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The Impact of Higher Education on Health Literacy: A Comparative Study between Urban and Rural China

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Abstract: *Health China 2030* calls for health equity. The strict household registration system, known as *Hukou*, results in an uneven distribution of social resources between urban and rural China. Higher education can promote social mobility and narrow health inequality. Health literacy is a significant indicator to predict health status. Drawing on national representative data recently collected, this study examines the impact of higher education on health literacy in urban and rural China. Propensity score matching was used to address potential selection bias. Ordinary least squares regressions and Oaxaca–Blinder decomposition techniques were conducted to explore urban-rural disparities in health benefits from higher education. The findings indicate that there are existing gaps in health literacy, higher education attainment, household income, and healthcare coverage between urban and rural China. Higher education attainment can significantly promote health literacy both in urban and rural China, after controlling for a series of demographic, socio-economic, and individual characteristics. Moreover, this study highlights a negative heterogenous treatment effect pattern: those who are less likely to attend college can obtain more health benefits from higher education than those who are more likely to be admitted into college. Public education and health programs, policies, and goals should be further optimized to promote integrated development in urban and rural China.

Keywords: health literacy; higher education; urban-rural disparity; selection bias; heterogeneity

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1. Introduction

Health China 2030 calls for narrowing the gap in basic health services between urban and rural areas to achieve universal health coverage and social equity. However, China's long-lasting distributional policies and household registration system (*Hukou*) have exacerbated urban-rural distinctions in rights and privileges regarding social welfare such as education, health care, and employment, which translates into health inequity. Education has the dual role as a driver of opportunity but also as a reproducer of inequality. It remains unclear whether an uneven distribution of educational resources in China's unique dualistic society will exacerbate or suppress the health inequities. Clarifying the relationship between education and health can provide further reference for policy makers and health practitioners.

Extensive prior studies have demonstrated multifarious mechanisms through which education influences health, encompassing economic, health-behavior, social-psychological factors, and access to health care [1–3]. However, uncertainty remains about the impact of education on health. On the one hand, education, health and health behaviors remain endogenous to confounded and unobserved individual characteristics and family socioeconomic factors. Moreover, the association between education and health may stem from 'reverse causation', as earlier health endowments could affect educational attainment later in life. On the other hand, the size and sign of the reported estimates vary greatly due to differences in estimation methods, measurements of health, birth cohorts and country contexts. For example, some find significant effect of education on health [4–6], and others report small or no effects [7–9].

However, it is noteworthy that the available evidence is mainly from developed countries [10,11], while there are limited reports of health gradients caused by education in China. Additionally, most research has focused on physiological and behavioral factors and lacks cognitive and literacy perspectives which have a lifelong impact on health. Compared with elementary and secondary education, higher education (HE) can provide more health benefits, which is very consequential for an individual's occupation, income, healthcare, living environment, and social connection [3,12]. Although China has the largest HE system around the world with 240 million people, the distribution of education resources between urban and rural areas is extremely unequal [13], and the access to HE varies among people with different socioeconomic status (SES). To reduce health disparities and improve population health, it is necessary to further explore the impact of HE on health among diverse groups in urban and rural areas to obtain a more complete vision of the education-health nexus in China.

To achieve the above-mentioned aims, we conducted a national survey focusing on health literacy (HL) in China. HL is a significant indicator of health status important to achieving health and well-being goals across the life-course for individuals, families and communities. HL refers to the knowledge, motivation, and the competency to access, understand, appraise, and apply information in daily life to make judgements and decisions regarding healthcare, disease prevention and health promotion [14]. Propensity score matching (PSM, introduced in detail in Section 3) was used to control the confounding factors, to decompose the net effect of HE on HL. Further, Oaxaca–Blinder decomposition techniques (OB, introduced in detail in Section 3) were conducted to explore to what extent HE, family background, and healthcare cause the urban-rural health disparities.

The rest of the paper is organized as follows. A literature review is provided in Section 2. The materials and methods used are described in Section 3. The results are presented in Section 4, and Section 5 illustrates the discussion. Finally, the conclusions will be drawn in Section 6.

2. Literature Review

We briefly review the current state of research on the education-health nexus. In the first part, we summarize the theoretical and empirical foundations of the relationship between education and health. In the second part, we critically assess the literature concerning the influence of education on health. In the third part, we propose innovative approaches to address two potential issues when exploring the education-health nexus.

Three broad theoretical perspectives have been taken by researchers about the relationship between education and health. First, the fundamental cause theory posits that social factors such as education are fundamental determinants of health and disease through material and nonmaterial resources such as higher income, safe neighborhoods, or healthier lifestyles [15]. Second, the human capital theory conceptualizes education as an investment that yields returns via raising efficiency in production. Education can develop a broad range of cognitive and non-cognitive skills, reasoning and self-efficacy, which can be utilized to improve health [16]. Third, the signaling or credentialing perspective views the attainment of credentials as a potent signal about one's skills and abilities and emphasizes the socioeconomic responses to such signals [16]. However, all the three theoretical approaches, focus on individual-level factors while leaving out the structural factors and broader social context in which the education and health processes are embedded. In sociology, education is also viewed as a 'sieve' more than a 'ladder' that reproduces inequality due to systematic differences in school resources, instructional quality, academic opportunities and other factors [17,18]. Especially HE can lead to labor market segmentation, which places individuals in different social structure positions, resulting in a differentiation of lifestyles, psychology, and social interactions, and this eventually leads to health inequality. Chinese youth have experienced increasingly unequal educational opportunities depending on their Hukou, ethnic, family background, the schools they attend, and the provinces where they live [19]. At this point, recognizing the dual nature of HE for population groups in urban and rural China with different SES is critical to developing policies and programs that decrease rather than unintentionally intensify social disparities.

Empirically, numerous studies have demonstrated a statistically significant and ongoing relationship between educational achievement and a variety of health consequences, including mortality, self-rated health status and morbidity using objective health measures such as blood pressure, BMI, hypertension, and chronic disease, and health-related behaviors such as smoking and drinking [20–22]. Some research has concluded that college graduates have better self-rated health and lower health deterioration, and can expect to live longer on average than those without a college degree [23]. HE can significantly reduce the probabilities of smoking and mortality [24] and impact health status through increasing income and improving living habits [25]. However, a considerable number of studies have failed to detect a statistically significant effect or have even found negative effects of education on health [8,26]. For example, Albouy et al. (2009) found no positive influence of education on mortality [7]. Wang et al. (2022) observed that higher-educated men are more likely to drink more, exercise less and take sedentary jobs [27]. In sum, there is no settled conclusion on the net effects of education on health. Moreover, limited research focuses on HL, which is an integral component of public health and education practice for maintaining functional health and has impacts on lifelong health.

In addition, there are two possible issues that need attention regarding the education-health nexus. One is potential selection bias. People with good health status may achieve higher educational levels. Educational attainment and several health outcomes share certain genetic factors since they are heritable phenotypes [28]. In this case, the omission of elements that jointly affect education and health, for example, family resources, birth condition, children's health and nutrition status, intellect and personality may lead to possible selection bias [29,30].

On the one hand, family socioeconomic position and family structure can have a large impact on an individual's educational attainment and health status [19]. Children born in advantaged families tend to have more years of schooling, and these families can provide sufficient nutrition for children, which will improve both children's cognitive development and their health status in later life [31]. In contrast, children born in disadvantaged families receive substantially less investment in human capital and may experience worse health in their early years. Additionally, for multi-child families, the 'sibling competition effect' in educational investment may constrain access to HE [32,33]. On the other hand, individual characteristics are critical factors in determining access to HE. Two types of personality, conscientiousness and openness, are correlated with HE attainment. Conscientiousness means being dependable, hardworking, and persistent, which consistently and favorably predicts high academic achievement [34]. Openness implies intellectualism, and imagination, which is positively correlated with grades [35]. In addition, self-efficacy, defined as an individual's belief in their capacity to organize and implement courses of action required to achieve desired performances, is a powerful indicator of educational performance [36].

Potential heterogeneous effects are another important influence on education and health. Individuals have different levels of health status and health behaviors, and can show remarkable heterogeneity in their benefits from HE. Two types of heterogeneous effects: positive heterogeneous treatment effect and negative heterogeneous treatment effect, have been supported according to two competing theories about which particular population subgroups can leverage greater health-related benefits from education. The positive heterogeneous treatment effect is supported by the theory referred to as 'resource multiplication', which draws on a perspective of cumulative advantage [37,38], and assumes that there are greater health benefits from education for the advantaged subpopulation with more access to a college degree as these individuals typically possess more endowments and social resources and have a preference for healthy lifestyles, which can become solidified and reinforced through the process of education. The negative heterogeneous treatment effect is supported by another theory referred to as 'resource substitution' [39,40], which posits that the improved sense of self-control, and economic and employment prospects through the process of education can bring more health benefits for those who encounter certain difficulties to enter college because they have more room for improvement and can use the inputs in the health production to function more properly [41].

To address the endogeneity issue, many studies have exploited compulsory schooling laws as an instrumental variable of education to investigate the effect of education on health. However, these effects only generalize to the subset of participants whose explained variable is affected by the instrument. Moreover, the health returns to HE cannot be estimated. In our study, within propensity score strata, covariates in the higher education group and the pre-higher education group are similarly distributed, so that stratifying on propensity score strata removes most of the bias due to the covariates [42]. In terms of potential heterogeneous effects, PSM based on diverse and representative samples that facilitates assessment of heterogeneity between the two groups across and within populations leverages explanatory variables in the entire populations and improves statistical power relative to instrument-based approaches with the same data. It is remarkable that choosing a method requires tradeoffs between statistical power, internal validity, measurement quality, and generalizability, both for propensity score matching and instrumental variables [43].

3. Materials and Methods

3.1. Setting, Sample, and Data Collection

From July to September 2021, we conducted a national survey to assess trends in the well-being of individuals, families, communities, and cities in China. Multistage cluster sampling was applied, and 120 cities were randomly selected from 23 provinces, as well as capitals of 5 autonomous regions, and 4 province-level municipalities. Quota sampling was carried out according to gender, age, and distribution of urban and rural areas. 9964 samples were obtained after excluding respondents under the age of 18, including 5796 urban residents and 4168 rural residents.

3.2. Measurement of Key Variables

3.2.1. Dependent Variable

The short-form health literacy questionnaire (HLS-SF12), which has been validated in six Asian countries with their general population [44], was used to measure HL. It exhibits excellent reliability and validity with a Cronbach's alpha of 0.94 in this study (Table A1 in Appendix A). Respondents rated each item on 4-point Likert scales (1 = very difficult, 4 = very easy). Using the formula: $Index = (mean - 1) \times \left(\frac{50}{3}\right)$, the indices for HL were standardized to unified metrics from 0 to 50.

3.2.2. Independent Variables

The main explanatory variable education was measured by the highest attainment of education. Which was translated into years of schooling as a continuous variable, with 0 as illiteracy, 6 as primary school, 9 as junior school, 12 as high school, 15 as an associate degree, 16 as a bachelor's degree, 19 as a master's degree, and 22 as a doctoral degree. Meanwhile, the educational attainment was coded as a binary variable, with '1' as an associate degree or above (higher education) and '0' as less than the associate degree (pre-higher education).

3.2.3. Control Variables

The propensity score values should be predicted conditionally on a series of covariates which may have significant impacts on education and health. In this study, such covariates include gender, ethnicity, the number of siblings, household income, BMI, personality (Conscientiousness and Openness), and self-efficacy.

Personality was measured by the Big Five Inventory Scale [45] on a 5-Likert scale (1 = strongly disagree, 5 = strongly agree). Conscientiousness was measured by two items: 'I see myself as someone who tends to be lazy (reversed)' and 'I see myself doing a thorough job'. Openness was measured by two items: 'I see myself having few artistic interests (reversed)' and 'I see myself as an active imagination'. The average score of the corresponding items was obtained for the two personality traits, respectively.

Self-efficacy was measured by the New General Self-Efficacy Scale [46]. Which comprises eight items that require respondents to rate the extent to which they agree with statements on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). An example item from this scale is, 'I can solve most problems if I invest the necessary effort'. The average score of the eight items was calculated to represent the level of self-efficacy.

3.3. Data Processing and Statistical Analysis

All data analysis was performed using R 4.1.2 (open-source free software under the GNU General Public License), including descriptive statistics, univariate analysis, Propensity score matching (PSM), Ordinary least squares (OLS), and Oaxaca-Blinder decomposition (OB).

Stage 1. Descriptive statistics and univariate analysis were conducted. *P*-values were calculated to examine whether there was a statistically significant difference in variables between urban and rural areas of China.

Stage 2. PSM was used under the counterfactual framework to match treated and control individuals on the probability of receiving the treatment [47] (Rosenbaum & Rubin 1983). A wide range of variables mentioned above were used to construct the propensity to receive HE. Then we matched treated and control individuals based on their propensity using the nearest neighbor matching algorithm (ratio = 1, caliper size = 0.05). A valid inference from PSM relies on a well-balanced distribution of each covariate between treated and control groups after matching. Therefore, the difference in HL can be attributed to whether receiving HE or not, instead of potentially confounding covariates.

Let

$HL_i(1)$ = Outcome of the *i*th resident receiving higher education

$HL_i(0)$ = Resident's outcome if they do not receive higher education

The impact of higher education is calculated by:

$$\Delta HL_i = HL_i(1) - HL_i(0)$$

However, either $HL_i(1)$ or $HL_i(0)$ is observable for each case.

Let 'HE' indicate higher education,

HE = 1 if resident has received higher education.

HE = 0 if otherwise.

The average treatment effect of higher education is calculated as:

$$\begin{aligned} ATT = E\{HL_i(1) - HL_i(0)|X, HE = 1\} = E\{HL_i(1)|X, HE = 1\} - E\{HL_i(0)|X, HE = 1\} \\ = E\{HL_i(1)|X, HE = 1\} - E\{HL_i(0)|X, HE = 0\} - E\{HL_i(0)|X, HE = 1\} - E\{HL_i(0)|X, HE = 0\} \end{aligned} \quad (1)$$

where X is the vector of the control variables.

This measure of impact is referred to as the 'average impact of the treatment on treated'.

In the above expression, $E\{HL_i(0)|X, edu = 1\}$ is not observed.

Then, let P(X) = P(D = 1 | X) be the probability of higher education residents.

PSM constructs comparison groups by matching observations with similar values of P(X) of whether to accept higher education, with two assumptions.

$$E\{HL_i(0)|X, HE = 1\} - E\{HL_i(0)|X, HE = 0\} = 0 \tag{2}$$

$$0 < P(X) < 1 \tag{3}$$

Equation (2) is known as the 'Conditional Mean Independence' which indicates that after controlling X, the average outcomes of those without higher education are identical to those receiving higher education in a counterfactual situation that they would have not received higher education, and Equation (3) ensures valid matches by assuming that P(X) is well-defined for all values of X.

Stage 3. The selection bias was examined by comparing the OLS regression results based on the matched sample with the original sample. If the effect of HE on HL shows marked variation between these two types of samples, we would treat it as evidence of selection bias.

Stage 4. As to the investigation of the heterogeneous treatment effect, Brand and Xie (2010) have proposed a hierarchical linear model [48]. In accordance with their methodology, people from the original sample were grouped into different blocks. These blocks were ordered based on their values of propensity scores, from the smallest to the largest. Then, the health benefit from HE was examined within each block. The pattern of these treatment effects across blocks was used to illustrate the type of heterogeneous treatment effect.

Stage 5. Introduced initially by Oaxaca and Binder (1973) to investigate gender wage inequalities in the labor market, OB is used to explain how much of the difference in mean outcomes across two groups is due to group differences in the levels of explanatory variables, and how much is due to differences in the magnitude of regression coefficients. The OB model is a counterfactual method with an assumption that 'rural residents had the same characteristics as their urban counterparts', and the urban-rural HL gap can be divided into two primary components:

$$\overline{H}_u - \overline{H}_r = \left(\overline{X}'_u - \overline{X}'_r\right)\hat{\beta}_u + \overline{X}'_u(\hat{\beta}_u - \hat{\beta}_r\Big) \tag{4}$$

where $\overline{H}_u$ and $\overline{H}_r$ are the HL status for urban and rural populations, X are the explanatory variables, and $\hat{\beta}_u$ and $\hat{\beta}_r$ indicate the coefficients of explanatory variables for the urban and rural populations, respectively. As a result, the urban-rural HL gap can be attributed to two parts: the endowment effect and the coefficient effect. The former represents the percentage attributable to different levels of the explanatory factors between urban and rural areas. The latter means the percentage attributable to explanatory factors having differential effects on HL between urban and rural areas.

4. Results

4.1. Descriptive Results

Table 1 shows the descriptive results for the entire sample as well as the rural and urban subsamples. Urban and rural respondents account for 58.2% and 41.8%, respectively, of the entire sample. There is a statistically significant difference in HL, educational attainment, household income, and healthcare between urban and rural subsamples at a 1% level. The mean score of HL in the urban subsample is 35.19, higher than the score of 32.89 in the rural subsample. The mean years of schooling in the urban subsample is 14.56, nearly 3 years more than the 11.76 years in the rural subsample. There is a noticeable discrepancy (72.7% vs. 45.9%) in the acquisition of HE between urban and rural subsamples. The inequality of household income is also noteworthy. In the urban subsample, middle- and high-income families make up 61.7% and 20.40%, respectively, both larger than the 47.7% and 8.40% in the rural subsample. As for healthcare, the percentage of employee healthcare is 41.6% in the urban subsample, far above the 12.6% in the rural subsample. However, the proportion of self-paid healthcare in the rural subsample is 25.5%, higher than the 15.0% in the urban subsample.

Table 1. Descriptive statistics and univariate analysis.

Variables	All	Urban	Rural	*p*
Total	9964	5796 (58.2)	4168 (41.8)	
HL score				0.000
Mean (SD)	34.23 (8.38)	35.19 (8.17)	32.89 (8.50)	
Years of schooling				0.000
Mean (SD)	13.39 (4.35)	14.56 (3.50)	11.76 (4.86)	
Educational attainment *n* (%)				0.000
Pre-higher education				
Illiteracy	365 (3.7)	93 (1.6)	272 (6.5)	
Primary school	650 (6.5)	147 (2.5)	503 (12.1)	
Junior school	1224 (12.3)	405 (7.0)	819 (19.6)	
High school	1596 (16.0)	936 (16.1)	660 (15.8)	
Higher education				
Associate degree	1413 (14.2)	975 (16.8)	438 (10.5)	
Bachelor's degree	3988 (40.0)	2654 (45.8)	1334 (32.0)	
Master's degree	563 (5.7)	452 (7.8)	111 (2.7)	
Doctoral degree	165 (1.7)	134 (2.3)	31 (0.7)	
Gender *n* (%)				0.161
Male	4591 (46.1)	2705 (46.7)	1886 (45.2)	
Female	5373 (53.9)	3091 (53.3)	2282 (54.8)	
Ethnicity				0.000
Han	9400 (94.3)	5515 (95.2)	3885 (93.2)	
Minority	564 (5.7)	281 (4.8)	1911 (6.8)	
Age *n* (%)				0.000
19–40	5332 (53.5)	3029 (52.3)	2303 (55.3)	
41–59	3486 (35.0)	2239 (38.6)	1247 (29.9)	
≥60	1146 (11.5)	528 (9.1)	618 (14.8)	
Marital status *n* (%)				0.000
Single/divorced/widowed	3740 (37.5)	1982 (34.2)	1758 (42.2)	
Married	6224 (62.5)	3814 (65.8)	2410 (57.8)	
Household income per capita (RMB) *n* (%)				0.000
Low				
≤1500	936 (9.4)	237 (4.1)	699 (16.8)	
1501–3000	1929 (19.4)	800 (13.8)	1129 (27.1)	
Middle				
3001–4500	2144 (21.5)	1225 (21.1)	919 (22.0)	
4501–6000	1740 (17.5)	1144 (19.7)	596 (14.3)	

Table 1. *Cont.*

Variables	All	Urban	Rural	*p*
6001–7500	962 (9.7)	673 (11.6)	289 (6.9)	
7501–9000	718 (7.2)	535 (9.2)	183 (4.4)	
High				
9001–10,500	527 (5.3)	397 (6.8)	130 (3.1)	
10,501–12,000	305 (3.1)	228 (3.9)	77 (1.8)	
12,001–13,500	123 (1.2)	96 (1.7)	27 (0.6)	
13,501–15,000	128 (1.3)	101 (1.7)	27 (0.6)	
≥15,001	452 (4.5)	360 (6.2)	92 (2.2)	
Healthcare *n* (%)				0.000
Self-paid	1930 (19.4)	868 (15.0)	1062 (25.5)	
Resident's	4688 (47.0)	2239 (38.6)	2449 (58.8)	
Employee's	2933 (29.4)	2409 (41.6)	524 (12.6)	
Public/Commercial	413 (4.2)	280 (4.9)	133 (3.2)	
Number of children *n* (%)				0.000
0	4002 (40.2)	2247 (38.8)	1755 (42.1)	
1	3058 (30.7)	2266 (39.1)	792 (19.0)	
2	2229 (22.4)	1074 (18.5)	1155 (27.7)	
≥3	675 (6.8)	209 (3.6)	466 (11.2)	

Note: χ^2 Tests for categorical variables and analysis of variance for continuous variables. The data is sourced from surveys conducted in 2021.

4.2. The Average HL Benefits from HE

The propensity scores were estimated by a logit model using both determinants of HE and factors that affect HL (Table A2 in Appendix A). Before PSM, significant differences were found in all the covariates except for ethnicity between two groups ($p < 0.05$). After PSM, no statistical differences were found in any of the covariates ($p > 0.05$). Standardized mean difference (SMD) is the most commonly used statistic to examine the balance of covariate distribution between treated and control groups. In this study, SMD is reported as less than 0.1 (Table A3 in Appendix A), which indicates the covariates predicting propensity scores are balanced [49]. It can also be confirmed in the distribution of K-density between the higher education and the pre-higher education group before and after matching (Figure 1).

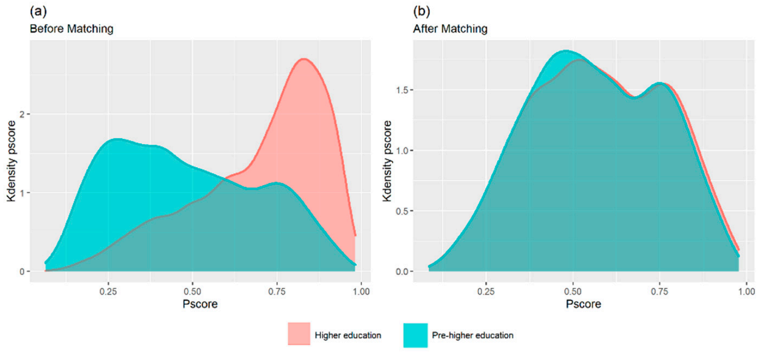

Figure 1. K-density distribution of propensity scores (**a**) before PSM; and (**b**) after PSM. Note: Graphics created by ggplot2 in R. https://cran.r-project.org/web/packages/ggplot2/index.html (accessed on 20 May 2022).

Furthermore, the difference in HL benefits from HE between urban and rural subsamples is compared. Table 2 presents the results of OLS. In general, HE is associated with a 0.76 unit increase in HL at a 1% level. The HL benefit from HE is more significant in the rural subsample ($\beta = 1.3,\ p < 0.01$) than that in the urban subsample ($\beta = 0.53,\ p < 0.1$). Concerning other demographic factors, urban *Hukou* is positively related to HL ($\beta = 0.67,\ p < 0.01$). The HL is lower in the old than in the young ($\beta = -3.58,\ p < 0.001$). In terms of socioeconomic status, a higher level of household income means higher HL in the urban subsample, whereas in the rural subsample, the middle level of household income ($\beta = 1.17,\ p < 0.01$) brings larger and more substantial HL benefits. Compared with self-paid, individuals with resident healthcare ($\beta = 0.85,\ p < 0.01$) and employee healthcare ($\beta = 1.63,\ p < 0.001$) have higher HL.

Table 2. Effects of HE on HL in matched and unmatched samples.

	Matched			Unmatched		
	All	**Urban**	**Rural**	**All**	**Urban**	**Rural**
Higher education (ref: Pre-higher education)	0.76 ** (0.26)	0.53 # (0.32)	1.3 ** (0.44)	1.21 *** (0.22)	1.01 *** (0.28)	1.76 *** (0.36)
Urban (ref: Rural)	0.67 ** (0.25)			0.94 *** (0.18)		
Female (ref: Male)	0.32 # (0.22)	0.32 # (0.29)	0.26 # (0.33)	0.27 # (0.16)	0.37 # (0.21)	0.11 # (0.25)
Ethnicity (ref: Minority)	1.06 * (0.47)	0.92 # (0.67)	1.08 # (0.66)	1.26 *** (0.35)	1.12 * (0.49)	1.33 ** (0.5)
Age (ref: 19–40)						
41–59	−0.87 ** (0.3)	−0.95 * (0.39)	−0.46 # (0.47)	−0.81 *** (0.23)	−0.6 * (0.29)	−0.86 * (0.38)
≥60	−3.58 *** (0.41)	−2.81 *** (0.56)	−4.28 *** (0.6)	−3.48 *** (0.33)	−2.45 *** (0.46)	−4.28 *** (0.48)
Marital status (ref: Single/divorced/widowed)	0.6 # (0.36)	0.1 # (0.48)	1.38 * (0.56)	0.53 * (0.26)	−0.11 # (0.33)	1.65 *** (0.42)
Household income per capita (CNY) n (%)						
Middle	1.14 *** (0.26)	1.12 ** (0.37)	1.17 ** (0.36)	1.44 *** (0.2)	1.19 *** (0.29)	1.56 *** (0.27)
High	2.25 *** (0.4)	2.95 *** (0.51)	0.72 # (0.68)	2.33 *** (0.27)	2.42 *** (0.35)	1.65 *** (0.48)
Healthcare (ref: Self-paid)						
Resident's	0.85 ** (0.3)	0.19 # (0.47)	1.39 *** (0.4)	0.97 *** (0.22)	0.69 * (0.33)	1.25 *** (0.3)
Employee's	1.63 *** (0.36)	1.02 * (0.49)	2.45 *** (0.6)	1.54 *** (0.26)	1.15 *** (0.35)	2.32 *** (0.45)
Public/Commercial	0.6 # (0.61)	0 # (0.79)	1.03 # (0.98)	0.53 # (0.44)	0.56 # (0.56)	0.15 # (0.74)
Number of children (ref: 0)						
1	−0.49 # (0.42)	0.07 # (0.55)	−0.94 # (0.67)	−0.77 * (0.3)	−0.43 # (0.38)	−1.15 * (0.52)
2	−0.32 # (0.44)	0.41 # (0.58)	−1.18 # (0.7)	−0.97 ** (0.33)	−0.39 # (0.42)	−1.78 ** (0.54)
≥3	−1.44 * (0.59)	−0.39 # (0.87)	−2.19 ** (0.84)	−2.33 *** (0.44)	−1.42 * (0.68)	−2.89 *** (0.64)
Observations	5560	2780	2780	9964	5796	4168

Note: Standardized regression coefficient, with standard errors in parentheses; # $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. The data is sourced from surveys conducted in 2021.

4.3. Potential Selection Bias

Table 2 presents the effect of HE on HL before and after PSM. It is evident that both the coefficients and their significance have declined. In other words, after taking into account the selection bias, the health-promotion function of HE is weaker. Additionally, the downward trend is more pronounced in the urban subsample.

4.4. The Heterogeneous HL Benefits from HE

In the subfigures of Figure 2, the x-axis represents the ID of propensity score blocks. The likelihood of HE attainment increases from block 1 to block 8. The y-axis represents the treatment effects, that is, the HL returns from HE for each block. Figure 2a depicts the general pattern of heterogeneous treatment effects for the entire sample. A downtrend line is revealed from block 1 to block 8, suggesting that the HL benefits from HE decrease as individuals' odds of attending college increase. This finding lends support to a negative heterogeneous treatment effect pattern. We then further explored the potential urban-rural difference in the extent of the heterogeneity in the HL benefits from HE. The heterogeneous treatment effects in the urban and rural subsamples are shown in Figure 2b, indicating that *Hukou* status may be attributed to the negative heterogeneous treatment effect pattern. Rural residents have fewer odds of obtaining HE but higher HL returns compared with their urban counterparts.

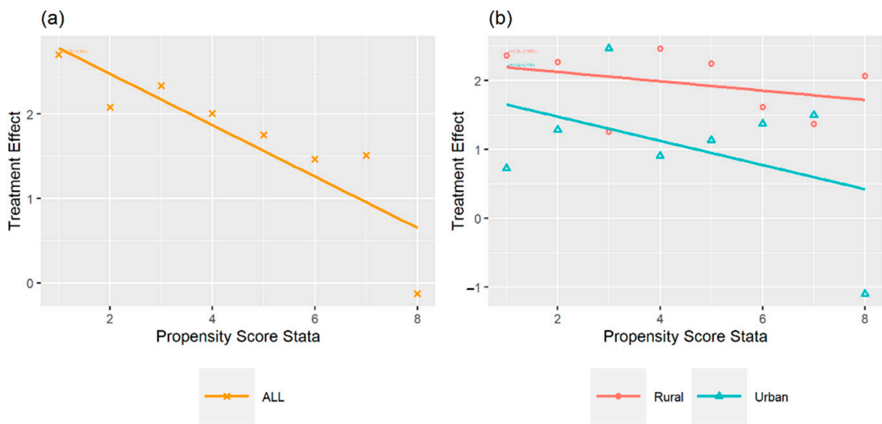

Figure 2. Heterogeneous treatment effects: (**a**) total sample; (**b**) urban and rural subsamples. Note: Graphics created by ggplot2 in R. https://cran.r-project.org/web/packages/ggplot2/index.html (accessed on 20 June 2022).

4.5. Oaxaca-Blinder Decomposition Analysis

The results of OB are presented in Table 3. The total gap in HL between the urban and rural residents is 2.305 ($p < 0.001$). Both the endowments effect ($Coef = 1.558$, $p < 0.001$) and the coefficients effect ($Coef = 0.747$, $p < 0.001$) are significant. A total of 67.59% of the HL gap can be explained by the endowment effect. To be specific, household income, HE attainment, and healthcare account for 19.78%, 16.66%, and 13.93% of the total HL gap, respectively. In other words, if the rural subsample were similar to the urban subsample in these three factors, the HL gap would narrow by 1.16. Meanwhile, the coefficient effect accounts for 32.41% of the total HL gap.

Table 3. Oaxaca–Blinder decomposition between urban and rural subsamples.

	Coef.	SE	Contrib. (%)
HL Score			
Urban	35.19 ***	0.107	-
Rural	32.89 ***	0.132	-
Difference (Urban–Rural)	2.305 ***	0.170	100
Explained part			
Higher education	0.384 ***	0.096	16.66
Gender	−0.002	0.004	−0.08
Ethnicity	0.027 **	0.012	1.19
Age	0.009	0.033	0.37
Marital status	0.191 ***	0.036	8.29
Household income	0.456 ***	0.079	19.78
Healthcare	0.321 ***	0.078	13.93
Number of children	0.172 ***	0.045	7.46
Total	1.558 ***	0.140	67.59
Unexplained part			
Total	0.747 ***	0.209	32.41

Note: ** $p < 0.01$; *** $p < 0.001$. The data is sourced from surveys conducted in 2021.

5. Discussion

Compared with previous studies conducted in several provinces or regions of China focusing on specific populations such as migrant workers, the elderly and other groups [50,51], this study makes contributions to understanding the HE-HL nexus for the entire adult group through a national representative survey. First, there are disparities in HL, HE attainment, household income, and healthcare coverage between urban and rural areas of China, which reveals the facts of social inequalities and uneven distribution of public resources. Consistent with previous studies, the HL of urban residents is significantly higher than that of ruralresidents because of their more effective and flexible access to higher-quality health medical resources and healthcare services [52]. Constricted by the lower economic development levels and education quality in rural areas of China, residents' awareness of investing in health and insurance is generally weaker. In addition, it is difficult for some rural residents to communicate with doctors for scientific disease control. Even worse, feudal thoughts and superstitions can lead rural residents to distrust doctors and refuse to go to the hospital or take medicine. Second, HE has a net significantly positive impact on HL for both urban and rural subsamples, after controlling for a series of demographic, socio-economic, and individual confounding factors. Since the conclusion is drawn based on a matched sample, it is robust to potential selection bias. Previous studies have drawn similar conclusions that education is independently associated with better health [53,54], and residents' ability to comprehend and interpret health information increases with educational level [55]. Moreover, many disease-preventive habits and attitudes can be cultivated in the course of education, whereas residents with lower educational attainment may have less access to economic resources and health-related information, and lack experience in consulting health professionals [56,57]. However, a recent study using the 1977 Resuming College Entrance Exam Policy in China as an instrument suggests education has no impact on healthy behaviors and cognitive abilities [27]. Further examination suggests that a straightforward analysis of the original sample without dealing with selection bias would overestimate the health benefits of HE. This is probably because HE institutions tend to choose candidates with better genetic, family, and social endowments, better health and health behaviors, and higher cognitive and non-cognitive skills rather than their inferior counterparts. In contrast, some studies have found the education-health effects could be underestimated by taking the kink effect and a wide range of mental health outcomes into consideration [58,59]. Besides the average health benefits, this research also highlights the negative heterogenous treatment effects. Compared with those who are less likely to obtain a college degree, individuals with higher odds of attending college have fewer health benefits from HE. A credible explanation may be that the high school graduates with more chances of attending college may have already acquired some pro-health attributes such as a healthy lifestyle, a higher sense of self-control, and better cognitive skills. As for those who are less likely to obtain a college degree, however, their health knowledge and skills might be learned primarily via college campus life. These results are in line with existing research, which illustrates that education provides greater health benefits for the disadvantaged population [60] and formal schooling can suppress preventable deaths among the vulnerable population by improving their health knowledge and skills [61]. For example, the research shows that women reap more mental and physical health benefits from HE than men [62]. In particular, the health of the rural residents and elderly women is more sensitive to education [63,64], and HE reduces depression symptoms more for individuals from poor families than those from better-off families [65]. Consistent with the 'resource substitution' theory, the conclusion suggests that education can function as an equalizing factor to break the cycle of socioeconomic inequality and narrow health disparity caused by social origins [66,67]. Finally, the inequalities in household income, HE attainment, and healthcare can explain nearly half of the urban-rural HL gap, which indicates that the socioeconomic inequalities can translate into health disparities.

The facts of urban-rural disparities presented in this study call for more attention to perfecting the mechanisms of education and healthcare provision, and addressing the systemic vulnerabilities to ensure more equitable education and health outcomes, which is a matter of fairness and social justice [68]. We make the following recommendations: (1) Educational attainment and increased literacy play fundamental roles in healthcare, disease prevention and health promotion, which can promote the overall health of human capital, generate health externalities for the individuals and their families, and cost less compared with the potential medical expenditures [69]. Therefore, traditional academic subjects need to be expanded to encompass training in health knowledge and skills. (2) Future health education and health promotion activities should be reinforced to cultivate health cognition, behavior, and habits, especially in rural areas of China. More health communication materials targeting a general audience should be developed to disseminate health knowledge and skills under health initiatives so that residents can become aware of and implement healthy lifestyles, ultimately forming healthy values. (3) The integrated development and the equitable allocation of social welfare resources should be promoted between urban and rural areas of China. Sufficient HE opportunities should be provided in underdeveloped areas to accelerate social mobility. As a result, vulnerable individuals could be encouraged and supported to pursue stable occupations, economic independence and happiness through the ladder of education. In addition, a more accessible and inclusive medical service system should be constructed and optimized both in urban and rural areas of China.

6. Conclusions

From a theoretical perspective, our study advances the understanding of the education-health nexus. The dual role of education has been recognized, both as a reproducer of inequality and a driver of opportunity. In China, although there exists health inequity caused by the uneven distribution of urban and rural education resources, consistent with the theory of 'resource substitution', HE is still the key channel to improve the HL of vulnerable groups and promote health equity. In practice, we have collected high-quality data at the national level, enabling a comprehensive overview of HL in urban and rural populations in China. In addition, by including individual endowment, family background and social structure factors as covariates, the education-health nexus has been embedded in the broader context of discussions about heterogeneity, which can support evidence-based policies and projects.

Several limitations are recognized in this study. The cross-sectional design makes it impossible to conclude the diachronic relationship between HE and HL. More longitudinal cohort studies are needed in the future. In addition, the spillover or intergenerational effects of education cannot be investigated based on our dataset. Moreover, it is still possible that certain influential covariates which confound the relationship between HE and HL are not considered in this paper. First, there are significant differences in HE admission rates among different provinces in China. Second, the quality of HE varies according to the levels and types of the HE institutions. Third, family cultural capital, such as parents' education level, may affect individuals' HL. In addition, the respondents' *Hukou* status before entering HE is not obtained, while some people will change from a rural to urban *Hukou* when they go to college and work in China. In conclusion, further research should be conducted to better understand the causal relationships and the intermediary mechanisms between education and health, and to support evidence-based public policies which have great potential to promote social equity.

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Data Availability Statement: Our data is not publicly available. If interested, please contact corresponding authors.

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Appendix A

Table A1. The short-form health literacy questionnaire and Cronbach α.

Items
Health Care
How do you find information on treatments of illnesses that concern you?
Do you understand the leaflets that come with your medicine?
How do you judge the advantages and disadvantages of different treatment options?
Do you call an ambulance in an emergency?
Disease Prevention
How do you find information on how to manage mental health problems like stress or depression?
Do you understand why you need health screenings (such as breast exam, blood sugar test, blood pressure)?
How do you judge which vaccinations you may need?
Do you decide how you can protect yourself from illness based on advice from family and friends?
Health Promotion
How do you find out about activities (such as meditation, exercise, walking, Pilates, etc.) that are good for your mental well-being?
Do you understand information in the media (such as Internet, newspaper, magazines) on how to get healthier?
How do you judge which everyday behavior (such as drinking and eating habits, exercise, etc.) is related to your health?
Can you join a sports club or exercise class if you want to?
Cronbach's α = 0.94

Table A2. The results of the logit probability model predicting propensity scores and p values.

Variables.	**Unmatched**		**Matched**	
	Coef. (SE)	***p***	**Coef. (SE)**	***p***
Gender	0.033 (0.009)	0.000	−0.007 (0.014)	0.616
Ethnicity	0.02 (0.019)	0.281	−0.022 (0.029)	0.459
Number of siblings	−0.132 (0.004)	0.000	−0.01 (0.006)	0.114
Household income	0.141 (0.007)	0.000	0.01 (0.011)	0.361
BMI	−0.011 (0.001)	0.000	0 (0.002)	0.858
Conscientiousness	−0.038 (0.006)	0.000	0.001 (0.009)	0.907
Openness	0.085 (0.006)	0.000	0.004 (0.009)	0.686
Self-efficacy	0.04 (0.007)	0.000	0.005 (0.011)	0.617

Note: The data is sourced from surveys conducted in 2021.

Table A3. Standardized mean difference of all the covariates before and after PSM.

Variables	Unmatched			Matched		
	Means Treated	Means Control	SMD	Means Treated	Means Control	SMD
Gender						
Male	0.449	0.479	−0.061	0.482	0.473	0.018
Female	0.551	0.521	0.061	0.518	0.527	−0.018
Ethnicity						
Han	0.050	0.068	−0.082	0.059	0.055	0.018
Minority	0.950	0.932	0.082	0.941	0.945	−0.018
Number of siblings						
0	0.301	0.101	0.436	0.154	0.139	0.032
1	0.364	0.191	0.359	0.265	0.261	0.009
2	0.166	0.239	−0.197	0.255	0.265	−0.027
≥3	0.169	0.469	−0.799	0.326	0.335	−0.024
Household income						
Low	0.210	0.412	−0.497	0.297	0.300	−0.005
Middle	0.588	0.512	0.154	0.586	0.596	−0.019
High	0.203	0.076	0.315	0.116	0.105	0.029
BMI	21.727	22.596	−0.281	22.292	22.300	−0.003
Conscientiousness	3.393	3.555	−0.204	3.496	3.494	0.003
Openness	3.330	3.005	0.428	3.138	3.128	0.013
Self-efficacy	3.625	3.524	0.150	3.571	3.561	0.014

Note: Source: The data is sourced from surveys conducted in 2021.

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