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RESEARCH ARTICLE

Does an upward intergenerational educational spillover effect exist? The effect of children's education on Chinese parents' health

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Abstract

Background Research on the presence of an upward spillover effect of children's education on parental health is rapidly developing. However, there are certain differences in the conclusions of relevant studies, and no consistent viewpoint has been reached.

Methods Using the exogenous differences in education generated by the expansion of higher education enrollment that China implemented as a reform in 1999, we analyze this issue by studying the effect of children's higher education on their parents' health.

Results The instrumental variable (IV) estimation results show that children who received higher education have a significant and positive effect on the physical health of their parents. Compared with the ordinary least squares (OLS) estimation results, the coefficient of the effect of children receiving higher education is larger in the IV estimation.

Conclusions Children's education can generate a significant active effect on parental health, affecting parental physical health via its effect on parental health cognition and health behaviors. Based on heterogeneity analyses, the effect of a son's education on parental health is more significant than the effect of a daughter's education, and among rural children, higher education has a more significant effect on parental health.

Keywords Intergenerational · Education · Health · Upward spillover · China

Introduction

Education and health are two components of human capital (Mushkin, 1962), and a complex relationship exists between the two. Education is an important factor that affects health, and education has been proven to be able to improve health (Baker et al., 2011;

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Lochner, 2011). Moreover, this kind of utility can be intergenerationally transferred. In analyzing the return on education, the existence of an intergenerational spillover effect should be fully considered (Bjrklund & Salvanes, 2010). Although the intergenerational spillover effect has gained universal attention, previous studies have all been based on the assumption that the effect is transmitted in only one direction, namely, from parents to children. Many empirical studies have analyzed the effect of parents' educational level on their children's health (Apouey & Geoffard, 2016; Schady, 2011) and mortality (Gage et al., 2013; Gakidou et al., 2010). However, this kind of effect is transmitted not only downward but also upward. We have reason to believe that well-educated children may have more resources to invest in the health of their elderly parents. If the children are living better lives because they have had more education, then parental morale may also be increased (Lundborg, 2018). Recent studies have also analyzed this effect, with all of them finding that children's education has an active effect on parental health (Sabater & Graham, 2016a; Yahirun et al., 2016; Zimmer et al., 2002) and mortality (Friedman & Mare, 2014; Sabater & Graham, 2016b; Torssander, 2013, 2014; Yang et al., 2016; Zimmer et al., 2007).

Although research on this kind of upward intergenerational spillover effect is rapidly developing, the relevant research results are still limited. There are also certain differences in the research conclusions. Some conclusions support the viewpoint that when children receive higher education, it can increase their parents' lifespan (De Neve & Fink, 2018; Ma, 2019), but other conclusions do not support this viewpoint (Lundborg & Majlesi, 2018). To a certain extent, the existence of this difference is due to the different situations in the countries under investigation in these studies. For example, in developed countries with comprehensive welfare systems that provide for vulnerable groups and elderly individuals, the upward spillover effect of children's education on their parents may not be very obvious (Fritzell & Lennartsson, 2005; Lennartsson et al., 2009; Torssander, 2013). However, in situations with lower resources, the marginal effect of this kind of additional support may be higher, and the resulting social support mechanisms may be more prominent (Cox & Jimenez, 1992; Frankenberg et al., 2002). In light of the varied results of causal research, the question of the upward spillover effect of children's education on their parents' health in different contexts has yet to receive a definitive answer.

In this paper, the effect of children's education on parental health is empirically analyzed in the context of China, a developing country. Although China has established a social security system with national coverage, the overall level of security is still relatively low. In addition to the formal social security support system, informal support based on the filial piety of the family plays an important role (Du, 2013; LaFave, 2017). In China, elderly adults strongly depend on the economic support of adult children (Cai et al., 2012). At the same time, China is undergoing rapid population aging, and elderly people in China have been traditionally more reliant on their families to provide for them. Unlike high-income countries, where the net financial transfer of family resources is from elderly individuals to young children, China's situation is precisely the opposite. For this reason, family discussions of economic and caretaking needs become tenser each passing day (Zhao, 2014). The socioeconomic status of children may play an increasingly important role in the lives of Chinese parents (Ma, 2019). Therefore, in an underdeveloped context such as the Chinese context, better-educated children can impart basic health knowledge and provide necessary help to their parents.

Since school education is an endogenous variable, we use data from the China Health and Nutrition Survey (CHNS) and adopt the instrumental variable/two-stage least squares (IV/2SLS) method to analyze the upward spillover effect of children's education on parental health. When Lundborg and Majlesi (2018), De Neve and Fink (2018), and Ma (2019)

analyzed the effect of children's education on parental health, they used basic education reform as an IV for children's education. In this paper, the National College Entrance Examination (NEMT) expansion that started in China in 1999 are used as the IV because well-educated children can better understand health knowledge and technology and share them with their parents, provide informal care for their parents, supervise their parents' medication use and urge their parents to take medications consistently, and be their parents' agents in dealings with the health and long-term care systems (Friedman & Mare, 2014). Although the NEMT expansion policy in China were uniformly implemented nationwide in 1999, due to the great differences in the scale of enrollment expansion in subsequent years among the various provinces of China, the magnitude of the opportunity to engage in higher education is affected by an individual's year of high school graduation and participation in NEMT and by the province of household registration at the time of high school graduation. In cases in which other factors are completely the same, exogenous differences in the opportunity to receive higher education are present for high school graduates whose household registrations are located in provinces with larger-scale enrollment expansion.

In this paper, we first replicate the existing findings indicating that when children receive higher education, it has an active and significant effect on their parents' physical health. Our ordinary least squares (OLS) estimation shows a significantly positive correlation between children receiving higher education and parental health. To address the problem of endogeneity, we use an IV estimation, and the IV estimation results also show that children's receipt of higher education has a significantly positive effect on parental physical health. Compared with the OLS estimation results, the correlation coefficient for children receiving higher education is larger in the IV estimation.

To expand the existing related research, analyses of the pathways by which children's education affects parental health are also conducted. Health knowledge may be an important mechanism because many behaviors that harm health may be changed by acquiring more and better health knowledge (Lundborg & Majlesi, 2018). The pathways by which children's education affects parental health are described in our study in terms of two aspects. The first is the effect of children receiving higher education on parental health cognition; the second is its effect on parental health behaviors. We find that children's higher education significantly affects their parents' degree of concern regarding physical exercise and healthy eating, and it also affects their parents' mastery of dietary knowledge. In terms of health behaviors, children's higher education generates a positive and active effect on parental participation in walking, tai chi, sports, fitness, and other activities that are beneficial to physical health; furthermore, it encourages parents to take more initiative to acquire dietary knowledge. Although there is no significant reduction in the frequency of parental alcohol consumption, the likelihood of smoking cigarettes is significantly reduced.

The rest of this paper is organized as follows. The second section discusses the potential pathways by which children's education may affect parental health. The third section provides information on the higher education enrollment expansion that was implemented as a reform in China. The fourth section describes the data and variables. The fifth section introduces the empirical model. The sixth section reports the main results and the potential influencing mechanisms. The seventh section presents the results of robustness tests. The eighth section is the conclusion and discussion.

The effect of children's education on parental health

Children's education can be connected to the health of elderly parents in a variety of ways, such as resource acquisition, mental health, and labor supply. Well-educated children can improve their parents' health by subsidizing and increasing parental expenditures and by helping them obtain a cleaner living environment, a pathway that is particularly important in a low-income environment (Carlton et al., 2012; Zhang & Smith, 2007). When well-educated children have higher incomes, they have the ability to protect their parents from stressful events and improve their parents' mental health by providing more support (Friedman & Mare, 2014; Lee, 2017). An improvement in children's socioeconomic status can also decrease parents' need to work, thereby improving their health status (Ma, 2019).

In addition to the ways above, when children are part of their parents' social network, their socioeconomic status may generate an independent effect on parental health through numerous behavioral processes (Berkman et al., 2000). Well-educated children can generate an effect on their parents' mastery of health knowledge, thereby affecting their health behaviors, which ultimately has an effect on parental health.

First, the direct health education that children receive has a direct effect on parents. Children share the health knowledge and skills they obtain at school with their parents, thereby increasing parental health knowledge and health cognition (Field and de la Roca, 2005). Health knowledge then further improves people's health behaviors, such as health concepts in terms of eating and exercising, which generates an active effect on people's health behaviors (Ferrini et al., 1994). Children may also actively oppose their parents' smoking cigarettes in the home and in the car, even though their influence may be limited by their position in the family or by social norms (Rowa-Dewar et al., 2014). Individuals with additional education or health knowledge have been proven to be able to increase their family members' participation in sports activities (Manios et al., 2013). Children who have received health education also share specific health knowledge with their parents and generate an active effect by encouraging their parents to engage in light physical exercise (Berniell et al., 2013).

Second, better-educated children also generate an indirect effect on parental health. Well-educated offspring have more knowledge regarding health and health-related technology than less-educated offspring, and they can share this knowledge with their parents; additionally, they have more economic means to provide their parents with material help (Friedman & Mare, 2014). Better-educated children have better health cognition and, therefore, better health behaviors; additionally, their health knowledge and health behaviors have an indirect effect on their parents' health behaviors (Cutler & Lleras-Muney, 2010). They may also increase their parents' use of the Internet (Belo et al., 2016), where the rapid and innovative development of participatory Internet communication (also known as "social media") provides opportunities for improving health behaviors (Korda and Itani, 2013).

In addition, regarding children, more highly educated people may be more familiar with modern society (Glewwe, 1999), as a result of which they may more easily accept modern medicine (Aslam & Kingdon, 2012; Cunningham et al., 2015). Higher education can also promote certain caregiving activities among children, and health departments may allow them to provide direct care to family members as a result (Hall, 1989; McGarry, 1998). Therefore, well-educated children can better understand health and technology and share this knowledge with their parents. They can help their parents by

providing informal care, ensuring that they are consistent in taking their medication, and becoming their agents in the health and long-term care systems (Friedman & Mare, 2014).

As shown in the discussion above, the effect of children's education on parental health can occur through different pathways, but the interactions between parents and children in different countries are different, and the effects that may be generated by these pathways are also different. For example, the public support systems in developed countries are more adequate, and the positive effect of children's education on improving parental health is not significant. However, in developing countries, where resources are relatively scarce, this kind of social support and resource acquisition mechanism may be more prominent (Friedman & Mare, 2014). Therefore, this paper is based on Chinese survey data, and it aims to analyze the effect of children receiving higher education on their parents' health and analyze the potential pathways that may affect parental health, such as health cognition and health behaviors.

Higher education enrollment expansion in China

China resumed NEMT in 1977 and started higher education enrollment expansion in 1999. Since then, the scale of higher education student enrollment in China has continued to expand. From 1977 to 1998, the number of students enrolled to take the college entrance examination in China increased from 270,000 to 1.08 million, with an average annual growth rate of 6.8%. On June 16, 1999, the former State Development Planning Commission and the Ministry of Education jointly issued an emergency notice, deciding that China's higher education will expand its enrollment by an additional 337,000 on the basis of the 230,000 enrollment at the beginning of the year in 1999. In December of the same year, the *Action Plan for Education Rejuvenation for the 21st Century* clearly proposed to "actively and steadily expand the scale of higher education, especially to vigorously develop higher vocational education". Since then, China has further expanded its higher education enrollment. Before the implementation of enrollment expansion at colleges and universities in 1999, the student enrollment in higher education in China was below 1 million people, but it reached 1.6 million people in 1999. Since 1999, the number of students enrolled based on the NEMT has maintained a rapid growth trend, reaching 7.91 million people by 2018, and the average annual growth rate for the number of people matriculating at universities from 1998 to 2014 was 11.1%. Figure 1 shows the development trend of China's higher education expansion since 1977. It illustrates the considerable increase in the number of students enrolled in higher education in China in 1999 compared with 1998, and a rapid increase is observable thereafter.

In the context of China's policy of higher education enrollment expansion, the magnitude of the opportunity to pursue higher education was affected by the year of an individual's high school graduation and participation in the NEMT and by the province of household registration at the time of high school graduation. The former determined the temporal difference in the opportunity to obtain higher education, while the latter determined the regional difference in the opportunity to obtain higher education. In terms of the temporal difference, China's higher education enrollment expansion policy was issued and implemented in 1999; therefore, 1999 is used as the boundary. For individuals who took the college entrance examination before 1999 (not including 1999), the opportunity to obtain higher education was not affected by the enrollment expansion policy, whereas for

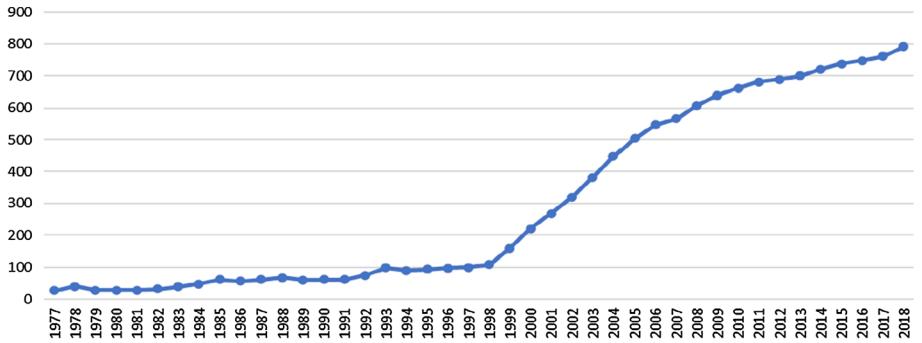

Fig. 1 Changing trends in the number of students enrolled in higher education in China from 1977 to 2018 (unit: 10,000 people). Source of Data: National Bureau of Statistics of China

those who took the college entrance examination in 1999 and thereafter, the opportunity to obtain higher education was affected by the enrollment expansion policy. When other factors were completely the same, individuals who took the college entrance examination in 1999 and thereafter were affected by the enrollment expansion policy and had more opportunities to access higher education. In terms of provinces and regions, although China's policy of higher education enrollment expansion was implemented for the residents of all provinces and regions at the same time (in 1999), the extent to which this policy affected the populations of different provinces differed. Chinese higher education implemented a "quota by province" student enrollment policy; that is, the extent to which student enrollment increased each year under the enrollment expansion policy differed for different provinces. Each year, the National Education Department determines the matriculation quota for student enrollment in all provinces in advance of the college entrance examination

Table 1 College enrollment rates in various Chinese provinces since 1999

	1999年	2000年	2005年	2010年	2013年
Beijing	80.00%	75.80%	71.38%	86.96%	87.79%
Hebei	41.00%	52.90%	63.98%	77.37%	90.72%
Liaoning	71.40%	72.99%	74.09%	88.87%	
Heilongjiang	55.90%	59.88%		90.70%	95.17%
Shanghai	70.40%	62.10%	77.20%	86.01%	89.09%
Jiangsu	67.10%	68.00%	73.61%	81.21%	85.76%
Shandong	44.10%	54.10%	72.60%	84.21%	88.95%
Henan	38.80%	51.00%	55.42%	64.16%	78.25%
Hunan	52.10%	52.90%	60.46%	82.98%	85.26%
Guangxi	53.50%	55.60%	54.70%	70.78%	70.78%
Guizhou	48.10%	61.70%	58.52%	58.16%	63.21%
Chongqing	67.10%	64.90%		70.72%	84.23%

(a) Source of Data: China Education Examinations Yearbook

(b) Limited by table space, the table only shows data for certain years

(c) Some data is missing in the table, because the "China Education Examination Yearbook" did not publish data for the relevant provinces of the year

(Table 1). In addition, the population of each province in China is different, and there is also a strict household registration system that determines that the examinees taking the college entrance examination must sign up and take the examination at the location corresponding to their household registration. These institutional regulations have caused great differences in the opportunities to obtain higher education among provinces in China, and such differences cannot be changed or controlled by individual or family efforts. In cases where other factors are completely the same, examinees whose household registrations are located in provinces with a larger scale of enrollment expansion may have more opportunities to obtain higher education.

We used the higher education enrollment expansion in all provinces of China as a natural experiment. Using the differences at the two levels of time and region resulting from the higher education enrollment expansion policy implemented in China to examine individuals' opportunities to enroll in higher education, we determined the student enrollment ratios for different years and provinces and used them as the IVs for educational level.

Methods

The overall regression model of our empirical analysis is as follows:

$$H_{\mathrm{ij}} = \sigma_0 + \sigma_1 CEdu_{ij} + \Delta\sigma_2 X_{ij} + \mu_{ij} \tag{1}$$

Formula (1) is a linear regression equation for parental health status and the effect pathways, where H_{ij} is the physical health status, health cognition, and health behaviors of individual i's parents living in province j. $CEdu_{ij}$ represents whether or not children had received higher education. X_{ij} represents other control variables that affect physical health, health cognition, and health behaviors, including the individual's age, gender, marital status, educational level, and household registration. μ_{ij} is the random error term. Since education is an endogenous variable, it is related to some unobserved factors that children and parents jointly face, such as innate ability and potential health. In addition, this relationship can be reversed; parents with a better health status can better invest in their children's education, thereby allowing the children to obtain more education. This phenomenon would create a problem of endogeneity in the OLS estimation, and bias would be present in the σ_1 estimation results.

Our empirical work was conducted in the context of the higher education enrollment expansion implemented as a reform in China in 1999. In China, the age of matriculation in primary school is six years. As mentioned above, this reform came into effect in 1999. Therefore, individuals born after the third quarter of 1981 could participate in the college entrance examination and could be affected by this reform. To a great extent, the higher education enrollment expansion in China has exogenously increased the opportunities to obtain higher education for the groups affected by this policy, but it did not have an effect on the number of years of education for other groups. At the same time, it is unrelated to other factors affecting whether an individual received higher education or to parental health. The different enrollment expansion matriculation rates of each province caused by the higher education enrollment expansion can be used as the IV involved in whether an individual received higher education.

Taking into account the endogeneity problem of the OLS estimation mentioned above and following existing related studies, we used the educational policy change used as the IV (De Neve & Fink, 2018; Ma, 2019). We used the IV method in a quasi-experimental

design to estimate the effect of children receiving higher education on parental health. The IV estimation used the 2SLS method. Formula (2) and Formula (3) are the first and second stages, respectively, of the 2SLS estimation model:

$$CEdu_{ij} = \alpha_0 + \alpha_1 X_{ij} + \alpha_2 Z_{ij} + \varepsilon_{ij} \tag{2}$$

$$H_{ij} = \beta_0 + \beta_1 CEdu_{ij} + \Phi\beta_2 X_{ij} + \mu_{ij} \tag{3}$$

In the first stage of the estimation (Formula 2), we estimated the effect of the NEMT expansion reform in China on whether an individual received higher education. In Formula (2), $CEdu_{ij}$ represents whether offspring i received or is receiving higher education, and the place of household registration is province k. Z_{ij} is the NEMT expansion matriculation rate of province j, the place of household registration to which offspring i belonged when he/she took the college entrance examination. X_{ij} represents other control variables.

In the second stage of the estimation equation (Formula 3), we used the NEMT expansion rate as the instrument for estimating the 2SLS regression model.

Data

CNHS data

The data we used came from the CHNS database. This database is based on a survey conducted jointly by the Carolina Population Center at the University of North Carolina in the U.S., international nutrition and food safety institutions, and the Chinese Centers for Disease Control and Prevention. The survey targets included 12 provinces, 4,400 families, and more than 19,000 individuals. The provinces selected for this survey basically covered regions with different geographic locations, different levels of economic development, different degrees of public resource abundance, and different health indicators: Beijing, Hebei, Shanghai, Chongqing, Guangxi, Guizhou, Heilongjiang, Henan, Hunan, Jiangsu, Liaoning, and Shandong. Thus, to a certain extent, they are reflect able to the overall situation in China. Since 1989, the CHNS has already been conducted 10 times in China.

Compared with previous large-scale in-home survey data, the main advantage of CHNS data is that the CHNS not only surveys the individuals residing long term in the family, such as the head of household, but also obtains information on other family members, such as offspring who were not residing at home for reasons such as attending school and performing migrant work, which avoids selectivity bias in the sample. The CHNS data provide a wealth of information regarding individuals' educational, such as detailed information about all educational stages, subjects studied, whether or not the person graduated, and the year of graduation. In addition, these data provide considerable information regarding an individual's health status, health cognition, and aspects such as healthy ways of living. We used the latest CHNS data released in 2015. Based on our research needs, we selected parents whose offspring affected by the NEMT expansion policy in China as the research object. In this way, the parent sample corresponding to the offspring sample that we selected had a larger age span, unlike many studies that used elderly parents as the study sample. This sample allowed us to explore the influence of children receiving higher education on the health of middle-aged to elderly parents. After screening, 3,680 parent samples were included for formal data analysis. In addition, the macro data related to the

higher education enrollment expansion in China that we used came from the website of the National Bureau of Statistics of China (http://www.stats.gov.cn/) and the *China Education Examinations Yearbook*.

Outcome variables

For the measurement of parental physical health, we used the health self-assessment in the CHNS and assigned values from 1 to 5 for individuals' health, representing very poor, poor, moderate, good, and very good, respectively.

Treatment variables

Demographic characteristics

We controlled for a series of parental demographic variables, including gender (male = 1, female = 0), age, marital status (married = 1, divorced/living apart = 0), educational level (illiterate = 0, primary school graduate = 1, junior high school graduate = 2, high school graduate = 3, secondary technical school/vocational school graduate = 4, college or university graduate = 5, master's degree and above = 6), household income (including total household income from wage/salary, pension, farming, fishing, raising livestock, small handicraft and small commercial household business, other sources of income and cash income from children).

Offspring characteristics

We used children's educational level reported in the CHNS questionnaire to determine whether they had received higher education. In addition to whether children had received higher education, we included variables such as the child's gender, his/her month and year of birth, and the province where the household was registered.

Regional characteristics

According to Smith et al. (2013), the unmeasured province characteristics of living had a significant effect on older adults' health in China. Therefore province fixed effects are estimated for health of parents. China has a strict household registration system, and the province where children take the NEMT is often the place of residence of their parents. We controlled for the parents' household registration variable (urban = 1, rural = 0), and the number of regular higher education institutions (Regular HEIs) in the province where the child's NEMT is held, to account for regional difference in the expansion of higher education enrollment. Provincial GDP per capita, number of Medical Personnels and hospital beds per 10,000 population in child's National College Entrance Examination (NEMT) year are included as additional controls, accounting for potential heterogeneity in economic and social development across provinces.

Instrumental variable

We used data in the *China Education Examinations Yearbook* from 1998 to 2014 on the student enrollment numbers planned for general higher education for each province for the year and the number of people who signed up for the NEMT to calculate the matriculation ratios for that year. Then, based on the children's year of high school graduation and the household registration information, we determined their corresponding school entrance opportunities, which were used as the IV. Hereafter, this variable is referred to as the "enrollment expansion matriculation rate" variable.

Certain differences in the policy implementation power of the higher education enrollment expansion in the different provinces in China led to differences in the opportunities for admission to higher education for high school graduates who participated in the college entrance examination in different years in different provinces.

Although the CHNS did not directly query individuals' time of high school graduation, we used their month and year of birth combined with the school entrance age requirement for compulsory education in China and the fixed number of years of study required for each stage of education in the educational system to roughly estimate when individuals took the college entrance examination. Specifically, for individuals born in January to August, their year of high school graduation and participation in the college entrance examination was calculated as the year of birth plus 18; for individuals born in September to December, the year they took the college entrance examination was calculated as the year of birth plus 19.

To make the enrollment expansion matriculation rate of each province in each year become the IV of whether or not the individual received higher education and to further estimate the effect of children receiving higher education on parental health, we used two variables, namely, the year in which individuals graduated from high school and participated in the college entrance examination and the provinces in which the household registrations were located the year of high school graduation, as pointers, and we combined the enrollment expansion matriculation rate variable with the data from the main CHNS database.

Effect pathways

Based on the social network theory of health (Berkman et al., 2000), we focused on exploring the social influence on the possible pathways by which children's education affects parental health. That is, after children have received more education, they use the family as a social network and transmit more health knowledge to their parents, thereby changing their parents' health cognition and behaviors.

Health cognition

The variables for measuring health cognition mainly included the following three items: understanding of the importance of physical activity and healthy eating, dietary knowledge, and understanding of dietary structure.

For the importance of physical activity and healthy eating, the specific questions were as follows: "At present, to what degree are you concerned with persisting in physical exercise for yourself?" and "In your current life, to what degree are you concerned with persisting

in healthy eating for yourself?". The answers given by the interviewees were assigned the following values: indifferent = 1, sometimes concerned = 2, often concerned = 3, and always concerned = 4.

Regarding dietary knowledge, there were 17 items; examples include "Eating habits such as eating lots of fresh fruits and vegetables are very beneficial to health", "Eating more sugar is beneficial to health", and "Eating different kinds of food is beneficial to health". Some items were inversely stated and were reverse scored; examples include "Eating high-fat food is beneficial to health" and "The heavier your weight, the healthier you are". The interviewees' answers were assigned the following values: strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly agree = 5. The interviewee's dietary knowledge was obtained by totaling the values of the answers for all 17 items. A higher score showed better mastery of dietary knowledge.

For understanding of dietary structure, the specific question was as follows: "Do you know the food pagoda for Chinese residents or the dietary guidelines for Chinese residents?"; possible responses were I know = 1 and I do not know = 0.

Health behaviors

Healthy behaviors mainly included preferences for sports activities. The specific questions were "Do you like to participate in walking or tai chi?", "Do you like to participate in sports (table tennis, badminton, tennis, soccer, basketball, volleyball, and so on)?", and "Do you like to participate in fitness activities?". The items were rated according to the following assigned values: I dislike it very much = 1, I dislike it = 2, I am neutral = 3, I like it = 4, and I like it very much = 5. The higher the value, the stronger the preference for sports activities was.

Unhealthy behaviors were mainly smoking cigarettes and drinking alcohol. The specific question regarding smoking was "Are you currently still smoking?"; the response options were smoking = 1 and not smoking = 0. The question regarding the current status with regard to drinking alcohol was "How frequently do you drink alcohol?"; the response options were I do not drink = 0, at least once per month = 1, I drink one to two times per month = 2, I drink one to two times per week = 3, I drink three to four times per week = 4, and I drink almost daily = 5.

In addition, we aimed to analyze parental behavior with regard to taking the initiative to acquire healthy eating knowledge. The specific question was "Would you take the initiative to understand or collect information related to dietary knowledge?"; the response options were I would = 1 and I never have = 0. See Table 2 for the descriptive statistics of the major variables studied.

Results

We first conducted an empirical analysis by replicating previous findings regarding the positive correlation between children's education and parental health. Then, we used the NEMT expansion matriculation rate in China as the IV to carry out IV estimation.

Effect of higher education enrollment expansion on parental health.

Table 3 shows the estimation results of each model. Viewed in terms of the specific regression results, the OLS estimation results and the IV-based 2SLS estimation show that the effect of children receiving higher education on parental health status is significant at

Table 2 Descriptive statistics of major variables. Source: China Health and Nutrition Survey (2015)

Variable	Mean	Std. Dev	N
Health measures			
Current health status	3.555	0.791	3517
Pathway measures			
Physically active	3.219	0.996	3406
Healthy diet	3.293	0.910	3406
Dietary knowledge	56.975	8.614	3406
Dietary structure cognition	0.211	0.403	3406
Walking, tai chi	3.189	1.495	3406
Sports	2.842	1.538	3406
Body building	2.884	1.536	3406
Smoking	1.016	1.711	3406
Drinking	0.915	0.283	1082
Seek nutrition knowledge	0.224	0.417	3406
Demographic characteristics			
Parent's age	53.668	6.366	3680
Parent's gender	0.450	0.493	3680
Parent's education	2.043	1.169	3522
Parent's marital status	0.960	0.211	3677
Household income	9.215	13.067	3622
Child characteristics			
Higher education	0.681	0.467	3680
Son	0.700	0.461	3680
Enrollment expansion matriculation rate	0.669	0.140	2432
Regional characteristics			
Parent's Hukou	0.309	0.459	3531
Number of Regular HEIs in child's NEMT year and province	75.321	30.2231	3680
Number of Medical Personnels per 10,000 Persons in child's NEMT year and province	31.1276	10.8172	3680
Number of Beds per 10,000 Persons in child's NEMT year and province	52.875	20.589	3680
Log of per capita provincial GDP in child's NEMT year and province	9.677	0.8143	3680

the 1% and 5% levels, respectively; that is, when children receive higher education, it is conducive to improving their parents' self-assessed level of health. Compared with the OLS estimation, the coefficient of the effect of children receiving higher education is larger in the IV estimation; that is, the effect on increasing the level of self-assessed parental health is stronger. The reason may be that the IV estimation simultaneously eliminates the effect of measurement errors. In the regression results for other control variables, the level of parental health decreases significantly as age increases; gender and marital status have no significant effect on self-assessed health status; the higher the parents' own level of education is, the higher their self-assessed level of health. Additionally, in terms of the type of household registration, individuals with urban household registrations have higher self-assessments of their own health.

The results of the weak identification test for the IV model show that the Cragg-Donald Wald statistic F value of the weak IV test is 33.254, which is far greater than 10;

Table 3 Effect of children receiving higher education on parental health

	OLS Current health status	First-stage regressions Higher education	IV-2SLS Current health status
Higher education	0.138*** (0.031)		0.858*** (0.336)
Enrollment expansion matriculation rate		0.509*** (0.097)	
Parent's age	− 0.005*** (0.003)	− 0.003 (0.002)	− 0.014*** (0.016)
Parent's gender	− 0.006 (0.027)	− 0.042** (0.019)	− 0.123 (0.210)
Parent's education	0.041*** (0.013)	0.122*** (0.009)	0.059* (0.051)
Parent's marital status	0.178*** (0.066)	0.087** (0.051)	0.094 (0.098)
Parent's Hukou	0.004* (0.031)	0.178*** (0.022)	0.491 (0.073)
Household income	0.005*** (0.001)	0.003*** (0.001)	0.003* (0.001)
Constant	3.470*** (0.387)	− 0.133 (0.267)	3.783 (0.391)
Observations	2,361	2,361	2,361
Province FE	Yes	Yes	Yes
R-squared		0.223	
IV F-stat			33.254
Durbin p value			0.018

Standard errors are in parentheses. *Statistical significance at 10%. **Statistical significance at 5%. ***Statistical significance at 1%

therefore, the IV we used was not weak. The Durbin-Hausman (DWH) test is statistically significant at the 5% level, which shows that the variable of receiving higher education has endogeneity.

Column 2 in Table 3 presents the regression results for the first stage of the 2SLS estimation. The coefficient of the enrollment expansion matriculation rate is significantly positive at the 1% level, which shows that the implementation of the higher education enrollment expansion policy in China has generated a significant effect on the opportunities for individuals to receive higher education. The greater the increase in the enrollment expansion matriculation rate of children's province is, the greater the opportunities they have to obtain higher education.

Heterogeneity

Next, we analyzed the heterogeneity of the effect of children receiving higher education on parental health. First, in terms of the gender difference, we considered the heterogeneity of the effects of sons and daughters receiving higher education on parental health as well as the difference in the effect that children's education has on their fathers and mothers. Then, given the urban–rural binary structure existing in China

Table 4 Effect of children receiving higher education on parental health: IV regression results

	(1) Sons	(2) Daughters	(3) Fathers	(4) Mothers	(5) Urban areas	(6) Rural areas
Higher education	0.921* (1.459)	0.742 (1.114)	1.712** (0.576)	0.614 (0.598)	4.272 (0.509)	1.488** (0.428)
IV F-stat	10.652	11.789	15.016	13.055	13.719	17.674
Durbin-Hausman *p* value	0.053	0.056	0.074	0.137	0.266	0.023
Observations	1662	801	1189	1270	899	1621

Regressions include the same sets of variables as in Table 2. Estimates of other variables are not reported. Standard errors are in parentheses. *Statistical significance at 10%. **Statistical significance at 5%. ***Statistical significance at 1%

and given that the development of rural areas is more delayed than the development of urban areas in China, we studied the heterogeneity between urban and rural areas with regard to the effect of children's education on parental health using parents' household registrations.

Columns (1) and (2) in Table 4 show that there are differences in the effects of sons and daughters receiving higher education on parental health. Sons have a greater effect on parental health, and this effect is significant at the 10% level; the effect of daughters is smaller and not significant. There is a greater difference between this result and that of existing studies. The research results of Lundborg and Majlesi (2018) suggest that since daughters are the primary caregivers for elderly parents, an increase in daughters' education has an active and significant effect on parents' survival. However, our result is not surprising, as it is in line with the actual situation in China. That is, traditionally in China, sons bear more of the responsibility for supporting their parents, while daughters bear less responsibility after marrying.

Next, we tested heterogeneity based on parents' gender. The specific results, presented in Columns (3) and (4), show that relative to mothers, the health status of fathers is more easily affected by children. Children's higher education has a significant effect on their fathers' health, and the coefficient of the effect is higher than that for mothers' health. Our results are similar to those of Berniell et al. (2013) and Lundborg and Majlesi (2018).

The urban–rural heterogeneity results are shown in Columns (5) and (6). When children from rural families receive higher education, it has a significant effect on their parents, and this effect is significant at the 5% level. The reason is that there is a greater gap between urban and rural areas in China in terms of overall development. The social security, educational level, and living environment of the rural population are all relatively low, which requires rural parents to be able to obtain support from their children, especially when their children have received higher education.

In summary, our heterogeneity analysis shows that children's higher education has a significant effect on their fathers' health but has no significant effect on their mothers' health. Influenced by the idea of "raising sons to provide for one's old age" in traditional Chinese culture, sons are often the most important care providers for their parents. At the same time, parents in rural families receive more help from their children who have obtained higher education, while the help obtained by urban parents is not significant.

Estimation results for potential pathways

To investigate the potential mechanisms underlying the survey results, we next analyzed the potential effect pathways. First, we estimated the effect of children receiving higher education on parental health cognition, including the importance of physical exercise to parents themselves and the importance that parents themselves attach to healthy eating, dietary knowledge, and the dietary structure. Second, we analyzed parental health behaviors, including the extent of parents' preferences for walking, tai chi, sports, and fitness, as well as current smoking and drinking habits and whether they take the initiative to acquire dietary knowledge.

Lundborg and Majlesi (2018) suggested that health knowledge may be an important mechanism because many unhealthy behaviors that can trigger illnesses may be changed by obtaining more health knowledge. Table 5 shows the effect of children receiving higher education on parental health cognition using IV regression. The results in Columns (1) and (2) show that children's higher education has a significant effect on the degree to which their parents are concerned with physical activity (Ppa) and a healthy diet (Phd); influenced by their children, parents increase how concerned they are with the importance of physical exercise and healthy eating. Column (3) presents the results of the effect of children receiving higher education on their parents' mastery of dietary knowledge (Dk). The IV regression results show that this influence is significant and positive; children's higher education significantly enhances their parents' mastery of dietary knowledge. The effect on dietary structure cognition (Dsc) is shown in Column (4); children's higher education significantly affects their parents' dietary structure cognition. Our results are similar to the research findings of Field (2005). His study showed that through schooling, children obtain a great deal of information; through their children, parents obtain the knowledge provided in the school's health education curriculum, and then, parents adjust their health behaviors based on their own actual situations.

Overall, the evidence provided in Table 5 shows that when Chinese children receive higher education, it has an active and significant effect on increasing the level of parental health cognition.

As Friedman and Mare (2014) pointed out, at least part of the link between children's education and parents' survival can be explained by parental health behaviors, including

Table 5 Effect of children receiving higher education on parental health cognition: IV regression results

	(1) Parent's Physically active	(2) Parent's Healthy diet	(3) Parent's Dietary knowledge	(4) Parent's Dietary structure cognition
Higher education	0.901** (0.482)	2.380** (1.158)	9.852* (4.164)	0.130*** (0.864)
Observations	2,249	2,249	2,249	2,249
Province FE	Yes	Yes	Yes	Yes
IV F-stat	16.380	20.997	20.771	24.797
Durbin-Hausman p-value	0.096	0.198	0.060	0.087

Regressions include the same sets of variables shown in Table 2. Estimates of other variables are not reported. Standard errors are in parentheses. *Statistical significance at 10%. **Statistical significance at 5%. ***Statistical significance at 1%

Table 6 Effect of children receiving higher education on parental health behaviors: IV regression results

	(1) Parent's Walking or tai chi	(2) Parent's Sports	(3) Parent's Body building	(4) Parent's Smoking	(5) Parent's Drinking	(6) Parent's Seek nutrition knowledge
Higher education	1.298** (1.259)	1.824** (1.498)	2.191* (1.316)	− 0.502** (0.247)	-1.396 (1.024)	0.589** (0.261)
Observations	2,249	2,249	2,249	735	769	2,249
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
IV F-stat	24.795	24.772	23.471	22.311	15.060	23.772
Durbin-Hausman *p* value	0.027	0.006	0.102	0.013	0.351	0.021

Regressions include the same sets of variables as in Table 2. Estimates of other variables are not reported. Standard errors are in parentheses. *Statistical significance at 10%. **Statistical significance at 5%. ***Statistical significance at 1%

parents' eating habits, alcohol consumption, persistence in using medication, and time spent on activities related to acquiring health cognition. Better-educated children can directly persuade or indirectly encourage their parents to change their health behaviors, thereby improving their parents' health status.

In Table 6, we show the IV regression results for the effect of children receiving higher education on parental health behaviors. The results in Columns (1), (2), and (3) show that when children receive higher education, it significantly affects parental health behaviors; the parents participate more in activities that are beneficial to physical health, such as walking, tai chi (Wt), sports, and body building (Bd).

In terms of behaviors that harm health, the results in Column (4) show that when children receive higher education, it significantly reduces their parents' likelihood of smoking cigarettes (Smoking), and this effect is significant at the 5% level. In contrast, children's higher education has no significant effect on their parents' alcohol consumption behavior. The specific results are shown in Column (5). Children receiving higher education do not significantly reduce the frequency with which their parents drink alcohol (Drinking).

In addition, in Column (6), we show the results for parents taking the initiative to improve their dietary knowledge. When children receive higher education, it significantly increases their parents' initiative-taking to seek nutrition knowledge (Snk). This result fits with the hypothesis that better-educated children have an active effect on parental health by influencing their parents to take the initiative to obtain dietary knowledge.

Robustness checks

We performed robustness tests to verify the study results above. See Table 7 for the regression results for all robustness tests.

First, we made certain corrections to the IV setting. As mentioned previously, since there is a strict household registration management system in China, we assume that the household registration of the individual did not change when participating in the college entrance examination and that it was consistent with his/her parents' household registration. We used this standard to determine the NEMT expansion matriculation rate corresponding to the province the individual lived in when he/she took the college entrance examination, and we used this rate as the IV. However, due to the existence of "immigrants

Table 7 Robustness tests

	(1) Robustness test 1	(2) Robustness test 2	(3) Robustness test 3
Higher education	0.825*** (0.445)	0.944*** (0.488)	− 0.0751** (0.347)
Observations	2,331	1,909	2,329
Province FE	Yes	Yes	Yes
IV F-stat	31.065	30.144	29.342
Durbin-Hausman *p* value	0.014	0.026	0.085

Regressions include the same sets of variables as in Table 2. Estimates of other variables are not reported. Standard errors are in parentheses. *Statistical significance at 10%. **Statistical significance at 5%. ***Statistical significance at 1%

taking college entrance examinations", the positive selection of the sample will cause an individual's opportunity to obtain higher education to increase, thereby causing the effect on parental health to be overestimated. To test the robustness of the aforementioned results, we used only the sample of individuals whose household registration was consistent with their place of birth. This approach cannot completely solve the problem of endogenous migration because individuals may change their household registrations before taking the college entrance examination and then move back to the place of household registration for high school graduation after taking the college entrance examination or after graduation from university. However, taking into account the strict household registration management policy in China, we believe the likelihood of such situations occurring is relatively low. The results in Column (1) of Table 7 show that when children receive higher education, it has a significant promoting effect on parental health status; although the coefficient of the effect is higher than the estimated coefficient rate using the full sample in Table 3, the difference is not large, which shows that our results have a certain robustness.

Second, we narrowed the age range of parents to test whether our results would change. In our full sample, the age span of parents was greater. Taking into account that the physical condition of elderly people is relatively poor, we tried to limit the sample to parents under 60 years of age to test the sensitivity of our results to narrowing the age range of parents. Based on the results in Column (2), when children receive higher education, it has a similarly significant promoting effect on parental health status, and this effect is significant at the 1% level.

Finally, we changed the measurement indicator for an individual's level of health. In the benchmark model, we used the health self-assessment as the measurement indicator of the level of parental health. To ensure the robustness of the estimation results, we used the situation of whether the parental individual suffers from a chronic disease, including hypertension, diabetes, stroke, tumor, and asthma, to measure the individual's health level, including. According to the regression results in Column (3), when children receive higher education, it has a significant and negative effect on parents suffering from chronic diseases, and the effect is significant at the 5% level.

Conclusion

Although many previous studies have shown that human capital can be transferred from older generations to younger generations, an increasing number of studies have found that the human capital of children has an upward spillover effect (De Neve & Kawachi, 2017). In particular, relevant studies in recent years have proven that children's education can generate a potential effect on the health of their parents (De Neve & Fink, 2018; Friedman & Mare, 2014; Lundborg & Majlesi, 2018; Ma, 2019). By providing causal evidence on the effect of Chinese children receiving higher education on the physical health of parents and the potential pathways of this effect, this papers enriches research on the relationship between children's education and parental health. In this paper, the college entrance examination enrollment expansion policy that was implemented as a reform in China was used, and the changes and differences in the scale of enrollment expansion for different years between different provinces were used as IVs. Doing so provided us with exogenous differences in the opportunities that children had to receive education. The IV estimation results show that when children receive higher education, it has a significant and positive effect

on the physical health of the parents. Compared with the OLS estimation results, the coefficient of the effect of children receiving higher education is larger in the IV estimation.

Taking into account the potential heterogeneity in the spillover effect of children receiving higher education on parental health (Lee, 2017; Lundborg & Majlesi, 2018), we conducted a heterogeneity analysis in relation to the three aspects of parents, children, and urban and rural areas in China. We found that when children receive higher education, it has a significant effect on their fathers' health, but there is no significant effect on their mothers' health. The effect of sons' education on parental health is significant, but the effect of daughters' education is not significant. Furthermore, the effect of children's higher education on parents in rural families is significant, but the effect on urban parents is not significant.

It is not surprising that we found that only the higher education of sons had a significant effect on parental health. The reason is that under Chinese tradition, sons bear the primary responsibility for supporting their parents. At the same time, sons have a greater influence within the family than daughters; thus, they can have an effect on changing parental health cognition and health behaviors. Parents in rural families are more significantly affected by their children receiving higher education, a finding that is also based on the actual situation in China. First, the binary structure of urban and rural areas in China has led to extremely uneven development between urban and rural areas; the urban population generally has a higher education level and higher incomes than the rural population. Second, the levels of social and pension security and medical security in urban areas are far higher than those in rural areas, and the extent to which the social security system is complete is also higher in urban areas than in rural areas. Third, the basic public medical facilities in China's urban areas are more complete, and the health awareness of the urban population is higher. Taken together, these factors have led to a relatively poor health status for China's rural population, and rural parents in China rely more heavily on their children for support. Therefore, the effect of rural children receiving higher education on parental health is more significant. Our estimations show that when groups that bear more caregiving responsibilities obtain higher education, parental health status is more significantly affected.

Discussion

The results above have some important policy implications. China has become an aging society, and the rate of aging continues to accelerate. Moreover, the educational level of the older generation is generally lower than that of younger generations. If an increase in children's educational level can generate an active effect on parental health, it will be beneficial to China by promoting the healthy aging of the elderly population. Although one cannot rely on improving the health status of elderly people in China through education policies, educational efforts can still be an important complementary policy for improving the health status of the overall population. In addition, if children receiving higher education can generate a positive effect on parental health, then greater importance should be attached to the education of the rural population in China. Such efforts could reduce education-related health inequalities by increasing the educational level of the rural population.

Authors' contributions All authors were involved in planning of the study and interpretation of results. WN and HWH conducted the data analysis and wrote the first draft of the paper. ZLL critically reviewed the paper and edited the manuscript. All authors read and approved the final manuscript.

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