On the Origin of Cognition: How Childhood Conditions Shape Cognitive Function in Old Age

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Abstract

This paper examines the long-term impact of early childhood conditions on cognitive function in old age. Using unique data from a longitudinal survey of Chinese elderly, we find that people with adverse childhood conditions measured by the paternal occupation, parental education, nutrition and medical conditions, not only have lower cognitive ability, but also exhibit faster cognitive deterioration at older ages. The results also indicate that female elderly suffer more from the adverse childhood conditions than males. Further mechanism analyses suggest that the educational attainment accounts for 16 to 26 percent of the association between early-life circumstances and cognitive function in old age.

Keywords: cognition, early childhood condition, elderly, ageing

JEL Classification: J14, I15, O15

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1. Introduction

Cognitive ageing not only threatens individuals' independence and quality of life, but also increases the burden on society's support systems for the elderly. Given the rapid population ageing of the world, one important theme for the researchers and policy makers is to understand the origin of cognition and its decline with ageing. Many studies have examined the contribution of early-life conditions on cognitive function in adulthood. However, much less is known about the association between early-life conditions and cognition in old age, in particular, the process of cognitive ageing. Using data from a longitudinal survey of Chinese elderly, this study investigates how early-life conditions shape cognition in old age by examining the relationship between socio-economic conditions during childhood and cognitive functioning as well as cognitive ageing.

Age-associated decline in cognitive functioning is inevitable due to biologic influence. However, according to the hypothesis of cognitive reserve (Stern, 2003; Jones et al., 2011), the clinical expression of cognitive impairment depends on the buffer effects of brain structure (e.g., brain size, neural density, and synaptic connections) and efficiency of brain networks (e.g., recruiting alternative neural networks to cope with challenge). Richards and Deary (2005) further developed the concept of cognitive reserve in a life course model. They conceived the cognitive reserve as the sum of lifetime inputs, including genes, early social and material environment, and physical health and lifestyle in adulthoods. These factors may not only impact cognitive ability at a given age, but also influence the capability of protecting cognitive deterioration over time, although the impacts on cognitive ability and cognitive decline may go through different mechanisms. For instance, factors affecting brain structure may cause persistent differences in cognitive ability, while factors affecting functional performance of brain networks may only display their compensative effects when people face cognitive challenge.

Two main hypotheses have been posited to explain the association between early-life conditions and cognition in old age—the latency model and the pathway model (Lyu and Burr, 2016; Zhang, Hayward, and Yu, 2016; Zhang et al., 2018; Ko and Yeung, 2019). According to the latency model, early-life conditions may have *direct* effects on the trajectories of cognitive development in the life course. Specifically, adverse conditions in the critical periods of brain development (such as the prenatal period and childhood) can have negative aggravated impacts on cognitive functioning until late life (Haan and Wallace, 2004). The pathway model, however, emphasizes that early-life conditions may *indirectly* impact cognitive abilities at older ages through educational attainment, occupational experiences, and living environment in adulthood. In particular, the educational attainment is found to be a powerful determinant of cognitive function in old age (Berkman, 2000; Banks and Mazzonna, 2012; Schneeweis, Skirbekk, and Winter-Ebmer, 2014).

Previous studies on the association between early life circumstances and cognitive abilities in late life have focused primarily on developed countries (Case and Paxson, 2008, 2009; van den Berg et al., 2010; Guven and Lee, 2012; Doblhammer, van den Berg, and Fritze, 2013; Aartsen et al., 2019). However, research from a developing country such as China can be of special interest. First, as in many other developing countries, China has not established comprehensive social support systems for old people (Yip et al., 2019), whereas its population is ageing more rapidly than the population of most other countries (United Nations, 2019). This reality raises significant social and economic challenges for the government and society. Second, many of China's current elderly were born in the first half of the twentieth century. They experienced severe hunger, wars, infectious diseases, and lack of educational opportunities during their childhood (Zeng, Gu, and Land, 2007). The adverse circumstances in their early lives were much worse than those of people in developed countries (Zhang, Gu, and Hayward, 2008), yet may widely exist contemporarily in many developing countries where child poverty calls for serious attention.

In this paper, we examine the long-lasting effects of adverse conditions during childhood on cognitive functioning in old age by using a national representative longitudinal data set of Chinese elderly aged 65 and above. The survey includes a standard test to measure the cognitive abilities of the respondents. Meanwhile, it collects abundant information on the circumstances of people's childhood, including nutritional deprivation, access to medical services, the father's main occupation, and years of schooling of the father and mother. Furthermore, the longitudinal feature of the data allows us to study the impact of early-life conditions on the rate of deterioration in cognitive function in late life, apart from its impacts on the level of cognitive function.

The results show that disadvantages during childhood are associated not only with a lower level of cognitive abilities in late life, but also with a more rapid decline in cognitive functioning. Specifically, we find that the elderly who have a childhood with father working as a farmer or receiving no formal education and those who have insufficient food or inadequate medical services during their childhood tend to perform worse in the tests on cognitive function.

Meanwhile, people whose father worked as a farmer, whose mother received no formal education, and those who experienced food deficiency during childhood have greater speed of deterioration in the ageing process of cognition. The results are robust after taking account of potential recall bias in measuring early-life conditions and selection bias caused by sample attrition.

Exploration of the mechanisms suggests that occupation in adulthood and educational attainment in particular are important pathways through which childhood conditions influence the level and deterioration rate of cognition at older ages. However, a large part of the associations cannot be explained by the observed characteristics of the respondents in their adulthood, indicating that childhood conditions may have direct effects on cognition in old age.

Further heterogeneity analysis suggests that the long-lasting association between childhood conditions and late-life cognition is more remarkable among females than males, implying that households are likely biased against girls in situations where resources are limited. Meanwhile, we find the associations are stronger for the thinking part of cognition (i.e., fluid intelligence) than the knowing part of cognition (i.e., crystallized intelligence).

The present study contributes to the extant literature in several aspects. First, while many studies have examined the impact of childhood conditions on the level of cognition in old age (Case and Paxson, 2008, 2009; Zhang, Gu, and Hayward, 2010; Kobayashi et al., 2017; Chan et al., 2019), studies examining the effect of childhood conditions on the rate of cognitive decline are fewer and the findings are inconclusive (Marden et al., 2017). This study is one of the few papers using longitudinal data to examine the association between early-life conditions and the rate of decline in cognition, namely the slope analysis as opposed to the level analysis

(Schneeweis, Skirbekk, and Winter-Ebmer, 2014). Examining effects of childhood conditions on the rate of cognitive deterioration is important for understanding the process of cognitive ageing and thinking of potential tools to mitigate the process from a public health perspective (Salthouse, 2006; Hale, 2017). Second, prior studies examining the relationship between early-life conditions and late-life cognition mainly use data from developed countries (van den Berg et al., 2010; Doblhammer, van den Berg, and Fritze, 2013; Aartsen et al., 2019; Zhang, Liu, and Choi, 2020). We complement the literature by using data from China, a developing country with a rapidly growing elderly population that experienced severe adverse situation in their childhood, and today are supported by imperfect social security systems. This paper also complements previous studies on the relationship that focus on people aged 80 years or younger in China (Pan, 2020; Lin and Chen, 2021a), by extending examination to people older than 80 leveraging a data set that oversampled the oldest-old. This extension can be particularly relevant to policy given the life expectancy of the county had risen to about 77 years by 2019 (United Nations, 2019). Lastly, this study quantifies the bounds for the relative importance of mediation variables on explaining the association between childhood conditions and cognitive function in late life.

Our research also relates to the broad economic literature that investigates the impacts of early-life conditions or interventions on outcomes in later adult life. These include academic achievement, economic behavior, and health status (Hoddinott et al., 2008, Bozzoli, Deaton, and Quintana-Domeque, 2009; Bharadwaj, Løken, and Neilson, 2013; Heckman, Pinto, and Savelyev, 2013; Campbell et al., 2014; Aizer et al., 2016; Hoynes, Schanzenbach, and Almond, 2016; Autor et al., 2019; Lazuka, 2020). However, less is known about whether the impacts persist through to old age, in particular, on their cognition.[1] This study complements this strand of literature by examining the long-term effects on cognitive function of elderly people among a handful of studies that mentioned earlier. The results from the study suggest that public policies directed at enhancing conditions during childhood will not only benefit the children, but will also achieve significant returns by improving cognitive well-being later in life, which is appealing given the high costs of caring for people with cognitive impairment.[2]

More broadly, this study ties into the literature on the intergenerational transmission of inequality in domains such as income, education, and health (Case, Lubotsky, and Paxson, 2002; Black, Devereux, and Salvanes, 2005; Ma, 2019; Gong, Lu, and Xie, 2020; Ma et al., 2021; Torres et al., 2021). Our paper complements this strand of literature by showing that differences in parental education and occupation that serve as important socio-economic conditions during childhood are mirrored in the inequality of cognitive abilities at older ages, which demonstrates a new channel for the intergenerational transmission of socio-economic inequality (Anger and Heineck, 2010).

The rest of the paper proceeds as follows. Section 2 introduces the data and measurements. Section 3 presents the empirical strategy. Section 4 reports the results of the main analysis, robustness, mechanisms, and heterogeneity. Section 5 concludes.

[1] See Bertoni (2015) for an example of studies examining other outcomes at older ages, which explored the relation between exposure to hunger in childhood and subjective well-being in late life.

[2] For example, the estimated global cost of dementia in 2015 was USD 818 billion, an increase of 35.4% compared to 2010 (Prince et al. 2015). Moreover, cognitive impairment are found to be important barriers to self-management of chronic diseases such as hypertension among older adults, which would further increase the burden of care services and supports (Lin and Chen, 2021b).

2. Data and Measurements

2.1. Data

The data used in this study are from the Chinese Longitudinal Healthy Longevity Survey (CLHLS), which is implemented by the Center for Healthy Aging and Development Studies at Peking University and is used widely by previous studies (Zeng, Gu, and Land, 2007; Zhang, Gu, and Hayward, 2008, 2010; An et al., 2019; Yu, Zhang, and Kobayashi, 2021). The baseline survey started in 1998 by randomly sampling elderly aged 80 and above from about 50% of the counties and urban districts in 22 Chinese provinces. Follow-up surveys were conducted in 2000, 2002, 2005, 2008, 2011, 2014, and 2018, respectively. Since 2002, the surveys included elderly respondents aged 65 and older. To ensure the age range is consistent across waves, we focus on the waves of 2002 and afterwards in our analysis. The survey incorporated a module of a standard test to measure cognitive functioning of the elderly. Meanwhile, it collected detailed information on the elderly's socio-demographic characteristics. In particular, it asked respondents about their socio-economic environment in childhood, including the paternal occupation, parental education, and status of nutrition and medical services. To avoid the problem of small sub-sample sizes at more advanced ages, the survey over-sampled the people who were aged 80 years and above. This feature provides us a unique opportunity to examine the relationship between childhood conditions and cognitive function among the oldest old, which is rarely observed in other data sets (Pan, 2020; Lin and Chen, 2021a). To adjust for the disproportional sampling, we use the sampling weights in the analysis below.

We use two sets of samples in this paper. To analyze the level of cognitive function, we use CLHLS 2005-2014 and exclude waves 2002 and 2018, since some measures on the childhood conditions were not available in these two waves. Specifically, the questions on paternal occupation during respondents' childhood and parental educational achievements are only available since wave 2005, and the information on medical services during childhood are unavailable in wave 2018. However, since the indicators of parental socio-economic status during respondents' childhood are time-invariant, we can impute the missing values of the variables that were not measured in waves 2002 and 2018 among individuals who were observed in successive waves 2002-2005 and 2014-2018, respectively. Therefore, for the analysis on the change in cognitive function, we use the sample of individuals who were observed in successive waves among the CLHLS 2002-2018. We exclude respondents who were older than 100 years, although the results are robust by including such observations.[3] Eventually, we obtained 36,634 observations from 19,225 individuals for the analysis on the level of cognition, whereas the analysis of change in cognitive function consisted of 27,451 observations from 13,450 individuals.

2.2. Measurements

Cognitive function. The CLHLS applies the Mini-Mental State Examination (MMSE) to measure cognitive function. The MMSE is widely used by clinicians and researchers to assess cognitive conditions of the elderly. The examination in the CLHLS follows international standards but modifies some questions based on the Chinese context (Zeng and Vaupel, 2002).[4]

[3] The results are available upon request.

[4] For example, in the orientation tests, the respondents were asked, "What is the animal year of this year?" and "What is the date of the mid-autumn festival?" Both questions are based on Chinese traditional culture and are therefore easier for the elderly to understand. Given that a significant number of the elderly in China are illiterate, the survey asked respondents to articulate food names rather than read or write a sentence in the test on verbal frequency.

It includes 24 questions to measure six dimensions of cognitive function: orientation, verbal fluency, memory (including immediate recall and delayed recall), numeracy, visual construction, and language. More specifically, orientation tested the elderly's sense of time and location, which was measured by a question asking the name of the respondent's residential county or district, and four questions asking the time of the day, the current animal year, the date of the mid-autumn festival, and the current season. Verbal fluency was measured by the number of food names the respondent uttered in one minute. For immediate recall, the interviewer read the words "table," "apple," and "clothes" sequentially, and asked the respondent to recall the list immediately, whereas for delayed recall, the respondent was asked to recall the same list again after the tests on numeracy and visual construction. Numeracy was assessed by simple arithmetic operations that subtracted 3 from 20 consecutively five times. For visual construction, the respondent was asked to draw a figure following the sample. The language tests consisted of six questions: name a pen and a watch, repeat a sentence, and follow a three-stage command (take paper using right hand, fold paper, and put paper on the floor). The respondent earned one point for each correct answer; for the test on verbal fluency, the respondent got one more point once for articulating a food name, and full marks are 7. Following the literature, we treat "unable to answer" as an incorrect answer (Fillenbaum, George, and Blazer, 1988; Herzog and Wallace, 1997; Nguyen et al., 2003). Adding the scores of each dimension, we obtain the cognitive function score, which ranges from 0 to 30. A higher score indicates better cognitive function.

Childhood conditions. We measure the elderly's socio-economic conditions during childhood by five indicators. The survey asked respondents "what was your father's main occupation during your childhood." Based on this question, we generate a dummy indicating that the paternal main occupation was farmer, which equals one if the answer was "agriculture, forestry, animal husbandry, or fishery worker," and zero otherwise (i.e., industrial worker, manager, and others). Meanwhile, the survey collected information on years of schooling of the respondents' parents. We define dummies that indicate zero year of schooling for fathers and mothers, respectively. Moreover, the survey asked respondents "whether you often went to bed hungry during childhood" and "whether you got adequate medical services during childhood." We define two dummies corresponding to the two questions with a value of one indicating adverse conditions (i.e., being hungry or lack adequate medical services), and zero otherwise. Finally, we aggregate the five indicators to construct an index for adverse childhood conditions. Thus, the index ranges from 0 to 5, with a higher index implying worse socio-economic status during childhood.

Other variables. To examine the mechanisms through which childhood conditions affect cognition in late life, we investigate four potential mediators, including respondents' educational level, main occupation before age 60, marital status, and types of residential place at the time of the survey. Specifically, we generate dummies indicating three levels of educational attainment (illiterate, primary school, and middle school and above), dummies defining four occupational categories (farmer, industrial worker, manager, and others), a dummy for being in marriage, and a dummy for living in urban areas. Additionally, in the analysis, we control for some socio-demographic characteristics including age, gender (male=1), and ethnicity (*Han*=1).

2.3. Descriptive Statistics

Figure 1 presents the average cognitive function score with 95% confidence intervals by childhood conditions. Specifically, Panel A to Panel F illustrate the age profiles of cognitive function by paternal occupation (working as a farmer or not), paternal and maternal education (receiving formal education or not), medical services during childhood (having adequate medical services or not), food deprivation during childhood (feeling hungry or not before going to bed), and the aggregate index of adverse childhood conditions (larger or smaller than its sample median). All six panels show a similar pattern: respondents who had worse socio-economic conditions during childhood not only have lower cognitive function scores in old age, but also exhibit faster deterioration in cognitive function with ageing.

Table 1 reports the summary statistics of the variables used in this paper, which are adjusted by the sampling weights. As shown, the average score of cognitive function is 26.87, with a standard deviation of 5.2. For the indicators of early-life conditions, 63% of the elderly had fathers working as farmers. The vast majority of the respondents' parents had never received formal education. Some 59% of the elderly lacked medical services during childhood, and 69% of them lacked sufficient food during childhood. Overall, the results suggest that most elders in our sample grew up under severe adverse conditions in their early life.

Regarding the socio-demographic characteristics, 49% of the respondents are male and 79% of them are of *Han* ethnicity. The average age of the sample is 73.2, with a standard deviation of 6.22. The elderly are not well educated. As shown, 43% of them are illiterate, 39% have received primary schooling, and only 18% have completed middle school education or above. For their main occupation before the age 60, 48% of the respondents are farmers, 14%

are industrial workers, 10% are managers, and 28% are classified as "others".[5] Some 63% of the elderly are married and 43% of them live in urban areas at the time of the survey.

To sum up, the features of our data, consisting of the elderly from age 65 to the oldest ages with sufficient variations in early-life conditions, enable us to explore the long-term effects of early life socio-economic status on cognitive function in old age.

3. Empirical Strategy

To examine the disparities in cognitive function among the elderly with divergent early life socio-economic conditions, we estimate the following equation,

$$y_{icpt} = \alpha E_{icpt} + \gamma X_{icpt} + \delta_c + \eta_{pt} + \varepsilon_{icpt}, \quad (1)$$

where the subscript i, c, p, and t represents the individual, birth year, residential province, and survey wave, respectively. y_{icpt} is the cognitive function score. E_{icpt} is a vector of five dummies indicating early-life socio-economic conditions of individual i. Specifically, it includes dummies of having a childhood with father working as a farmer, having father who never received formal schooling, having mother who never received formal schooling, having insufficient medical services during childhood, and experiencing food deprivation during childhood. The coefficient vector α is of interest and we expect the estimates should be negative. X_{icpt} is a set of observable socio-demographic characteristics, including age, age squared, and dummies for male and *Han* ethnicity. δ_c is the birth year fixed effect, which captures common macro factors that affect the corresponding cohort. η_{pt} is the residential province by wave fixed effect; it absorbs time-invariant factors such as geographic conditions

[5] In the occupation type "others", around 65% performed housework, 13% were self-employed, 5% were military service personnel, 4% reported they had never worked, and 13% were unknown.

in the residential place and time-variant factors such as economic development in the province of residence. With this specification, we compare the variation in cognitive function within the same birth cohort who lived in the same province and are interviewed in the same wave, by fixing the observed individual characteristics. ε_{icpt} is an error term, which is clustered at the individual level to allow for serial correlation of cognition within individual.

To investigate whether early-life conditions affect the deterioration rate in cognitive function at older ages, we follow Schneeweis, Skirbekk, and Winter-Ebmer (2014) and estimate the effect of early-life conditions on the change in the cognitive function scores based on the following specification,

$$y_{icpt} - y_{icpt+w} = \beta E_{icpt} + \zeta X_{icpt} + \delta_c + \eta_{pt} + \varepsilon_{icpt} - \varepsilon_{icpt+w}, \quad (2)$$

where $y_{icpt} - y_{icpt+w}$ refers to the change in the cognitive function score measured in survey year t compared to that measured in the successive survey year $t + w$. The definitions of the independent variables are the same as in Equation (1), whereas the factors captured by fixed effects could be different. For example, δ_c captures common factors that affect the change in cognitive function for the same cohort, and η_{pt} absorbs determinants of change in cognitive function that are common to respondents living in the same province and being interviewed in the same wave. The coefficient vector β is of our interest and we posit the estimates are positive, i.e., respondents with adverse childhood conditions will experience faster deterioration in cognition.

4. Results

4.1. Main Results

In this section, we start by presenting the empirical results of disparities in cognitive function among the elderly with various socio-economic conditions in their childhood, and then investigate how these childhood conditions are associated with the deterioration rate of cognitive function at older ages.

Table 2 reports the ordinary least squares (OLS) estimates based on Equation (1). Column (1) includes only the five indicators of the socio-economic conditions of childhood and a constant term in the regression. Columns (2) add a vector of socio-demographic characteristics to the specification of column (1), whereas column (3) further control for the birth year fixed effects and residential province fixed effects. Column (4) presents the results of the full model as Equation (1) by replacing the residential province fixed effects in column (3) with residential province by wave fixed effects. Column (5) applies the specification of column (4) but replaces the five early-life indicators with the aggregate index of adverse childhood conditions. All the regressions are estimated using the sampling weights.

Column (1) shows that all the five indicators of adverse childhood conditions exhibit significantly negative associations with the score of cognitive functioning at older ages, which are consistent with the pair-wise associations as reflected in Figure 1. Column (2) shows that the results are robust after controlling for socio-demographic characteristics, except that the estimated coefficients of the indicators decrease and the estimate for the coefficient of having uneducated mother becomes statistically insignificant. The signs of the control variables are consistent with expectation. On average, males have higher cognitive function scores than females.[6] The coefficients of age and age squared indicate that cognitive function declines at an increasing rate with ageing, which is in line with the pattern shown in Figure 1. The elderly who are of *Han* ethnicity have lower cognitive function scores than those of the minority, although the difference is not statistically significant. Column (3) indicates the results are robust after controlling for birth year fixed effects and residential province fixed effects.

Column (4) reports the results of our preferred specification. As shown, the elderly who had a childhood during which their fathers worked as farmers have 0.66 lower cognitive function scores, which is different from 0 at the 1% significance level. The elderly with uneducated fathers have 0.65 lower scores than those with educated fathers, and the estimate is statistically significant at the level of 1%. Having uneducated mothers is associated with 0.22 lower cognitive scores, but the association is statistically insignificant. The elderly who lacked adequate medical services during childhood have 0.51 lower scores, and those who had insufficient food during childhood have 0.36 lower scores. Both estimates are statistically significant at the 1% level. Column (5) reports the coefficient of the aggregate index. As shown, people with a one-point higher index of adverse childhood conditions have 0.52 lower cognitive scores when they get old. The estimate is significant at the 1% level. We take the estimates in columns (4) and (5) as the benchmark results in the analyses below.

To get a sense for the magnitude of the point estimates, we standardize cognitive function scores by survey wave and cohort and run regressions using the same specifications as in Table 2. As shown in Table A1, most of the estimates are comparable to those in Table 2. Specifically,

6 We dig deeper into the gender gap in cognitive function score in the heterogeneity analyses below.

column (4) of Table A1 shows that the elderly who had childhoods with fathers working as farmers have a 0.15 standard deviation lower scores of cognitive function. The elderly with uneducated fathers or uneducated mothers have 0.15 standard deviation or 0.07 standard deviation lower scores, respectively. The elderly who lacked adequate medical services during childhood have 0.13 standard deviation lower scores, whereas those who experienced food deprivation during childhood have 0.08 standard deviation lower scores. Column (5) shows that the cognitive function score decreases by 0.12 standard deviation as the index of adverse childhood conditions increases by one point (or by around one standard deviation), and the estimate is significant at the level of 1%.

We then turn to investigate the impact of early-life conditions on the deterioration rate of cognitive function at older ages based on Equation (2). Column (1) of Table 3 shows that the elderly who had childhoods with father working as a farmer experienced significantly faster deterioration in cognitive function than the reference group. Similarly, the elderly with uneducated mothers or those who lacked sufficient food during childhood also show a significantly faster decline in cognitive function in their late life. After controlling for the fixed effects, the signs and significance of the coefficients of interest remain robust. Specifically, column (4) shows that, given the other factors fixed, having a childhood with father working as a farmer is associated with faster decline in cognition, by a lower score of 0.3 points (or 0.06 standard deviation) in every three years, than those whose father worked in other occupations. The estimate is statistically significant at the level of 1%. Meanwhile, the elderly who had uneducated mothers and those who lacked sufficient food during childhood also exhibit significantly faster deterioration in cognitive function than their counterparts, by 0.33 points (or 0.06 standard deviation) and 0.15 points (or 0.03 standard deviation), respectively. For the aggregate index in column (5), the estimate implies that the cognitive function score of elders who had worse socio-economic conditions during childhood decreases by 0.17 more points (or 0.03 standard deviation) every three years, which is significant at the 1% level.

In summary, the results indicate that the elderly with worse childhood conditions measured by the paternal occupation, parental education, medical services, and nutrition, not only have lower level of cognitive function, but also exhibit a higher rate of deterioration in cognition. These results suggest that adverse early-life conditions may have persistent detrimental effects on people's cognitive functioning at their older ages.

4.2. Robustness Checks

One concern of the above analyses is that the childhood conditions are measured based on self-reports on retrospective questions, which causes recall bias that may be correlated with the cognitive ability of the elderly. Specifically, respondents with lower cognitive ability might report their early-life conditions more inaccurately. If this is the case, estimates on the relationship would be biased, although the direction of bias is ambiguous. To address the concern, we conduct the analyses separately among respondents with normal cognition and those who were cognitively impaired, and examine whether the associations simply reflect some spurious correlation due to recall bias. Following Zhang, Gu, and Hayward (2008), we define a respondent to be cognitively impaired if his or her cognitive score was smaller than 18, and consider their cognitive functioning to be normal, otherwise. As shown in Table A2, the results are actually robust for respondents with normal cognition. Specifically, among these people, we observe those with adverse childhood conditions have significantly lower cognitive function and exhibit faster decline in cognition. For the people who were cognitively impaired, we generally do not observe significant correlations between early-life conditions and the level of cognition or the change in cognition. In the analysis below in Section 4.4, we show results that adverse childhood conditions have significantly negative associations with different dimensions of cognitive functioning besides memory. Overall, these results suggest that the benchmark estimates are unlikely mainly driven by spurious correlation between cognitive ability and recall bias in measuring childhood conditions.

Another concern regarding the recall bias is that recall errors might also derive from a form of bias called "coloring", namely, the rating of experience may be affected by respondents' current situation (e.g., socio-economic status). If this is the case, estimates of the effect of childhood conditions on cognitive abilities (or cognitive deterioration) in old age are likely to be downward (or upward) biased. To address the concern, we re-examine the association between childhood conditions and old-age cognitive abilities (or cognitive deterioration) for respondents currently with high- and low-income, respectively. Table A3 shows that the estimates from both groups are generally consistent with the benchmark results, indicating that even conditional on current income status the associations remain robust. Such results should reduce the concern about spurious correlation caused by recall errors due to the coloring effect.

In the analyses on change in cognitive function, we focus on the sample of respondents observed in successive waves. One may worry that the estimates would be biased due to sample attrition. Specifically, if the elderly with worse health are less likely to be observed successively in the follow-up survey as indicated by previous studies (An and Liu, 2016), then we may underestimate the effect of adverse early-life conditions on the deterioration of cognitive function. To ascertain the direction and magnitude of the bias, we apply the method of inverse probability weighting following Wooldridge (2010). To be specific, we first estimate a probit model using the full sample of each wave: $\text{Prob}(D = 1|Z) = \Phi(Z)$, where D is a dummy indicating whether the individual was observed in the next wave and Z is a set of predictors.[7] We then predict the probability of being followed up based on the estimation, and construct a new weight variable by timing the inverse of the estimated probability and the original sampling weight. Table A4 reports the results using the same specification as Table 3 but adjusted by the new weight variable. As shown, the signs and statistical significance of the estimates are similar to the benchmark results, except that the positive association between having an uneducated father and cognitive deterioration becomes significant statistically at the level of 10%. Consistent with the conjecture, the magnitude of the estimates are generally larger after correcting for sample attrition in successive waves, except for the coefficient of having a childhood with father working as a farmer. However, the differences are small and none of them is statistically significant (not reported). Overall, the results suggest that the sample attrition is unlikely to be a severe threat to the analyses on the change in cognitive function.

Another related concern is that, although the sample is representative of the elderly aged 65 and above at the time of survey, it comprises only the survivors of adverse childhood experiences, which may suffer from a sample selection problem if the likelihood of being survived by the time of the survey is correlated with adverse childhood conditions (Bozzoli,

[7] The predictors include individuals' socio-demographic characteristics (i.e., age, age squared, gender, ethnicity, education, the occupation before age 60, marital status, and types of the residential place), dummies of birth cohort, interaction terms between residential province and survey wave, and an indicator of suffering from cancer.

Deaton, and Quintana-Domeque, 2009; Hu, Liu, and Fan, 2016). Prior research has found negative impact of adverse conditions on the longevity (Black, Hsu, and Taylor, 2015). We thus conceived our estimates of the impact of early-life conditions on late-life cognition to be lower bounds. An ideal way to address the selective mortality is to control for cumulative mortality rates from birth year to the survey year (Mazzonna, 2014). Unfortunately, we do not have such data. Instead, we examine whether our results are robust by controlling for province-cohort-wave fixed effects. With this specification, we can account for differences in regionally specific cumulative mortality rate. Table A5 reports the results. For easy comparison, we repeat the benchmark estimates in Columns (1), (2), (5), and (6). As shown, when we account for differences in regionally specific cumulative mortality rate by controlling for the province-cohort-wave fixed effect, the estimates are very similar to the benchmark results.[8] It is worth mentioning that the results are very similar if we control for birth cohort by wave fixed effects or residential province by birth cohort fixed effects along with residential province by wave fixed effects (results are available upon request). These results should further alleviate concerns related to possible bias induced by selective mortality.

Lastly, one may worry about learning effects on the cognitive test, i.e., respondents who participate the survey multiple times will perform better in the test (Banks and Mazzonna, 2012). The problem might be more important for slope analysis (i.e., change in cognition). To account for the potential learning effects, we control for dummies indicating the number of times that a respondent was observed in previous waves. The results barely change compared

[8] The number of observations are slightly different in the two specifications due to dropping of singleton observations in multiple-level fixed effect. The results are almost the same if we restrict the regression sample of the benchmark specification to be the same as that of the specification of multiple level of fixed effects. The results are available upon request.

to the benchmark estimates (available upon request), implying that learning effects are unlikely to seriously bias our estimates.

4.3. Mechanisms

What are the pathways of the long-term association between early-life conditions and cognitive function in old age? In this section, we explore the mechanisms by mediation analysis. Specifically, we estimate the following specification,

$$y_{icpt} = \alpha E_{icpt} + \gamma X_{icpt} + \theta M_{icpt} + \delta_c + \eta_{pt} + \varepsilon_{icpt}. \qquad (3)$$

where M_{icpt} is a vector of the mediators. Previous studies have highlighted the role of educational achievement and occupational experience in determining cognitive function of the elderly (Maguire et al., 2000; Berkman, 2000; Banks and Mazzonna, 2012; Schneeweis, Skirbekk, and Winter-Ebmer, 2014), as well as the impacts of early-life conditions on education and labor market outcomes for adults (Hoddinott et al., 2008; Maluccio et al., 2009; Lazuka, 2020). Research also has found marriage could be important pathway from early-life conditions to health in late life (van den Berg and Gupta, 2015). Meanwhile, the literature has documented stark differences in cognitive function between rural and urban residents in China (Cai, 2021), and found that early-life conditions may affect one's ability or desire to migrate (Barrett and Mosca, 2013a, 2013b). Therefore, we include the educational level of the respondent (illiterate, primary school, and middle school and above; taking illiterate as reference), the occupation category of the respondent before age 60 (farmer, industrial worker, manager, and others; taking farmer as reference), the marital status (currently married or not; taking unmarried as reference), and the place of residence (rural vs. urban; taking rural as reference) in the vector of the mediators. The other variables in Equation (3) are defined in the same way as in Equation (1). We test the two hypotheses on explaining the mechanism, namely the latency model and the pathway model, by comparing the estimates of parameter α from Equations (1) and (3). While the pathway model predicts that the coefficients of childhood conditions would attenuate after controlling for the mediators, the latency model indicates the childhood markers are still significant predictors even conditional on the mediation variables (Case, Fertig, and Paxson, 2005; Zhang, Gu, and Hayward, 2008). In a similar vein, we investigate the mediation effects of these variables on the rate of deterioration in cognition by the following specification:

$$y_{icpt} - y_{icpt+w} = \beta E_{icpt} + \zeta X_{icpt} + \kappa M_{icpt} + \delta_c + \eta_{pt} + \varepsilon_{icpt} - \varepsilon_{icpt+w}, \qquad (4)$$

where we add the vector of the mediators (i.e., M_{icpt}) into Equation (2).

To assess the extent to which the mediation factors can explain the long-term effects of childhood conditions on cognitive function at older ages, we draw upon the decomposition techniques used by Hsin and Xie (2014) and focus on the estimated effects of the aggregate index. Specifically, we first estimate coefficient α based on Equation (3), denoted as α^{full}. Then, we exclude factor m_{icpt}^{k} from Equation (3) and obtain the estimate of α, denoted as α^{full-k}, where m_{icpt}^{k} corresponds to one of the four groups of mediators mentioned earlier, $k = \{1,2,3,4\}$. We calculate $\underline{D}_k = \alpha^{full-k} - \alpha^{full}$ as the lower bound for the explanatory power of the mediator m_{icpt}^{k}. To obtain the upper bound for the estimate, we first estimate coefficient α based on Equation (1), i.e., excluding all the four mediators in the equation, denoted as α^{base}, and then add mediator m_{icpt}^{k} to the regression to obtain an estimate of α, denoted as α^{base+k}. We calculate $\overline{D}_k = \alpha^{base} - \alpha^{base+k}$ as the upper bound for the explanatory power of the mediator m_{icpt}^{k}. The same procedure applies to estimating the explanatory power of the mediators for the impact of childhood conditions on the *change* in cognitive function at older ages.

Columns (2) and (4) of Table 4 report the estimates based on the specification of Equation (3) using the score of cognitive function as the dependent variable. For the convenience of comparison, columns (1) and (3) replicate the benchmark results in columns (4) and (5) of Table 2, correspondently. Similarly, columns (5) through (8) present the results using the change in cognitive function scores as the outcome variable.

Comparing the estimated coefficients in regressions with and without controlling for the mediation variables, we find the magnitude of the point estimates for the childhood conditions decreases in absolute value. Meanwhile, the mediation variables strongly predict the cognitive scores at older ages. Specifically, the elderly with primary school education or above perform significantly better in the tests of cognitive function than those who are illiterate, whereas the elderly working as managers or in other occupations have significantly higher cognitive function scores than those working as farmers before the age of 60. The dummies for being married and living in urban areas positively correlate with cognitive function, both of which is significant at the 10% level or above. These results indicate that the mediators explain part of the associations between early-life conditions and cognitive function at older ages. We can draw similar conclusions by comparing columns (3) and (4), where we use the aggregate index of adverse childhood conditions. Specifically, the absolute value of the point estimate decreases from 0.52 to 0.33 after controlling for the mediation variables, and the mediators are significantly associated with the cognitive score.

Turning to the relationship between childhood conditions and the deterioration of cognitive function at older ages, the associations tend to attenuate in magnitude after controlling for the mediation variables. Meanwhile, the effect of food insufficiency during childhood on the deterioration of cognitive function at older ages turn out to be insignificant at the 10% level. The coefficients of the mediators imply that the elderly with higher education levels have a significantly lower rate of decline in cognitive function.

Table 5 reports the results that quantify the extent to which the mediation variables explain the relationship between childhood conditions and the level and rate of decline of cognitive function at older ages, where we focus on the results of the aggregate index of adverse childhood conditions. The first row replicates the coefficients of the aggregate index in columns (3) and (7) of Table 4. The second row shows the coefficients from columns (4) and (8) of the same table, as well as the percentages as a share of the estimates reported in the first row. The third row presents the differences between the coefficients in the first two rows and the corresponding percentages, which can be perceived as the part of the associations that are explained by the mediators. The bottom panel in Table 5 reports the estimates of the lower bound and upper bound for the explanatory power of the four groups of mediators based on the method described earlier.

The results show that, in total, the mediators explain 37.6% of the long-term association between the early-life conditions and the score of cognitive function at older ages. Among them, the educational attainment explains around 16% to 26%, whereas the occupation, marital status, and place of residence account for 7.5% to 19.6%, 0.2% to 1.5%, and 1.2% to 6.9%, respectively. In addition, the mediators predict 23.5% of the associations between the early-life conditions and the deterioration in cognition at older ages. Again, the association was mostly mediated by the respondents' educational levels, which accounts for around 15% to 20% of the effect of childhood conditions on the rate of cognitive deterioration.

These results imply that the educational attainment and occupation plays vital roles in the long-term effect of childhood conditions on both the level and the rate of decline of cognitive function among the elderly. There is little evidence that the marital status or the choice of residential location plays a significant role in mediating the negative effects of adverse childhood conditions on cognitive abilities in old age. For the latter factor, it is likely because most of the elderly did not migrate during their lifespan.[9] Although the mediators explain a significant portion of the effect, more than half of the effect remains unexplained. This suggests childhood conditions may directly affect cognitive function in old age, which is in line with prediction of the latency model.

4.4. Heterogeneity Analysis

Heterogeneity by gender and age group

Table 6 examines the heterogeneity of the results by gender and age group of the respondents. Specifically, Panel A reports results of regressions on the cognitive function score as specified in Equation (1), while Panel B shows the results of regressions on the change in cognitive function scores as in Equation (2). Columns (1) and (2) present the results using the subsamples of female and male, respectively, and columns (3) to (4) present the results by age group.[10]

The results on the level of cognitive score by gender suggest that early-life conditions

[9] In our analysis sample, only 28 percent of the elderly lived outside the county of their birth at the time of the survey.

[10] The sum of observations of the two age groups is slightly different from the total observations reported in earlier tables, due to dropping of singleton observations to avoid overestimating statistical significance in the estimation.

affect the cognitive function score in a similar way for females and males. Comparison on the magnitude of the estimates indicates that the associations of childhood conditions with cognitive scores are stronger among females than males. These results imply that female elders suffer more from the adverse childhood conditions than male elders do. This coincides with the conjecture that, given limited resources, parents will give priority to their sons over their daughters according to the traditional values of son preference (Lhila and Simon, 2007). Regarding the rate of decline in cognitive function, most signs of the point estimates are consistent with the hypothesis that adverse conditions during childhood accelerate the deterioration of cognitive function at older ages, although the estimates are only significant for the impact of paternal occupation on the cognition of females.

An examination of the heterogeneity by age group of the respondents reveals that the associations between early-life conditions and the level of cognitive function in late life are robust for both the age groups 65-80 and above 80. Meanwhile, the results suggest that the associations are generally stronger for the older group, except for the estimates of access to medical services. The results on the change in cognitive function indicate that, similar to the benchmark results, having a childhood with father working as a farmer, having an uneducated mother, and lacking sufficient food in childhood significantly speed up cognitive deterioration among the elderly aged 65-80, whereas the estimates for these factors are not significantly different from 0 among the older group except for the paternal occupation. Overall, the results imply that the adverse early-life conditions accelerate deterioration of cognitive function mainly during 65-80 years old, and the cognitive disparity persists after 80 years old.

Heterogeneity on different dimensions of cognitive function

As described in Section 2.2, the measure of cognitive function consists of several dimensions, including orientation, verbal fluency, immediate recall, delayed recall, numeracy, visual construction, and language. According to the literature, these dimensions can be further loosely classified into two categories (McArdle et al., 2002; Salthouse, 2006). One is the crystallized intelligence. It refers to recalling stored knowledge and past experiences, which covers the orientation and verbal fluency. The other category is the fluid intelligence. This involves comprehension and reasoning, which covers the other dimensions of cognitive functioning. Fluid intelligence are likely to be vulnerable to age-associated decline, whereas crystallized intelligence are less likely to be so (Richards and Deary, 2005). Thus, investigating whether childhood conditions have heterogeneous effects on different dimensions of cognitive function may provide insights into the way in which early life factors have long-term effects on cognition.

Table 7 presents the results using the same specification as that in column (4) of Table 2 but replaces the outcome with the measures by dimension. To make the results comparable across dimensions, we standardize the scores for each dimension by cohort and survey wave. Panel A reports the results using the aggregate index of adverse childhood conditions, while Panel B presents the results by including all five indicators of childhood conditions.

As shown in Panel A of Table 7, the estimated impact of the aggregate index on each dimension of cognitive functioning is negative and statistically different from 0 at the significance level of 1%. Among them, the estimated effects on the fluid intelligence (specifically, visual construction, numeracy, and language) are greater than the crystallized intelligence (i.e., orientation and verbal fluency). The results in Panel B further confirm this conclusion by examining the effects of five indicators of childhood conditions separately. Finally, as mentioned earlier, these results should alleviate the concerns of spurious correlation between cognitive function and recall bias in measuring childhood conditions, given the results are robust to cognitive dimensions other than memory.

Table A6 reports the estimates of the association between childhood conditions and change in each dimension of cognitive functioning. As shown in Panel A, the deterioration rates of orientation, verbal fluency, numeracy, and language significantly increase with adverse childhood conditions, while the associations with decline in memory and visual construction are not significantly different from 0 at significance level of 5%. Evidence on the association with individual factors during childhood are generally consistent with those of the aggregate index. Overall, these results indicate that the effects of childhood conditions on the rate of cognitive decline are heterogeneous across cognitive dimensions.

5. Conclusion

This paper examines the long-term relationship between childhood conditions and cognitive function at older ages by using unique longitudinal data of the elderly aged 65 and above in China. The results suggest that the elderly with adverse childhood conditions not only have lower scores of cognitive function but also exhibit a faster rate of deterioration in cognition. The analyses on the mechanisms indicate that the educational attainment is one of the most important channels mediating the effects of socio-economic conditions during childhood. Estimation on the bounds implies that the educational attainment accounts for about 16 to 26 percent of the associations between childhood conditions and the level of cognitive function of the elderly, and about 15 to 20 percent of the association between childhood conditions and the cognitive decline in old age. Moreover, after controlling for the plausible mediators, i.e., education, occupation, marital status, and living environment as adults, we still observe significant effects of the childhood conditions, suggesting that environments in early life may have direct impacts on the trajectory of cognitive development. Further analyses suggest that female elderly suffer more from adverse conditions during childhood than males, which aligns with the traditional values of son preference. Lastly, while socio-economic conditions during childhood have persistent effects on all dimensions of cognitive function in late life, the effects are more pronounced for the fluid intelligence than the crystallized intelligence.

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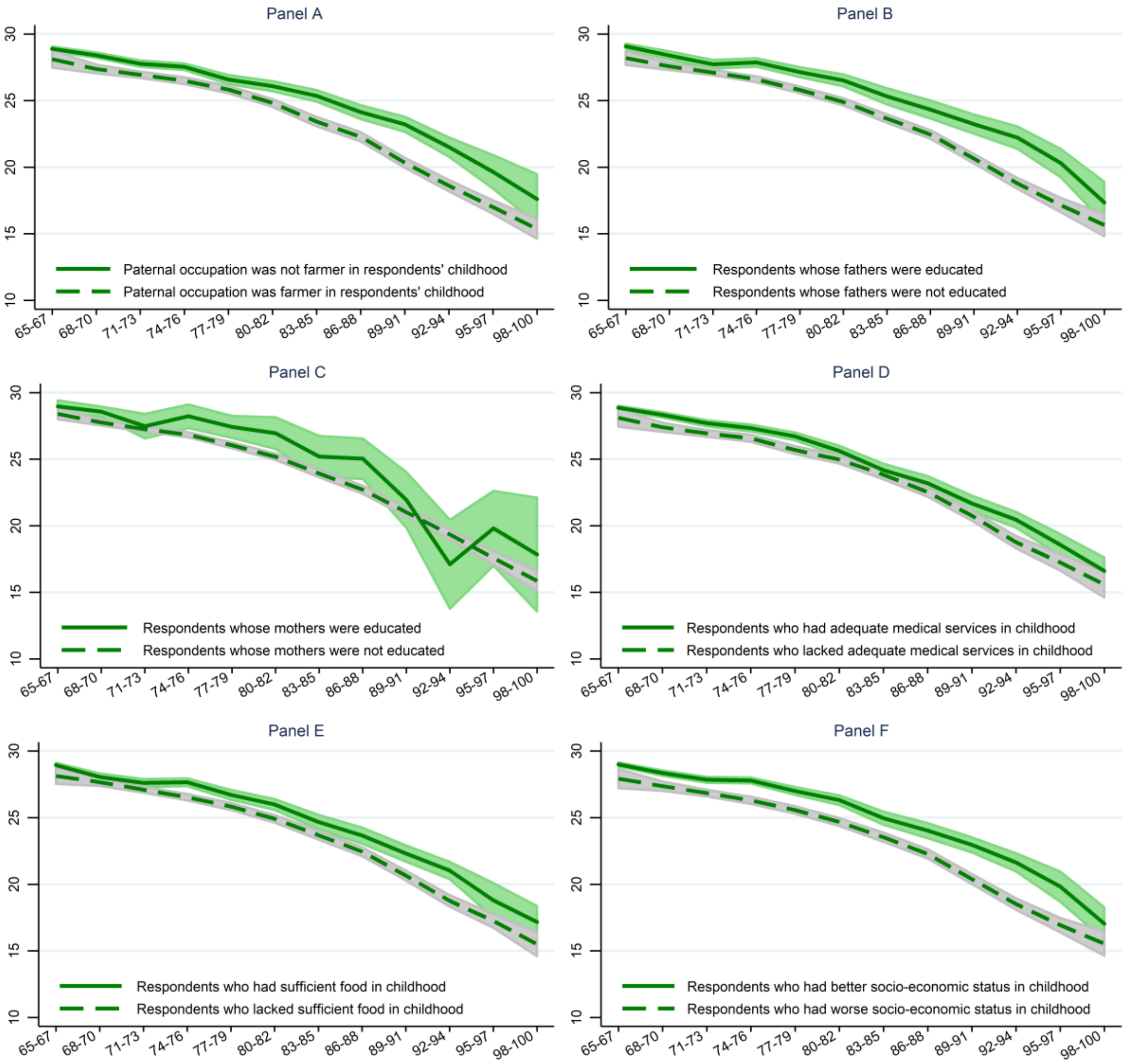
Figures and Tables

Figure 1. Age profiles of cognitive score by childhood conditions



Notes: The figure plots age profiles of the average cognitive score and 95% confidence intervals by childhood conditions. The solid line in each panel is for elders with favorable early-life conditions, while the dash line is for those with adverse early-life conditions. Panel A depicts the disparities by fathers' occupations (working as a farmer or not). Panel B and C are by fathers' and mothers' education (receiving formal education or not), respectively. Panel D is by condition of medical services during childhood (having adequate medical services or not). Panel E is by food deprivation during childhood (feeling hungry or not before going to bed). Panel F is by the index of adverse childhood conditions (the index is equal to or larger than the sample median or not).
Source: CLHLS 2005, 2008, 2011, 2014.

Table 1. Summary statistics

Variables	Mean	S.D.
Cognitive function score	26.87	5.20
Have childhood with father working as a farmer	0.63	0.48
Have uneducated father	0.77	0.42
Have uneducated mother	0.96	0.20
Lack adequate medical services in childhood	0.59	0.49
Lack sufficient food in childhood	0.69	0.46
Index of adverse childhood conditions	3.64	1.16
Male	0.49	0.50
Han nationality	0.79	0.41
Age	73.20	6.22
Education: Illiterate	0.43	0.50
Education: Primary school	0.39	0.49
Education: Middle school and above	0.18	0.38
Occupation: Farmer	0.48	0.50
Occupation: Worker	0.14	0.34
Occupation: Manager	0.10	0.30
Occupation: Others	0.28	0.45
Married	0.63	0.48
Live in urban	0.43	0.50
Observations	36634	

Notes: The table reports the mean and standard deviations of the main variables used in this paper. All statistics are calculated using the sampling weights.
Source: CLHLS 2005, 2008, 2011, 2014.

Table 2. Cognitive function at older ages and childhood conditions

	Cognitive function score				
	(1)	(2)	(3)	(4)	(5)
Have childhood with father working as a farmer	-1.004***	-0.695***	-0.671***	-0.663***	
	(0.110)	(0.111)	(0.115)	(0.116)	
Have uneducated father	-0.847***	-0.672***	-0.651***	-0.652***	
	(0.108)	(0.102)	(0.109)	(0.110)	
Have uneducated mother	-0.473***	-0.207	-0.214	-0.220	
	(0.173)	(0.174)	(0.160)	(0.161)	
Lack adequate medical services in childhood	-0.718***	-0.552***	-0.493***	-0.508***	
	(0.111)	(0.105)	(0.087)	(0.087)	
Lack sufficient food in childhood	-0.600***	-0.497***	-0.364***	-0.362***	
	(0.107)	(0.103)	(0.088)	(0.089)	
Index of adverse childhood conditions					-0.521***
					(0.049)
Male		1.041***	1.030***	1.022***	1.024***
		(0.128)	(0.123)	(0.125)	(0.125)
Han ethnicity		-0.220	-0.184	-0.208	-0.293**
		(0.142)	(0.147)	(0.148)	(0.145)
Age		0.990***	0.861***	0.969***	0.974***
		(0.159)	(0.142)	(0.161)	(0.161)
Age squared/100		-0.809***	-0.723***	-0.774***	-0.778***
		(0.099)	(0.094)	(0.092)	(0.092)
Constant	29.441***	-0.480	4.168	-0.917	-0.831
	(0.189)	(6.248)	(5.304)	(7.572)	(7.565)
Birth year fixed effect			Yes	Yes	Yes
Residential province fixed effect			Yes		
Residential province by wave fixed effect				Yes	Yes
Observations	36634	36634	36634	36634	36634

Notes: The table reports the OLS estimates of regressions on the cognitive function score. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2005, 2008, 2011, 2014.

Table 3. Change in cognitive function at older ages and childhood conditions

	Change in cognitive function scores (difference between waves)				
	(1)	(2)	(3)	(4)	(5)
Have childhood with father working as a farmer	0.386***	0.283***	0.304***	0.298***	
	(0.076)	(0.090)	(0.094)	(0.094)	
Have uneducated father	0.158	0.116	0.150	0.144	
	(0.109)	(0.109)	(0.104)	(0.103)	
Have uneducated mother	0.350*	0.291*	0.324*	0.331*	
	(0.182)	(0.177)	(0.174)	(0.181)	
Lack adequate medical services in childhood	0.071	0.029	0.048	0.057	
	(0.074)	(0.074)	(0.073)	(0.073)	
Lack sufficient food in childhood	0.160**	0.143*	0.149**	0.146*	
	(0.076)	(0.075)	(0.076)	(0.076)	
Index of adverse childhood conditions					0.166***
					(0.035)
Male		-0.086	-0.103	-0.098	-0.094
		(0.076)	(0.072)	(0.072)	(0.072)
Han ethnicity		0.127	0.153	0.229**	0.300***
		(0.095)	(0.095)	(0.100)	(0.088)
Age		-0.766***	-0.963***	-0.961***	-0.959***
		(0.125)	(0.165)	(0.186)	(0.186)
Age squared/100		0.569***	0.698***	0.693***	0.691***
		(0.081)	(0.109)	(0.110)	(0.110)
Constant	0.156	25.767***	33.120***	33.168***	33.240***
	(0.185)	(4.784)	(6.222)	(8.230)	(8.224)
Birth year fixed effect			Yes	Yes	Yes
Residential province fixed effect			Yes		
Residential province by wave fixed effect				Yes	Yes
Observations	27451	27451	27451	27451	27451

Notes: The table reports the OLS estimates of regressions on the change in cognitive function scores over two adjacent waves of the CLHLS. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table 4. Mechanisms of how childhood conditions shape cognitive function at older ages

	Cognitive function score				Change in cognitive function scores (difference between waves)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Have childhood with father working as a farmer	-0.663***	-0.310***			0.298***	0.233**		
	(0.116)	(0.101)			(0.094)	(0.092)		
Have uneducated father	-0.652***	-0.426***			0.144	0.097		
	(0.110)	(0.102)			(0.103)	(0.113)		
Have uneducated mother	-0.220	-0.080			0.331*	0.310*		
	(0.161)	(0.153)			(0.181)	(0.185)		
Lack adequate medical services in childhood	-0.508***	-0.418***			0.057	0.048		
	(0.087)	(0.083)			(0.073)	(0.072)		
Lack sufficient food in childhood	-0.362***	-0.204**			0.146*	0.118		
	(0.089)	(0.088)			(0.076)	(0.075)		
Index of adverse childhood conditions			-0.521***	-0.325***			0.166***	0.126***
			(0.049)	(0.042)			(0.035)	(0.038)
Male	1.022***	0.413***	1.024***	0.418***	-0.098	0.037	-0.094	0.039
	(0.125)	(0.105)	(0.125)	(0.104)	(0.072)	(0.092)	(0.072)	(0.092)
Han ethnicity	-0.208	-0.192	-0.293**	-0.192	0.229**	0.152	0.300***	0.186*
	(0.148)	(0.160)	(0.145)	(0.155)	(0.100)	(0.115)	(0.088)	(0.110)
Age	0.969***	0.950***	0.974***	0.954***	-0.961***	-0.961***	-0.959***	-0.959***
	(0.161)	(0.157)	(0.161)	(0.157)	(0.186)	(0.186)	(0.186)	(0.186)
Age squared/100	-0.774***	-0.752***	-0.778***	-0.756***	0.693***	0.693***	0.691***	0.691***
	(0.092)	(0.090)	(0.092)	(0.091)	(0.110)	(0.110)	(0.110)	(0.110)
Married		0.678***		0.672***		-0.050		-0.055
		(0.161)		(0.162)		(0.097)		(0.097)
Live in urban		0.242*		0.244*		0.105		0.102
		(0.138)		(0.139)		(0.099)		(0.099)

(continued on the next page)

Table 4 (continued)

	Cognitive function score				Change in cognitive function scores (difference between waves)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Education levels (reference: illiterate)								
Primary school		1.127***		1.135***		-0.318***		-0.313***
		(0.169)		(0.169)		(0.114)		(0.111)
Middle school and above		1.336***		1.341***		-0.417***		-0.414***
		(0.193)		(0.192)		(0.147)		(0.142)
Main occupation before age 60 (reference: farmer)								
Worker		0.231		0.228		0.222*		0.204
		(0.160)		(0.159)		(0.132)		(0.133)
Manager		0.452***		0.439***		-0.050		-0.076
		(0.165)		(0.163)		(0.132)		(0.131)
Others		0.512***		0.501***		-0.177*		-0.224**
		(0.137)		(0.137)		(0.105)		(0.104)
Constant	-0.917	-2.553	-0.831	-2.454	33.168***	33.468***	33.240***	33.622***
	(7.572)	(7.283)	(7.565)	(7.275)	(8.230)	(8.257)	(8.224)	(8.255)
Birth year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	36634	36634	36634	36634	27451	27451	27451	27451

Notes: The outcome variable in columns (1) to (4) is the cognitive function score, while the outcome variable in columns (5) to (8) is the change in cognitive function scores. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table 5. Decomposition of the explanatory power of mediation factors

	Cognitive function score				Change in cognitive function scores (difference between waves)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Magnitude	Percentage			Magnitude	Percentage		
Index of adverse childhood conditions	-0.521				0.166			
Index of adverse childhood conditions (control for all mediation factors)	-0.325	62.4			0.126	75.9		
Magnitude explained by all mediators	-0.196	37.6			0.039	23.5		
	Lower bound		Upper bound		Lower bound		Upper bound	
	Magnitude	Percentage	Magnitude	Percentage	Magnitude	Percentage	Magnitude	Percentage
Magnitude explained by education	-0.083	15.9	-0.137	26.3	0.025	15.1	0.033	19.9
Magnitude explained by occupation	-0.039	7.5	-0.102	19.6	0.012	7.2	0.016	9.6
Magnitude explained by marital status	-0.001	0.2	-0.008	1.5	0.000	0.0	0.001	0.6
Magnitude explained by residential place	-0.006	1.2	-0.036	6.9	-0.003	-1.8	-0.006	-3.6

Notes: The upper part of the table replicates the estimated coefficient of the index of adverse childhood conditions reported in Table 4, whereas the bottom part reports the lower bound and upper bound for the explanatory power of the four mediators, namely, education, occupation, marital status, and residential place of the respondents. See the text for details on the method for calculating lower and upper bounds. The left wing of the table (i.e., columns 1-4) reports the results for the cognitive function score, while the right wing (i.e., columns 5-8) reports the results for the change in cognitive function scores. All the percentages are calculated by the ratio of their left-hand-side coefficient to the coefficient in the first row of each wing, respectively.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table 6. Heterogeneity analysis

	By gender		By age group	
Subsample	Female	Male	65-80	>80
	(1)	(2)	(3)	(4)
Panel A: Cognitive function score				
Have childhood with father working as a farmer	-0.844***	-0.443***	-0.598***	-1.098***
	(0.178)	(0.121)	(0.129)	(0.206)
Have uneducated father	-0.801***	-0.483***	-0.582***	-1.170***
	(0.185)	(0.131)	(0.120)	(0.220)
Have uneducated mother	-0.251	-0.073	-0.218	-0.571
	(0.214)	(0.249)	(0.167)	(0.461)
Lack adequate medical services in childhood	-0.532***	-0.465***	-0.558***	-0.181
	(0.135)	(0.111)	(0.094)	(0.182)
Lack sufficient food in childhood	-0.501***	-0.266**	-0.317***	-0.600***
	(0.130)	(0.128)	(0.096)	(0.186)
Observations	19160	17474	14202	22427
Panel B: Change in cognitive function scores (difference between waves)				
Have childhood with father working as a farmer	0.406***	0.193	0.229**	0.907***
	(0.135)	(0.131)	(0.102)	(0.241)
Have uneducated father	0.097	0.176	0.136	0.284
	(0.131)	(0.171)	(0.112)	(0.257)
Have uneducated mother	0.210	0.459	0.365*	-0.055
	(0.234)	(0.292)	(0.192)	(0.696)
Lack adequate medical services in childhood	-0.016	0.128	0.103	-0.418*
	(0.099)	(0.107)	(0.078)	(0.223)
Lack sufficient food in childhood	0.147	0.152	0.192**	-0.242
	(0.105)	(0.114)	(0.082)	(0.239)
Observations	14353	13098	14053	13395
Individual level controls	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes

Notes: Columns (1) and (2) report the OLS estimates based on the subsamples of females and males, respectively, while columns (3) to (4) report the estimates based on the subsamples of age groups 65-80 and above 80, respectively. Panel A reports the results using the cognitive function score as the outcome variable. Panel B reports the results using the change in cognitive function scores as the outcome variable. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table 7. Cognitive function at older ages by dimension and childhood conditions

Cognitive function score by dimension	Orientation	Verbal frequency	Immediate recall	Delayed recall	Numeracy	Visual construction	Language
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A							
Index of adverse childhood conditions	-0.077***	-0.068***	-0.053***	-0.072***	-0.093***	-0.130***	-0.089***
	(0.012)	(0.009)	(0.011)	(0.010)	(0.011)	(0.009)	(0.013)
Panel B							
Have childhood with father working as a farmer	-0.111***	-0.105***	-0.032	-0.069***	-0.117***	-0.116***	-0.134***
	(0.032)	(0.024)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Have uneducated father	-0.087***	-0.091***	-0.088***	-0.081***	-0.119***	-0.151***	-0.101***
	(0.025)	(0.021)	(0.023)	(0.024)	(0.024)	(0.029)	(0.025)
Have uneducated mother	-0.064**	0.036	0.064	-0.118***	-0.013	-0.136***	-0.099***
	(0.031)	(0.046)	(0.076)	(0.042)	(0.050)	(0.053)	(0.034)
Lack adequate medical services in childhood	-0.066***	-0.054***	-0.075***	-0.082***	-0.092***	-0.135***	-0.092***
	(0.021)	(0.019)	(0.019)	(0.020)	(0.020)	(0.021)	(0.021)
Lack sufficient food in childhood	-0.053**	-0.054***	-0.046**	-0.042*	-0.069***	-0.115***	-0.030
	(0.021)	(0.020)	(0.019)	(0.022)	(0.020)	(0.023)	(0.026)
Individual level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	36634	36634	36634	36634	36634	36634	36634

Notes: The outcome variables in each column represent one dimension of cognitive function. Panel A reports the OLS estimates of regressions using the same specification as in column (5) of Table 2, while Panel B reports those of regressions with the same specification as in column (4) of the same table. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2005, 2008, 2011, 2014.

Online Appendices

Table A1. Normalized cognitive function at older ages and childhood conditions

	Cognitive function score (normalized)				
	(1)	(2)	(3)	(4)	(5)
Have childhood with father working as a farmer	-0.152***	-0.149***	-0.148***	-0.147***	
	(0.024)	(0.029)	(0.029)	(0.029)	
Have uneducated father	-0.162***	-0.157***	-0.148***	-0.148***	
	(0.024)	(0.026)	(0.026)	(0.026)	
Have uneducated mother	-0.069*	-0.068	-0.073*	-0.074*	
	(0.040)	(0.042)	(0.038)	(0.039)	
Lack adequate medical services in childhood	-0.141***	-0.134***	-0.122***	-0.125***	
	(0.024)	(0.024)	(0.021)	(0.021)	
Lack sufficient food in childhood	-0.106***	-0.110***	-0.081***	-0.080***	
	(0.024)	(0.024)	(0.023)	(0.023)	
Index of adverse childhood conditions					-0.121***
					(0.012)
Male		0.206***	0.203***	0.201***	0.202***
		(0.028)	(0.027)	(0.027)	(0.027)
Han ethnicity		-0.022	-0.028	-0.033	-0.049
		(0.039)	(0.037)	(0.037)	(0.034)
Age		-0.027	-0.037	-0.021	-0.020
		(0.036)	(0.034)	(0.035)	(0.035)
Age squared/100		0.021	0.022	0.011	0.010
		(0.022)	(0.022)	(0.020)	(0.020)
Constant	0.439***	1.225	1.855	1.254	1.262
	(0.043)	(1.398)	(1.289)	(1.656)	(1.655)
Birth year fixed effect			Yes	Yes	Yes
Residential province fixed effect			Yes		
Residential province by wave fixed effect				Yes	Yes
Observations	36634	36634	36634	36634	36634

Notes: The table reports the OLS estimates of regressions on the standardized (by survey wave and cohort) cognitive function score. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: CLHLS 2005, 2008, 2011, 2014.

Table A2. Examination on recall bias in measuring childhood conditions: Heterogeneity by cognitive ability

Subsample	Cognitive function score				Change in cognitive function scores (difference between waves)			
	Score⩾18		Score<18		Score⩾18		Score<18	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Have childhood with father working as a farmer	-0.245***		-0.204		0.333***		2.772***	
	(0.054)		(0.509)		(0.097)		(1.005)	
Have uneducated father	-0.344***		-0.656		0.241**		2.528**	
	(0.054)		(0.638)		(0.110)		(1.044)	
Have uneducated mother	-0.060		1.005		0.395**		0.503	
	(0.123)		(1.204)		(0.198)		(3.002)	
Lack adequate medical services in childhood	-0.226***		0.111		0.141*		0.953	
	(0.048)		(0.409)		(0.079)		(0.832)	
Lack sufficient food in childhood	-0.265***		0.201		0.121		0.281	
	(0.050)		(0.469)		(0.084)		(0.894)	
Index of adverse childhood conditions		-0.256***		-0.047		0.214***		1.407***
		(0.021)		(0.214)		(0.036)		(0.397)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29966	29966	6668	6668	24752	24752	2699	2699

Notes: The table reports the OLS estimates based on the subsamples of respondents with normal cognition (score⩾18) and those who were cognitively impaired (score<18). The outcome variable in columns (1) to (4) is the cognitive function score, while the outcome variable in columns (5) to (8) is the change in cognitive function scores. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table A3. Examination on recall bias in measuring childhood conditions: Heterogeneity by income level

Subsample	Cognitive function score				Change in cognitive function scores (difference between waves)			
	Low income		High income		Low income		High income	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Have childhood with father working as a farmer	-0.753***		-0.475***		0.214		0.398***	
	(0.146)		(0.141)		(0.138)		(0.148)	
Have uneducated father	-0.725***		-0.586***		0.097		0.258**	
	(0.192)		(0.118)		(0.178)		(0.122)	
Have uneducated mother	-0.301		-0.199		0.448		0.207	
	(0.315)		(0.183)		(0.300)		(0.234)	
Lack adequate medical services in childhood	-0.530***		-0.434***		0.090		0.024	
	(0.112)		(0.113)		(0.111)		(0.113)	
Lack sufficient food in childhood	-0.505***		-0.166		0.175		0.208*	
	(0.125)		(0.119)		(0.126)		(0.117)	
Index of adverse childhood conditions		-0.599***		-0.400***		0.155***		0.217***
		(0.075)		(0.048)		(0.058)		(0.048)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19228	19228	16775	16775	15115	15115	12265	12265

Notes: The table reports the OLS estimates based on the subsamples of respondents currently with low- or high-income. The outcome variable in columns (1) to (4) is the cognitive function score, while the outcome variable in columns (5) to (8) is the change in cognitive function scores. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table A4. Change in cognitive function at older ages and childhood conditions: Accounting for sample attrition

	Change in cognitive function scores (difference between waves)				
	(1)	(2)	(3)	(4)	(5)
Have childhood with father working as a farmer	0.350***	0.223**	0.258***	0.253***	
	(0.078)	(0.090)	(0.093)	(0.092)	
Have uneducated father	0.209*	0.162	0.199*	0.190*	
	(0.109)	(0.108)	(0.105)	(0.104)	
Have uneducated mother	0.357*	0.289	0.333*	0.333*	
	(0.183)	(0.176)	(0.172)	(0.177)	
Lack adequate medical services in childhood	0.086	0.031	0.052	0.064	
	(0.076)	(0.076)	(0.075)	(0.074)	
Lack sufficient food in childhood	0.159**	0.133*	0.156**	0.148*	
	(0.078)	(0.078)	(0.079)	(0.079)	
Index of adverse childhood conditions					0.169***
					(0.034)
Male		-0.094	-0.109	-0.110	-0.108
		(0.078)	(0.074)	(0.074)	(0.074)
Han ethnicity		0.156	0.184*	0.249**	0.293***
		(0.095)	(0.096)	(0.100)	(0.088)
Age		-0.733***	-1.019***	-1.013***	-1.014***
		(0.113)	(0.159)	(0.174)	(0.174)
Age squared/100		0.548***	0.742***	0.726***	0.726***
		(0.073)	(0.105)	(0.105)	(0.105)
Constant	0.224	24.478***	34.848***	35.152***	35.346***
	(0.185)	(4.361)	(5.987)	(7.573)	(7.569)
Birth year fixed effect			Yes	Yes	Yes
Residential province fixed effect			Yes		
Residential province by wave fixed effect				Yes	Yes
Observations	27451	27451	27451	27451	27451

Notes: The table reports the OLS estimates of regressions on the change in cognitive function scores over two adjacent waves of the CLHLS. All regressions are estimated using inverse probability weights to adjust for sample attrition. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table A5. Robustness of results by accounting for regionally specific cumulative mortality rate

	Cognitive function score				Change in cognitive function scores (difference between waves)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Have childhood with father working as a farmer	-0.663***		-0.628***		0.298***		0.276***	
	(0.116)		(0.121)		(0.094)		(0.097)	
Have uneducated father	-0.652***		-0.602***		0.144		0.095	
	(0.110)		(0.123)		(0.103)		(0.117)	
Have uneducated mother	-0.220		-0.318*		0.331*		0.334	
	(0.161)		(0.183)		(0.181)		(0.207)	
Lack adequate medical services in childhood	-0.508***		-0.485***		0.057		0.063	
	(0.087)		(0.092)		(0.073)		(0.081)	
Lack sufficient food in childhood	-0.362***		-0.391***		0.146*		0.194**	
	(0.089)		(0.093)		(0.076)		(0.084)	
Index of adverse childhood conditions		-0.521***		-0.510***		0.166***		0.163***
		(0.049)		(0.052)		(0.035)		(0.036)
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes			Yes	Yes		
Residential province by wave fixed effect	Yes	Yes			Yes	Yes		
Residential province by birth year by wave fixed effect			Yes	Yes			Yes	Yes
Observations	36634	36634	36395	36395	27451	27451	26969	26969

Notes: The table compares the benchmark estimates and estimates from specification which accounts for regionally specific cumulative mortality rate by province-cohort-wave fixed effect. The number of observations are slightly different in the two specifications due to dropping of singleton observations in multiple-level fixed effects. The outcome variable in columns (1) to (4) is the cognitive function score, while the outcome variable in columns (5) to (8) is the change in cognitive function scores. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.

Table A6. Cognitive decline at older ages by dimension and childhood conditions

Change in cognitive function score by dimension	Orientation	Verbal frequency	Immediate recall	Delayed recall	Numeracy	Visual construction	Language
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A							
Index of adverse childhood conditions	0.015***	0.016***	0.010	0.009*	0.019***	0.001	0.017***
	(0.003)	(0.005)	(0.006)	(0.005)	(0.004)	(0.009)	(0.004)
Panel B							
Have childhood with father working as a farmer	0.024**	0.043***	0.027*	-0.000	0.023**	-0.009	0.036***
	(0.010)	(0.012)	(0.015)	(0.014)	(0.011)	(0.024)	(0.011)
Have uneducated father	0.008	0.004	0.016	0.005	0.018	0.037	0.019
	(0.012)	(0.012)	(0.011)	(0.016)	(0.013)	(0.024)	(0.012)
Have uneducated mother	0.011	0.031	0.049	0.028	0.054**	-0.015	0.017
	(0.014)	(0.028)	(0.052)	(0.026)	(0.024)	(0.044)	(0.015)
Lack adequate medical services in childhood	0.017**	0.009	-0.005	-0.009	0.016*	-0.018	-0.000
	(0.007)	(0.012)	(0.010)	(0.012)	(0.009)	(0.019)	(0.010)
Lack sufficient food in childhood	0.014*	0.007	-0.005	0.036***	0.014	0.003	0.016*
	(0.008)	(0.010)	(0.010)	(0.013)	(0.010)	(0.020)	(0.009)
Individual level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Residential province by wave fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27451	27451	27451	27451	27451	27451	27451

Notes: The outcome variables in each column represent change in cognitive function scores (by dimension) over two adjacent waves of the CLHLS. Panel A reports the OLS estimates of regressions using the same specification as in column (5) of Table 3, while Panel B reports those of regressions with the same specification as in column (4) of the same table. All regressions use the sampling weights. The standard errors reported in parentheses are clustered at the individual level. Significance: *** p < 0.01, ** p < 0.05, * p < 0.1.
Source: CLHLS 2002, 2005, 2008, 2011, 2014, 2018.