). In our sample, 10.9 points on the WISC-IV is equal to 1 SD. This means that a 1-SD increase in WISC-IV scores is correlated with a 0.33-SD increase in academic achievement, or almost one year of learning (Hill et al., 2008; Li et al., 2020).[4] For Raven's IQ, the coefficient is slightly smaller. A one-point increase in Raven's IQ corresponds to a 0.01-SD increase in academic achievement (Row 2, Columns 2 and 6; significant at 1 %). As 1 SD of Raven's IQ corresponds to 15.35 points, a 1-SD increase in Raven's IQ correlates to a 0.15-SD increase in academic achievement. This is a difference of more than half a year of learning (Hill et al., 2008; Li et al., 2020). In either case, it is clear that a student's IQ is an important determinant of gains in academic achievement.

Grit also is positively associated with academic achievement, regardless of whether we control for student and family characteristics (Row 7, Columns 3 and 7; significant at 1 %). Compared with students who received grit scores of 1, the academic achievement of students with grit scores of 5 was higher by 0.17 SDs. This means that, on average, a one-point increase in grit correlates with about a 0.034-SD increase in academic achievement. Because 1 SD of grit is 0.58 points, this means that an increase of 1 SD in grit correlates to a 0.019-SD increase in academic achievement. Although the magnitude of this coefficient is not as great as that for IQ, it suggests that grit also contributes to academic achievement. Previous research supports this finding: Although IQ is the strongest predictor of academic achievement (Kuncel et al., 2004; Sackett et al., 2012), studies in the United States have found that grit also plays an important role in both academic achievement (Bazelais

[4] According to Hill et al. (2008), the growth of standardized mathematics scores of students is approximately 0.30 SDs from sixth to seventh grade, 0.32 SDs from seventh to eighth grade, and 0.22 SDs from eighth to ninth grade.

Table 2
Descriptive analysis of cognitive abilities and non-cognitive skills: comparisons between different types of students.

Variables		Raven's IQ		Difference	Grit		Difference
		Mean	SE		Mean	SE	
Gender	male	88.88	[0.56]	0.54	3.34	[0.02]	−0.11***
	female	88.33	[0.55]		3.45	[0.02]	
Boarding status	boarding	87.87	[0.64]	−1.49*	3.39	[0.02]	−0.01
	not boarding	89.36	[0.57]		3.40	[0.02]	
Father education level	at least 9 years	89.45	[0.61]	1.32*	3.43	[0.02]	0.06**
	less than 9 years	88.13	[0.56]		3.37	[0.02]	
Mother education level	at least 9 years	89.42	[0.74]	1.03	3.46	[0.03]	0.08***
	less than 9 years	88.39	[0.56]		3.38	[0.02]	
Household consumption asset index	top 25 %	89.83	[0.82]	2.75***	3.41	[0.02]	0.05*
	bottom 25 %	87.08	[0.69]		3.36	[0.02]	
Father migration status	father migrated	87.96	[0.56]	−1.24**	3.41	[0.02]	0.03
	father not migrated	89.20	[0.54]		3.38	[0.02]	
Mother migration status	mother migrated	88.51	[0.89]	−0.12	3.38	[0.03]	−0.02
	mother not migrated	88.63	[0.50]		3.40	[0.02]	
Left-behind child status	left behind	88.72	[0.93]	0.12	3.39	[0.04]	−0.01
	live with parents	88.59	[0.49]		3.40	[0.02]	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Note: Father/mother migration status is defined as migrating to a city for more than 6 months in the last year.

et al., 2016; Strayhorn, 2014; Tuss et al., 1995) and attainment (Duckworth, 2016).

We also examine the strength of the relationships between IQ, grit, and academic achievement gains relative to other factors that also may be associated with academic achievement. To do so, we compare the effect sizes of 1-SD shifts in IQ and grit to that of the other statistically significant explanatory variable, household assets (Column 8). When we compare the effect sizes, it is clear that IQ has a much stronger influence: A 1-SD difference in Raven's IQ is associated with a 0.15-SD increase in academic achievement, much higher than the difference of 1 SD in household assets (-0.03 SDs).

A difference in grit score is also associated with a significant increase in academic achievement. A 1-SD increase in grit correlates with a 0.019-SD increase in academic achievement gains, however, which is much smaller than that of IQ (0.15 SDs).

3.4. Academic achievement among low-IQ and normal-IQ students

Table 4 shows the differences in academic achievement between low-IQ students (who have IQ scores below 85) and students with a normal IQ (IQ scores at or above 85). We find that students in the low-IQ group have significantly lower academic achievement than do students in the normal-IQ group. Students with a low WISC-IV scored 0.96 SDs below students with a normal IQ (Row 1, Column 3; significant at 1 %), and students with low Raven's IQ scored 0.75 SDs below students with a normal IQ (Row 1, Column 3; significant at 1 %). These differences are equivalent to between two and three years of schooling (Hill et al., 2008; Li et al., 2020). In other words, students with a low IQ are up to three grade levels behind their normal-IQ peers.

Finally, we isolate the contribution of IQ and grit to academic achievement gains for low-IQ and normal-IQ students. The results of this analysis are presented in Table 5. For both groups, the WISC-IV and Raven's IQ tests are still significantly predictive of academic achievement gains. A one-point increase in the WISC-IV score corresponds to an increase in academic achievement gains of 0.01 SDs for low-IQ students (Row 1, Columns1) and 0.03 for normal-IQ students (Row 1, Columns5; significant at 1 %). A one-point increase in Raven's IQ corresponds to a 0.01-SD increase in academic achievement gains for low-IQ students and a 0.02-SD increase for normal-IQ students (Row 2, Columns 2, 4, 6, and 8; all significant at 1 %). In other words, a difference of 1 SD in Raven's IQ corresponds to about half of a year of schooling for low-IQ students and one year of schooling for normal-IQ students (Hill et al., 2008; Li et al., 2020).

Importantly, the relationship between grit and academic achievement gains changes when we examine low-IQ and normal-IQ students separately. For students in the normal-IQ group, grit still significantly contributes to gains in academic achievement: Compared with students who received grit scores of 1, the academic achievement of students with grit scores of 5 increased by 0.20 SDs without controlling for IQ (Row 7, Column 7; significant at 1 %) and increased by 0.19 SDs, controlling for IQ (Row 7, Columns 8; significant at 1 %). For students in the low-IQ group, however, the relationship between grit and academic achievement gains is no longer statistically significant (Rows 4–7, Columns 3 and 4).

This finding suggests that, for students with low IQ, passion, perseverance, and hard work (i.e., grit) cannot improve academic achievement. Our results contradict those of Light and Nencka (2019), who found that low-ability students appear to benefit by substituting grit for cognitive ability. There are three possible reasons for this difference. First, the Light and Nencka study used achievement test scores (based on knowledge and reasoning skills in mathematics and reading) as a proxy for cognitive ability, whereas our study uses IQ scores to measure cognitive ability. In addition, Light and Nencka used the within-sample distribution to identify students with low cognitive ability, rather than using a common division criterion for low cognitive ability (such as our IQ < 85). This means that they may not be measuring the role of grit for students with cognitive delays, specifically. Finally, Light and Nencka examined academic attainment as the main outcome variable, whereas our study uses academic achievement (learning gains) as the main outcome variable. It may be that the relationship to grit differs for academic attainment and learning. For example, students with higher grit may be more likely to remain in school compared to students with low grit scores. The results of our study indicate that, when students are cognitively delayed (as defined by IQ scores below 85), the negative effects on academic performance cannot be compensated for by increased grit.

Several limitations should be considered when considering our results. First, it is possible that other unobserved factors, such as student motivation or aspiration, also may influence the measured relationship between student grit scores and learning gains. For example, studies have shown that intrinsic motivation may influence academic performance through a student's effort (Goodman et al., 2011; Kusurkar et al., 2013). Thus, the degree to which students feel intrinsically motivated to learn may affect both their grit scores and their learning. Further research is needed to understand these associations.

Second, it is possible that academic achievement may be underestimated for students with either low IQ or low grit. If low-IQ students with low grit are less likely to take a math test seriously, their test scores

Table 3
Relationship between academic achievement, IQ, and grit for the full sample.

Variables	Academic Achievement (Learning Gains)							
	Without Controlling for Individual and Family Characteristics				Controlling for Individual and Family Characteristics			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WISC-IQ	0.03***				0.03***			
	(0.00)				(0.00)			
Raven's IQ		0.01***		0.01***		0.01***		0.01***
		(0.00)		(0.00)		(0.00)		(0.00)
Grit								
1			Reference	Reference			Reference	Reference
2			0.05	0.06			0.06	0.06
			(0.05)	(0.04)			(0.05)	(0.04)
3			0.03	0.03			0.04	0.04
			(0.05)	(0.05)			(0.05)	(0.05)
4			0.08	0.08			0.08*	0.08*
			(0.05)	(0.05)			(0.05)	(0.05)
5			0.17***	0.16***			0.17***	0.16***
			(0.05)	(0.05)			(0.05)	(0.05)
Gender (1 if female)					0.09	0.01	0.01	0.00
					(0.08)	(0.03)	(0.03)	(0.03)
Boarding status (1 if boarding at school)					0.10	−0.07*	−0.09**	−0.07
					(0.12)	(0.04)	(0.04)	(0.04)
Household consumption asset index					0.07	−0.03*	−0.03*	−0.03*
					(0.05)	(0.02)	(0.02)	(0.02)
Father migration index					−0.12	0.00	−0.01	0.00
					(0.09)	(0.03)	(0.03)	(0.03)
Mother migration index					−0.11	0.01	0.02	0.01
					(0.11)	(0.04)	(0.04)	(0.04)
Father education level								
Primary school					Reference	Reference	Reference	Reference
Junior high school					0.10	0.02	0.03	0.02
					(0.09)	(0.03)	(0.03)	(0.03)
High school					0.43**	0.05	0.07	0.05
					(0.19)	(0.06)	(0.07)	(0.06)
College or University					0.75*	0.03	0.05	0.05
					(0.43)	(0.14)	(0.14)	(0.14)
Mother education level								
Primary school					Reference	Reference	Reference	Reference
Junior high school					0.03	0.01	0.00	0.00
					(0.10)	(0.04)	(0.04)	(0.04)
High school					−0.30	0.17**	0.17**	0.16**
					(0.20)	(0.08)	(0.08)	(0.08)
College or University					−0.27	0.16	0.22	0.16
					(0.38)	(0.18)	(0.19)	(0.18)
Constant	−2.70***	−1.23***	0.05	−1.27***	−2.69***	−1.25***	−0.00	−1.30***
	(0.56)	(0.20)	(0.18)	(0.20)	(0.55)	(0.20)	(0.18)	(0.21)
Academic achievement at beginning of seventh grade	yes	yes	yes	yes	yes	yes	yes	yes
Class fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	472	2459	2459	2459	472	2459	2459	2459
R-squared	0.575	0.364	0.322	0.367	0.599	0.367	0.326	0.370

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note: Father/mother migration status is a binary variable which is 1 if the father/mother of the student migrated to a city for work for more than six months in the past year.

may actually be lower than their true ability. In addition, the results from our regression model still show a positive correlation (although not statistically significant) between grit scores and math test scores for students with low IQ, meaning that the true correlation coefficient of grit on math scores may be larger than the estimated coefficient. Therefore, the coefficient that we report should be treated as a lower bound of the true correlation. To the extent that this is true, it is possible that grit may play an even larger role in student academic performance than what we report here.

4. Conclusion and policy implications

This paper examines the relationship between cognitive ability, grit, and learning gains among junior high school students in rural China. Using data from 2931 seventh-grade students in rural northwestern China, we describe the distribution of two types of IQ scores (WISC-IV and Raven's IQ), as well as factors correlated to IQ and grit. Most importantly, we examine the relationship between IQ, grit, and learning gains for both the full sample and students with low and normal IQs.

Our results show that nearly 40 % of the students in our sample are cognitively delayed. This is more twice the rate of cognitive delay in a normal population. This rate, however, is similar to that of cognitive delays found in rural infants and toddlers in the same region and across rural China (Wang et al., 2019). Further, sample students have lower grit than do other comparable populations.

That such a high proportion of students have a below-average IQ is particularly troubling, as it indicates that many children are at risk of being left behind in school. Indeed, we find that, although IQ and grit are both positively correlated with academic achievement (at a magnitude of 0.3 for IQ and 0.07 for grit), IQ has the greatest association with academic achievement compared to all other student and family characteristics, including grit. In addition, when we consider low-IQ and normal-IQ students separately, we find that the academic achievement of low-IQ students is up to 0.95 SDs behind that of normal-IQ students.

Table 4
The differences between low IQ and normal IQ students in terms of academic performance and non-cognitive skills.

Variables	Low IQ (IQ < 85) (1) Mean/SE	Non-Low IQ (IQ> = 85) (2) Mean/SE	Difference (2)-(1)
Using WISC IQ			
Academic performance (Math Score)	−0.59	0.37	0.96***
	[0.06]	[0.06]	
Using Raven's IQ			
Academic performance (Math Score)	−0.48	0.272	0.75***
	[0.04]	[0.04]	

The value displayed for t-tests are the differences in the means across the groups. Standard errors are clustered at class level.
* p < 0.10; ** p < 0.05; *** p < 0.01.

We also find that the positive relationship between grit and academic achievement is significant only for normal-IQ students. In other words, cognitive delays significantly lower the ability of students to learn at the level and pace of junior high school, and motivation, perseverance, and hard work (i.e., grit) cannot compensate for the achievement gap.

Taken together, our results indicate that poor cognition contributes to the poor educational outcomes of China's rural students. This has significant implications for China's future growth. China is attempting to transition to an economy based on value-added, high-wage industries, which involves a high demand for skilled labor. International experience demonstrates that individuals in this type of economy will need to acquire skills taught at the level of high school or above if they hope to be competitive in these higher value-added industries (Autor et al., 1998; Bresnahan, 1999; Bresnahan et al., 2002). If cognitive delays inhibit the academic achievement of rural students, China will fail to endow its rural labor force with such skills. This means not only that many individuals may have a difficult time finding employment but also that newly emerging industries may falter from a short supply of skilled labor. As a result, China's economy may experience slowed development

Table 5
Relationship between learning gains, IQ, and grit by IQ subgroups.

Variables	Learning gains							
	Low IQ Group				Normal IQ Group			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WISC-IQ	0.01				0.03***			
	(0.02)				(0.01)			
Raven's IQ		0.01***		0.01***		0.02***		0.02***
		(0.00)		(0.00)		(0.00)		(0.00)
Grit								
1			Reference	Reference			Reference	Reference
2			0.07	0.07			0.06	0.07
			(0.08)	(0.08)			(0.06)	(0.06)
3			−0.03	−0.03			0.07	0.05
			(0.09)	(0.08)			(0.07)	(0.06)
4			0.06	0.06			0.09	0.07
			(0.08)	(0.08)			(0.06)	(0.06)
5			0.03	0.00			0.20***	0.19***
			(0.09)	(0.09)			(0.06)	(0.06)
Female	−0.08	−0.01	−0.01	−0.01	0.24*	0.02	−0.01	0.01
	(0.20)	(0.05)	(0.05)	(0.05)	(0.13)	(0.04)	(0.04)	(0.04)
Boarding status (1 if boarding at school)	0.10	−0.18***	−0.19***	−0.18***	0.17	−0.01	−0.03	−0.01
	(0.30)	(0.07)	(0.07)	(0.07)	(0.18)	(0.06)	(0.06)	(0.06)
Household consumption asset index	0.04	−0.03	−0.02	−0.03	0.15**	−0.04*	−0.04*	−0.04*
	(0.12)	(0.03)	(0.03)	(0.03)	(0.06)	(0.02)	(0.02)	(0.02)
Father migration status	−0.15	0.02	0.02	0.03	−0.08	−0.01	−0.00	−0.01
	(0.22)	(0.05)	(0.05)	(0.05)	(0.13)	(0.04)	(0.04)	(0.04)
Mother migration status	−0.07	−0.12*	−0.11*	−0.12*	−0.27	0.10*	0.10*	0.10*
	(0.25)	(0.07)	(0.07)	(0.07)	(0.17)	(0.05)	(0.05)	(0.05)
Father education level								
Primary school	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Junior high school	0.16	0.05	0.05	0.05	−0.05	0.02	0.04	0.02
	(0.19)	(0.06)	(0.06)	(0.06)	(0.13)	(0.04)	(0.04)	(0.04)
High school	0.55	−0.04	−0.01	−0.04	0.45	0.08	0.15*	0.09
	(0.64)	(0.11)	(0.11)	(0.11)	(0.28)	(0.09)	(0.09)	(0.09)
College or university		−0.17	−0.20	−0.18	0.51	0.08	0.10	0.11
		(0.35)	(0.36)	(0.35)	(0.61)	(0.16)	(0.17)	(0.16)
Mother education level								
Primary school	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Junior high school	−0.14	0.00	0.00	0.01	0.06	0.01	0.00	0.00
	(0.23)	(0.06)	(0.06)	(0.06)	(0.14)	(0.05)	(0.05)	(0.05)
High school	−0.55	0.38**	0.32**	0.39***	−0.28	0.12	0.15	0.11
	(0.58)	(0.15)	(0.15)	(0.15)	(0.28)	(0.10)	(0.10)	(0.10)
College or University	−0.00	0.72	0.74	0.74	−0.47	0.04	0.08	0.03
	(1.06)	(0.51)	(0.52)	(0.52)	(0.44)	(0.20)	(0.21)	(0.20)
Constant	−1.91	−1.16***	−0.41	−1.18***	−2.13**	−2.01***	0.16	−2.10***
	(2.02)	(0.34)	(0.29)	(0.34)	(0.84)	(0.35)	(0.23)	(0.35)
Class fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Observations	189	882	882	882	283	1577	1577	1577
R-squared	0.791	0.489	0.478	0.491	0.770	0.390	0.362	0.394

Note: We divided students into Low IQ and Normal IQ groups using IQ = 85 as cutoff. * p < 0.10; ** p < 0.05; *** p < 0.01.
Father/mother migration status is a binary variable which is 1 if the father/mother of the student migrated to a city for work for more than six months in the past year.

(Khor et al., 2016).

The prevalence of low cognitive ability is a result of many factors in school and at home, including educational and health inputs. The literature demonstrates that, to improve cognitive ability, measures must be taken as early as possible. Early childhood is the period with the greatest brain malleability and neurobiological capacity for cognitive development (Heckman, 2013), whereas cognitive ability usually has stabilized by the time children reach adolescence (Luna et al., 2004). Therefore, we recommend that policymakers increase investments in early childhood development, i.e., before children enter school. Effective nutrition and parenting interventions can reduce the number of children who face delays in early childhood and, in turn, the number of children who continue to face delays in later life (Aboud and Yousafzai, 2015). Our results also point to certain "target groups" that may have the greatest need for such programs, namely, poor families and families with low parental education levels.

Measures also must be taken to address the needs of current junior high school students. Considering that nearly 40 % of junior high school students are cognitively delayed and that cognitive delays are linked to lower academic achievement, there is a need for effective programs and educational resources that address the learning needs of cognitively delayed students and prepare them for life after school. Future research should investigate in-school and at-home interventions that may improve the academic performance and non-cognitive skills of China's rural school-age children.

Ultimately, the most important implication of these results is that policymakers and educators must develop educational systems that recognize and address the needs of cognitively delayed students in rural China. If the results of our research are true for other regions of rural China, more than a third of rural primary school students might be cognitively delayed. This calls for the modification of existing policies and the creation of new ones to identify cognitive delays among rural children in infancy, childhood, and adolescence and provide resources to address their learning challenges. Targeted policies and programs would help to bring educational equity to students who are cognitively delayed, giving them greater means to succeed and create value in society.

Declaration of Competing Interest

The authors have no conflicts of interest to declare.

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