

Qi, Shouwei; Li, Xiang; Matthews, Kent

Working Paper

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Cardiff Economics Working Papers, No. E2024/4

Provided in Cooperation with:

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Suggested Citation: Qi, Shouwei; Li, Xiang; Matthews, Kent (2024) : The intergenerational effect of parental health shocks on adult children fertility decisions in China, Cardiff Economics Working Papers, No. E2024/4, Cardiff University, Cardiff Business School, Cardiff

This Version is available at:

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Shouwei Qi, Xiang Li and Kent Matthews

January 2024

ISSN 1749-6010

Cardiff Business School
Cardiff University
Colum Drive
Cardiff CF10 3EU
United Kingdom
t: +44 (0)29 2087 4000
f: +44 (0)29 2087 4419
business.cardiff.ac.uk

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The Intergenerational Effect of Parental Health Shocks on Adult Children Fertility Decisions in China

Shouwei Qi^a, Xiang Li^a and Kent. Matthews^{b,c,a*}

January 2024

*^aSchool of Public Finance and Taxation, Zhongnan University of Economics and Law;
^bCardiff Business School, Cardiff University, UK; ^cNottingham University Business School,
University of Nottingham Ningbo China.*

Abstract

We investigate the intergenerational effect of parental health shocks on the fertility choices of adult children in China. By using a comprehensive longitudinal dataset of Chinese households, severe and unexpected health shocks to parents have been identified. To address sample imbalance issues in survey data and endogeneity concerns characteristic of traditional health shock studies, we employ two matching methodologies: Coarsened Exact Matching (CEM) and Propensity Score Matching (PSM). Our findings indicate that parental health shocks significantly postpone the reproductive age of adult children and reduce their likelihood of having more children than they originally planned. We also find persistent differences in fertility decisions for the first, second and third child among adult children. The economic constraints inferred from this study have notable implications on the reduced fertility behavior of adult children, thereby affecting their entire reproductive life cycle.

Keywords: parental health shocks, fertility decisions, intergenerational effect

JEL: D01, D31, I12, I13, J18

1. Introduction

The global decline in birth rates has drawn significant attention in recent years. China, in 2022, registered its first population decrease in over six decades. Despite implementing pro-natalist policies¹ like the repeal of the one-child policy in 2016, the world's most populous nation continues to experience a decline or stagnation in its total fertility rate (TFR) (Yang et al., 2022). This paper contributes to the ongoing academic discourse by examining a previously overlooked factor: the effect of parental health shocks on fertility decisions in China.

This paper suggests that parental health shocks act as significant negative economic shocks to offspring, potentially altering their fertility behavior. Parental health shocks may lead to a re-evaluation of adult children's fertility decisions in two ways. Firstly, a severe parental health shock may lead to increased medical costs and reduced income due to inability to work, placing financial strain on adult children and possibly delaying or preventing the childbearing decision of the adult children. Secondly, adult children may need to devote more time to caring for their sick parents, reducing the time available for their own childbearing and childrearing. This proposition holds relevance in China, a country where the elderly population often lacks sufficient financial and medical security. We analyze the intergenerational economic spillover effects of these parental health shocks on the childbearing decisions of adult children. By investigating the intergenerational spillover effects of health on fertility, our research unveils an overlooked dimension of China's declining fertility rate.

Former studies have associated fertility decisions extensively with economic variables like income, wealth, and employment status (Bellani, 2020; Arpino, Luppi, and Rosina, 2021), as well as historical events such as land reforms and malnutrition (Ali et al., 2022; Li and Menon, 2022). However, these studies often struggle with endogeneity issues, such as unemployment resulting from childbearing (Wagstaff, 2010). In societies lacking social security, health shocks can significantly escalate family expenditure and the direct costs of child-rearing (Pohl et al., 2014). Evidence supporting this claim can be found in studies exploring similar concepts. For example, research by Lindeboom et al. (2016) shows that health shocks not only impact the individual experiencing the shock but can have intergenerational effects. These effects can manifest in reduced wealth accumulation, as demonstrated by Conley and Thompson (2011), and this economic consequence can

¹ Chinese Communist Party Central Committee, the State Council. The decision on optimizing the fertility policy to enhance the long-term balanced development of population. 2021. http://www.gov.cn/xinwen/2021-07/20/content_5626190.htm.

indirectly influence the fertility decisions of adult children.

Our research contributes to the existing literature by closely examining how parental health shocks impact the fertility decisions of adult children, particularly in the unique demographic context of China. This is distinct from prior research that has mainly focused on the factors of gender, income, and education. Our study, drawing on rich longitudinal data, unpacks the crucial but often neglected aspects of parental health in shaping adult children's fertility decisions. By investigating parental health shocks as a potential source of these intergenerational effects, our study bypasses the endogeneity issue, offering a more direct depiction of how familial economic situations and fertility decisions interact. Besides, considering parental health shocks helps to sidestep potential reverse causality from childbearing affecting the health status of adult children.

In the backdrop of China's significant demographic transitions and recent shift from one-child to two-child policy and third-child policy, our research question holds a timely relevance. Understanding the influences on fertility behavior has become pivotal in a society grappling with rapid aging and shrinking workforce, making this study not just academically rigorous, but also empirically relevant. Furthermore, given China's aging population and rising healthcare costs, the potential influence of parental health shocks on fertility decisions has gained prominence, underscoring the importance of our study.

This study fuses the economic implications of parental health shocks with Becker's (1960) influential research on childbearing decision-making. We posit that these shocks can not only affect individual health but also markedly disturb the economic stability of entire families due to lost income and healthcare expenditures. We tackle common endogeneity problems in health shock studies by employing Coarsened Exact Matching (CEM), Propensity Score Matching (PSM), linear and non-linear panel data model strategies. Our selection of health shock variables – severe chronic diseases that largely stem from accumulated long-term lifestyle factors – allows us to evade potential reverse causality issues.

Our empirical results reveal that parental health shocks decrease the probability of adult children having children by 10.5% and defer the average age of first childbirth for women and men by 0.436 and 0.824 years, respectively. By insulating families from the economic repercussions of health crises, such policies could potentially lessen their influence on fertility choices. Beyond economic considerations, our results also shed light on the profound influence of parental health shocks on the life trajectory of adult children. Parental health shocks can reshape adult children's priorities and decisions, from their financial management to family planning, signifying an intense parent-child interaction often

overlooked.

The remainder of the paper is organized as follows. Section 2 contextualizes the institutional background in China. Section 3 presents a general model of fertility decisions. Section 4 explains the identification strategy and data. Section 5 outlines the empirical results and analysis, while Section 6 concludes with policy recommendations based on our findings.

2. Institutional background.

The inverse relationship between fertility rates and economic development is a well-established empirical fact across different nations. However, this association is particularly complex in China due to the intricate web of socio-economic factors and state-imposed family planning policies shaping household fertility decisions. An essential component that needs consideration in the context of fertility decisions is the economic fallout of parental health shocks on Chinese families, especially considering China's unique demographic transitions and familial structures.

2.1 China's Population Policy and its Economic Implications on Fertility Decisions

China's unique birth policy makes its demographic transition different from other countries. Table 1 shows the fertility policy shifts in China. China had an enforced birth-limit policy since the late 1960s with the "Later, Longer, and Fewer" family-planning campaign (later marriage, longer intervals between births, and fewer children). In 1982, family planning was set as a basic national policy, and the government started to directly target the number of children per family, requiring a couple to have only one child. According to the World Bank (2004), fertility in China has declined from 5.78 in 1970 to 1.89 in 2000.

In recent years, the authorities have progressively relaxed these policies. Changes included the easing of birth spacing restrictions in some provinces and relaxation of the "double-single two-child" policy by 2011. The one-child policy was phased out in 2013 and formally ended in 2015. By 2016, the policy termination's cumulative effect saw the birth rate climb to 17.86 million, the highest since 2000. Yet, population growth remained below official targets, with a "fertility cliff" appearing in 2017². In May 2021, the government announced the "three-child policy," reversing the long-standing population limitation policies due to concerns over declining fertility and rapid population aging.

² These policy modifications have had profound impacts on the family structure and intergenerational support system in China. For instance, the one-child policy transformed the traditional extended family structure into a nuclear family structure, leading to a sharp decline in the average family size.

Notably, the response to this policy alteration has been less than anticipated (Zeng & Hesketh, 2016), suggesting that the current low fertility rate reflects active choices rather than policy constraints. This tepid response underscores the criticality of examining the socio-economic variables shaping fertility decisions in China.

Table 1
Fertility Policy in China

Policy	Time
Encouragement of fertility	1949-1953
Family Planning	1954-1977
One-Child Policy	1978-2001
Two-child Policy (Selective)	2002-2015
Two-child Policy (Universal)	2016-2021
Third-child Policy	2021-Current

Source: <http://en.nhc.gov.cn>

2.2 Intergenerational Characteristics of Chinese Families

Chinese families display unique intergenerational traits that profoundly influence fertility decisions. Chinese familial structures, shaped by traditional Confucian values, place significant emphasis on filial piety and the continuity of family lineage. Historically, this translated into a preference for sons who were entrusted with the care of their elderly parents. The traditional Chinese family model leaned heavily towards close familial bonds, typically manifesting as intergenerational co-residence (Zeng & Hesketh, 2016), where elderly individuals predominantly relied on support from their offspring (Zhang and Zhu, 2021).

However, the one-child policy heralded a shift from the conventional intergenerational co-residence to the predominance of nuclear families, leading to the '4-2-1' structure (four grandparents, two parents, one child). This alteration is crucial as, in extended family environments, the impact of parental health shocks could be cushioned through intergenerational resource transfers. In contrast, in a nuclear family setup, a single child might bear the full brunt of a parent's health shock, affecting their financial, emotional, and psychological well-being. This has, in turn, intensified the perceived 'cost' of childbearing, potentially influencing the prevailing low fertility rates even amidst policy relaxations.

While we focus predominantly on the economic and social ramifications of parental health shocks on fertility decisions, we acknowledge the shift from intergenerational co-residence to nuclear families. The shift towards nuclear families has further spotlighted the burden on the younger generation, given China's low fertility rate, aging population, limited social security, and modest welfare provisions. This can perpetuate a cycle of

intergenerational poverty, with profound implications for fertility decisions.

Additionally, we acknowledge the importance of quantifying the proximity among generations, as it may affect the degree and nature of intergenerational transfers. However, our data do not allow us to measure the exact distance or frequency of contact between adult children and their parents. Therefore, we use household registration (Hukou) as a proxy for co-residence status, and we control for city differences and urban-rural fixed effects in our empirical analysis. We also conduct a robustness check using a subsample of households that report living with their parents or parents-in-law in the same dwelling unit.

The low fertility rate and aging population in China have only intensified the challenges faced by families in caring for their elderly members, with the burden of elderly care becoming increasingly significant for the younger generation. The lack of social security and low level of social welfare in China mean that adult children must provide most financial support to their elderly parents, affecting not only their economic status but also their own health and well-being. Thus, the impact of parental health shocks on families can create a vicious cycle of intergenerational poverty, which has significant implications for fertility decisions.

3. A general model of fertility choice

Our framework aligns the effects of parental health shocks with Becker's (1960) foundational work on fertility decision-making. We posit that health shocks extend beyond affecting individual health, and significantly impact the economic stability of entire families due to lost income and heightened healthcare expenditures. Drawing on the theory of adult children maximizing utility subject to a budget constraint, a time constraint, and a child quality production function, we examine how parental health shocks affect the allocation of time between work, leisure, and childcare and how this, in turn, influences fertility decisions.

At the beginning of period t , each adult couple has one unit of time available for allocation between work (T_k), leisure (l_k), and childcare (Q_k). The wage per unit of time is represented by ω . Under the assumption of parental altruism, if the parents are not affected by health shocks and the adult children decide to have a child in period t , the parents will help in taking care of the child, sharing Q_O of the childcare time. This reduces the amount of childcare time required by the adult children, who only need to allocate $Q_k - Q_O$ to childcare.

However, in the event of a parental health shock, the situation changes. In addition to making a transfer payment I_t to support their affected parents, the adult children also lose the support of their parents in childcare. The interplay between these two opposing forces will

shape the fertility decisions of adult children in the presence of parental health shocks.

To model the decision-making process, we adopt the Constant Elasticity of Substitution (CES) utility function, as it can be viewed as a problem in Bellman's equation for a Barro-Becker style dynasty with parental altruism. Our framework assumes the utility of consumption follows the functional form $\frac{c^{1-\delta}}{1-\delta}$ where $0 < \delta < 1$. This approach is consistent with the works of Barro, (1974) and Becker & Barro (1988) who explore CES utility functions in the context of intergenerational altruism and fertility decisions. For simplicity, we let the wage of the adult children (ω) serve as the budget constraint. The quality of each child (q) is also considered a crucial factor in shaping fertility decisions. Quality is assumed to be equal across families but differing between families and its utility is represented by $V(q)$, with higher quality children leading to higher utility. The cost of each unit of quality is denoted by π .

In addition, we acknowledge leisure as an alternative use of time and model its utility as a function of $\varphi(L)$. The fertility preference of adult children is defined as $Y=Y(n, \pi q, B)$, which depends on the number of children they have (n), the cost of raising a child (πq), and the availability of help in childcare (B). Our model suggests that as the number of children in a family increase, the marginal cost of having an additional child also increases.

The optimization problem of adult children k at period t is modeled using equation (1) and (2), which incorporates the trade-off between the benefits and costs of having children. The benefits of childbearing are represented by the expected utility of childbearing, while the costs are represented by the cost of having each child, πq . Equation (2) represents the budget constraint faced by adult children at period t . On the left side, we have the income and support received from parents, symbolized by ω_k and I_t , where ω_k represents the unit wage of the adult children, L_k denotes the time for leisure, and $Q_{k,t}$ and $Q_{0,t}$ represent the childcare time and the time parents help in taking care of the child respectively. The right side of the inequality accounts for the costs associated with raising children and consumption $c_{k,t}$, where π denotes the cost of each unit of child quality, n denotes the number of children, and binary B indicates the presence of a parental health shock.

Our utility function incorporates the term $Y_{k,t}V_{k,t}(q)$ to represent the trade-off between the quantity and quality of children. The utility function also includes the adult children's labor supply and the preference for having children, represented by the value of having children, $Y_{k,t}V_{k,t}(q)$. Specifically, $Y_{k,t} = Y_{k,t}(n, \pi q, B)$ for the adult child k in the t period. The value of $Y_{k,t}$ is negatively correlated with the number of children and the cost of having

each child, but positively correlated with the amount of childcare that can be shared with their parents. $Y_{k,t}$ represents the fertility preference of adult children, which depends on the number of children they have, the cost of raising a child, and the availability of help in childcare. The higher the value of $Y_{k,t}$, the greater the utility obtained from choosing to have children. This term is crucial in capturing the dynamics of fertility decisions in our model.

The utility of adult children K in period t can be expressed as:

$$\max_{c,n,q,\ell} U_{k,t}(c, l, V) = \frac{c_{k,t}^{1-\delta}}{1-\delta} + \varphi(L_k) + nY_{k,t}V_{k,t}(q) \quad \#(1)$$

s. t.

$$\left\{ \begin{array}{l} \omega_k \{1 - L_k - [Q_{k,t} - Q_{0,t} * Q_{0,t}(1 - B)]\} + I_t * (1 - B) > c_{k,t} + n\pi q \\ T_{k,t} + L_k + Q_{k,t} - Q_{0,t} * (1 - B) = 1 \end{array} \right. \quad \#(2)$$

The model considers the binary decision of whether the parents of the adult children receive a health shock in a given period, represented by the binary variable B . If the parents receive a health shock, $B=1$, and $B=0$, otherwise. The parental health shock impacts the fertility decision of adult children by altering their expected utility of childbearing.

The closed-form solution for optimal fertility, n^* , is derived as given in equations (3) (see Appendix for details). In the absence of a health shock, $B=0$, the optimal fertility is given by equation (4). With a health shock, $B=1$, the optimal fertility is given by equation (5). The effect of a health shock on fertility is shown in equation (6). The results show that parental health shocks lower the fertility of the adult children, represented by the inequality $Y_{k,t}(B=1) < Y_{k,t}(B=0)$.

$$n^* = \frac{\omega_k + I_t(1 - B) - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t}(1 - B))}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}V_{k,t}(q)} \right]^{\frac{1}{\delta}} \quad \#(3)$$

$$n_{B=0}^* = \frac{\omega_k + I_t - \omega_k L_k}{\pi q} - \frac{\omega_k(Q_{k,t} - Q_{0,t})}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}} \quad \#(4)$$

$$n_{B=1}^* = \frac{\omega_k - \omega_k L_k}{\pi q} - \frac{\omega_k Q_{k,t}}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} \quad \#(5)$$

$$\Delta n^* = \frac{I_t + \omega_k Q_{0,t}}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}} + \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} \#(6)$$

The model also accounts for the impact of a parental health shock on each of the first, second, and successive child of adult children. The cost of having each child πq is determined at the beginning of the period. The fertility preference of adult children is represented by $Y_{k,t}(\alpha, B)$, $Y_{k,t}(\beta, B)$, and $Y_{k,t}(\gamma, B)$ for 0, 1, and 2 children, respectively, at period t . Parameters α , β , γ capture various the difference in socio-economic and demographic factors for families with 0, 1, and 2 children, that can impact fertility decisions. With constant value of B , the fertility preference increases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$. This is because the more the number of children they have before period t , the lower the fertility preference is. And this means that the marginal benefit of having an additional child is highest when there are no children (i.e., $Y_{k,t}(\alpha, B=0)$ is the highest) and decreases with each successive child.

The function Δn^* from equation (3) is a concave function of $Y_{k,t}(\alpha, B)$ (the derivation can be found in the section 1.3 of the appendix). Therefore, the maximum value of Δn^* is achieved when $Y_{k,t}(\alpha, B)$ is at its lowest value, i.e., when fertility preference is $Y_{k,t}(\gamma, B)$. Thus, we have shown that Δn^* is decreasing as the fertility preference increases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$, which means that parental health shock has a negative impact on adult children's choice to have another child, with the impact increasing with each successive child. From the above, we propose the following hypothesis:

H1: The parental health shock has a negative impact on the fertility decision of adult children.

H2: The negative impact of the parental health shock on the fertility decision of adult children increases with the number of children the adult child has prior to period t .

4. Methods and data

4.1 Parental Health shocks

Former studies on measuring health shocks have primarily focused on catastrophic health expenditures (Kruk et al., 2009), subjective self-evaluation of health status (Fang and Zou, 2013), and changes in activities of daily living (ADL) (Genoni, 2012). Each of these

measurements suffered from issues such as measurement inaccuracies (self-rated health status) and lack of sensitivity to long-term impacts (ADL changes).

It is also important to consider the potential correlation with variables like income and education. While such a correlation is plausible, several studies (Liu, 2016; Islam & Maitra, 2012) have shown that health shock such as the death of a family member (particularly the main income earner), and injuries resulting from traffic accidents or fires, align more with these exogeneity requirements due to their random, unpredictable nature without significant correlation with one's income or education level. Hence, we define a parental health shock as an unexpected diagnosis of major illnesses such as stroke, tumor, and cardiac infarction, which have a pronounced, enduring impact on family economics. We select these specific illnesses due to their random and unpredictable nature, and they significantly affect family economics in a long-lasting way. This definition overcomes the shortcomings of previous measures by using objective, verifiable data (diagnosis of specified illnesses) and focusing on health events with significant long-term implications.

We choose to represent these parental health shocks as a binary variable for two reasons. First, it reflects the stark impact of these events: either a major health shock has occurred, or it hasn't. This representation aligns with the data structure of the CHNS survey questions, which record the occurrence (or non-occurrence) of specific diagnoses. Second, the binary variable captures the severe, abrupt nature of these health shocks more accurately than a continuous variable might. It should be noted that while this binary representation provides a clear-cut method for identifying health shocks, it may not capture the subtleties of illness severity or progression over time. However, we believe its simplicity and objective nature outweigh these potential drawbacks.

To establish the timing of health shocks and health status, we employed the CHNS survey questions that record the age of initial diagnosis. We considered a parental health shock to have occurred if either parent was diagnosed with a specified illness in a given year. To address the potential reverse causality that may arise from parents exerting marginal effort to raise their grandchildren, the effect of parental health shock on the birth of the first child is evaluated using samples where the parental health shock occurred prior to the birth of the first child. The regression results (presented in Table 5) are statistically significant, indicating that even if this identification problem exists for the second and subsequent children, it does not alter the effect of the health shock on the first child's birth.

4.2 Identification strategy

Given that parental health shocks are not randomly assigned across households, traditional regression analyses may produce biased estimates. In response, we employ a matching strategy that simulates random assignment by making the treated (experienced health shocks) and untreated (did not experience health shocks) groups comparable on observed characteristics. This methodology reduces the likelihood of selection bias and allows for more robust causal inference. We first divide the samples of the treatment groups that have had a health shock into three treatment groups according to the relationship between the shock year and the reproductive behavior, as shown in Table 2. And set the control groups corresponding to each treatment group.

Here, we focus on understanding the immediate and observable impacts that parental health shocks can have on the fertility decisions of adult children. While our study does not directly measure completed fertility, we believe that our findings provide valuable insights into how these immediate health shocks can influence fertility decisions.

Table 2
Treatment and control groups of health shock

	Treatment Groups	Control Groups
Situation 1	The shock happened before the first child was born	Have one or more children, and there are no health shocks
Situation 2	The shock happened after the first child and before the second child	Have two or more children, and there are no health shocks
Situation 3	The shock happened after the second child before the third child	Have three or more children, and there are no health shocks

CEM-PS matching: We use a three-step process combining Coarsened Exact Matching (CEM) and Propensity Score Matching (PSM). CEM, as an innovative matching technique, can reduce imbalance between treated and control units while retaining a significant portion of the sample compared to traditional methods. CEM has been widely used in policy evaluation since it was proposed by Blackwell et al. (2009). While extremely effective, one limitation of CEM is its requirement for discretization when dealing with continuous matching variables. PSM, on the other hand, assigns a propensity score to each unit in the sample, reducing the dimensionality of the matching problem and allowing for better balancing across a range of observable characteristics. However, PSM relies heavily on the assumption of common support between treatment and control groups.

Given the individual strengths and weaknesses of both CEM and PSM, our strategy is to integrate these methods. In our proposed three-step matching methodology, we first employ CEM to minimize imbalance and maximize sample retention. We then incorporate PSM's propensity score into the CEM matching variables, enabling a broader consideration of

observable characteristics, and addressing the issue of data loss from discretizing continuous variables.

The selection of the covariates is crucial in ensuring the validity of the causal impact estimation. In this paper, the variables used in the matching process include the parents' work sector, medical insurance status, Hukou, job type, income, education level, and age. These variables were chosen based on their relevance to the research question and their potential impact on the parental health shocks and fertility decisions of the adult children. In the sample used in our study, we determined family relationships based on legal Hukou registrations, meaning the fertility decisions we observed were from a married sample. Specifically, we coded the education level according to the discretization of years of education in the educational system in China, which corresponds to 0=never been to school; 1=elementary school; 2 =middle school; 3=high school;4 =technical school; 5=college; 6=graduate and above, we coded the nature of one's working into: working in the public sector =1; working in the nonpublic sector =0; we coded the information of individual medical insurance into : with medical insurance=1; without =0; we coded the Different types of jobs into: white collar =1; blue collar=2; others=3. Hukou: city =1; rural =0; and we input average income level of the parents, the education level of the parents, age of the parents as covariates of the PSM to compute the PS as the covariate for the second CEM. Table 3 shows the overall imbalance of covariates before and after the matching given by the L1 statistic, introduced in Iacus et al., (2011) as a comprehensive measure of global imbalance. The overall imbalance of pretreatment covariates in the treated group and that in the control group are reduced significantly, which means that the matching process works well.

Table 3
Imbalance checking before and after the matching.

	Multivariate L1 distance	Univariate imbalance (Categorical covariates)							
			L1	mean	min	25%	50%	75%	max
Before Matching	0.27193459	Working in Public sector (Parent)	0.01663	0.08345	0	0	0	0	0
		Medical insurance (Parent)	0.09487	0.20497	0	0	0	-1	0
		City (Hukou)	0.01113	-0.09934	0	-1	0	0	0
		Type of job (Parent)	0.05865	-0.25731	0	1	1	0	0
	Multivariate L1 distance	Univariate imbalance (Categorical covariates)							
			L1	mean	min	25%	50%	75%	max
After Matching	1.941E-13	Working in Public sector (Parent)	1.2E-13	0.02821	0	0	0	.	.
		Medical insurance	1.1E-13	0.04347	0	0	0	.	.

		(Parent)							
		City (Hukou)	1.9E-13	-0.01873	0	0	0	.	.
		Type of job (Parent)	1E-13	-0.07605	0	0	.	.	.
Before Matching	Multivariate L1 distance	Univariate imbalance (P-score for numerical covariates)							
			L1	mean	min	25%	50%	75%	max
	0.2865	P-score	0.2865	0.89623	0	1	1	1	0
After Matching	Multivariate L1 distance	Univariate imbalance (P-score for numerical covariates)							
			L1	mean	min	25%	50%	75%	max
	2E-13	P-score	2E-13	4.1E-13	0	0	.	.	.
Before Matching	Multivariate L1 distance	Univariate imbalance (Numerical covariates)							
			L1	mean	min	25%	50%	75%	max
	0.53909539	Parents's age	0.37818	-11.44	4.5	-6.5	-11	-16.5	-28
		Parents's income	0.14155	-4824.2	73920	-719.43	-1778.4	-5882.4	-590000
		Parents's education	0.08521	0.05958	0	0	0	0	-4
After Matching	Multivariate L1 distance	Univariate imbalance (Numerical covariates)							
			L1	mean	min	25%	50%	75%	max
	0.34469562	Parents's age	0.07165	-0.07322	4.5	0.5	0.5	0.5	-6
		Parents's income	0.0616	0.1957	2.89	0.104	0.14	0.06	-0.2149
		Parents's education	0.03888	-0.06737	0	0	0	0	-4

Panel data models: We also incorporate panel data models to mitigate any bias caused by time-invariant unobservable characteristics of households. By separating the dependent variable into the decision to have a child, the age at birth, and the number of children, we can capture nuanced differences in fertility behavior. We then create separate models for each component.

For the decision to have a child, we employ a probit regression model:

$$P(Y1_{it} = 1) = \Phi(\alpha_0 + \alpha_1 * shock_{i't} + \alpha_2 * x_{it} + A_c + B_t + D_d + \varepsilon_{it}),$$

$$i = 1, ..., N; t = 1993, ..., 2015 \#(7)$$

Here, $\Phi(\alpha_0 + \alpha_1 * shock_{i't} + \alpha_2 * x_{it} + A_c + B_t + D_d + \varepsilon_{it})$ is the cumulative distribution function of the standard normal distribution.

For the age at which they gave birth, we use a linear regression model, conditional on the decision to have a child:

$$Y2_{it} = \alpha_0 + \alpha_1 * shock_{i't} + \alpha_2 * x_{it} + A_c + B_t + D_d + \varepsilon_{it},$$

$$i = 1, ..., N; t = 1993, ..., 2015, \text{ conditional on } Y1_{it} = 1 \#(8)$$

For the number of children, we use an ordered probit regression model, conditional on the decision to have a child:

$$P(Y3_{it} = k) = \Phi(\alpha_0 + \alpha_1 * shock_{i't} + \alpha_2 * x_{it} + A_c + B_t + D_d + \varepsilon_{it} + \mu_k)$$

$$i = 1, ..., N; t = 1993, ..., 2015, \text{ conditional on } Y1_{it} = 1 \#(9)$$

where Φ is the standard normal cumulative distribution function, and μ_k is the k -th threshold, with i representing the household, and t representing the year.

$Y1_{it}, Y2_{it}, Y3_{it}$ represents the fertility choices of the adult children i in period t , including the decision to have a baby, the age at which they gave birth, and the number of their children. $shock_{it}$ is a dummy variable that represents whether the parents receive a health shock. x_{it} includes other control variables that may impact children's fertility choices, such as children's income, education, nature of work, medical insurance participation, age, and health check. The model also controls for city differences A_c , time fixed effects B_t , and urban and rural fixed effects D_d . ε_{it} represents the random disturbance.

4.3 Data source and variable definition

The China Health and Nutrition Survey (CHNS) is a longitudinal dataset that employs a multi-stage cluster sampling method, covering samples from different income levels in cities and rural areas. The survey provides detailed family relationship information over an extended period, enabling the tracking of economic status, fertility status, and other pertinent details for the sample. Data from 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, and 2015 were selected from 12 provinces covering China's eastern, central, and western regions, including Jiangsu, Shandong, Beijing, Shanghai, Liaoning. To account for China's special population policy, we added regression results to the basic regression analysis using data from the year the "comprehensive two-child" policy was implemented in 2015.

In terms of the variables of interest, we examine the adult children's willingness to have different numbers of children, specifically whether to have the first, second, or third child, and the age at which each fetus was born. Table 4 provides descriptive statistics for the variables, including health shocks, smoking, drinking, and healthcare examinations. The average value of the parents' health shocks in a certain period is 0.031, indicating a low incidence of parents' health shocks in the family. Additionally, the average age of men and women giving birth to their first child is 27 and 25, respectively, and the average number of births is between one and two.

In Table 4, the variable 'First' represents the decision to have the first child. A mean of 1 indicates that all the individuals in the sample opted to have a first child. The standard deviation (SD) of 0 further confirms the uniformity of this decision across the sample. This might seem counterintuitive at first, but it's essential to note that our sample is filtered to only include those who have made a decision regarding their first child. The data in Table 4

primarily focuses on the fertility decisions of the sample. While the variable 'First' indicates a unanimous decision to have a first child, it's crucial to understand this in the context of our sample. The impact of health shocks on these decisions is elaborated in subsequent sections, where we delve deeper into the correlation between parental health shocks and fertility choices.

Table 4
Descriptive statistics of main variables

Variable	Definition	N	Mean	Std. Dev	Min	Max
Health shocks	Parental health shocks	81374	.031	.172	0	1
W_age_1	The age at which a woman (adult child) gives birth to her first child	81374	25.506	4.459	16	50
M_age_1	The age at which a man (adult child) parents his first child	80533	27.481	5.182	16	59
W_age_2	The age at which a woman (adult child) gives birth to her second child	36760	28.440	4.620	18	52
M_age_2	The age at which a man (adult child) parents his second child	36640	27.446	5.141	19	64
W_age_3	The age at which a woman (adult child) gives birth to her third child	12190	30.664	4.759	19	55
M_age_3	The age at which a man (adult child) parents his third child	12180	30.316	5.205	21	53
First	Whether to have the first child	83088	1	0	1	1
Second	Whether to have the second child	83088	0.432	0.495	0	1
Third	Whether to have the third child	83088	0.142	0.349	0	1
edu_1	Education level of the man (adult child)	82072	2.437	1.512	0	9
income_1	Income level of the man (adult child)	34355	14488.08	28306.26	0	1312837
public_1	If the man (adult child) works in public sector	32737	0.310	0.463	0	1
edu_2	Education level of the woman (adult child)	82893	2.047	1.572	0	9
income_2	Income level of the woman (adult child)	31291	10934.75	21885.91	0	1125274
public_2	Whether the woman (adult child) works in public sector	26759	0.242	0.429	0	1
P_age	The age of the parents	30111	63.431	16.162	19.5	125
P_edu_hat	Education level of the parents	83088	2.386	0.906	1	3
P_public	If the parents work in public sector	11457	0.202	0.401	0	1
P_med_insur	If the parents have medical insurance	15940	0.471	0.499	0	1
hh_inc_hat	Relative level of family income	46813	2.025	0.816	1	3
lag_hh_exp~t	Lagging relative level of family income	28174	2.010	0.815	1	3
Childcare_1	Average hours cared for children (male adult child)	18425	0.118	0.712	0	6
Childcare_2	Average hours cared for children (female adult child)	24471	0.4	1.977	0	15
P_Childcare_max	Average hours cared for the adult child's children (maximum of the two parents)	4133	0.385	2.542	0	32
P_Childcare_mean	Average hours cared for the adult child's children (mean of the two parents)	8798	0.442	2.208	0	20

N	Number of fertility.	81374	1.704	.921	1	5
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5. Empirical analysis

5.1 *The impact of health shocks on the number of children born.*

We focus on the impact of health shocks on the family's reproductive behavior, including the timing and number of children born. We first present the basic regression results in Table 5, which reveals that the health shocks experienced by parents have a significant negative effect on the number of children born, as shown in the second column. Additionally, when we restrict the sample to the year of the "Comprehensive Two-Child" policy implementation in 2015, as presented in the third column, the negative impact of parental health shocks on fertility remains significant.

Table 5
Estimates of the impact of health shocks on the number of children born.

	The number of children born (whole sample)	The number of children born (2015)
Health shocks	-0.105*** (0.026)	-0.199*** (0.056)
Log of income	0.050*** (0.009)	-0.409*** (0.026)
Constant	1.257*** (0.092)	1.977*** (0.020)
Time fixed effect	YES	YES
Region fixed effect	YES	YES
Observations	40472	4723

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

5.2 *The impact of health shocks on the fertility choices (additional child) of adult children*

In our study, we emphasize the importance of the timing of health shocks in relation to fertility decisions. To address potential reverse causality and ensure clarity in our analysis, we specifically evaluated the effect of parental health shocks on the birth of the first child using samples where the parental health shock occurred prior to the birth of the first child. This approach was taken to provide a clear temporal distinction and avoid potential confounding factors.

Table 6-A provides the estimated impact of parental health shocks on fertility decisions regarding the first child. The treatment group, where the parent's health shock occurred before the birth of the first child, is compared to the control group, which did not experience any parental health shock. The results indicate that parental health shocks significantly delayed the reproductive age of adult children. The estimated delay for fathers and mothers were 0.824 years and 0.436 years, respectively, and both are statistically significant at the 1%

level. The effect on fathers' childbearing age is larger than on mothers, reflecting the greater financial burden borne by men in China. The estimation results in column (3) show that parental health shocks did not significantly impact the probability of having a second child. To account for the effect of human capital on fertility, we add children's education status as a control variable in columns (4)-(6). The results show that parental health shocks still significantly delayed the age at which the first child was born, with a slightly smaller coefficient. However, the impact on whether to have a second child remained insignificant. Thus, parental health shocks delayed the age of having the first child and did not significantly affect having a second child. We control for the children's income and the nature of their work to account for the family's economic capacity and expectations regarding the health shock.

Table 6-B presents the estimated impact of parental health shocks on adult children's decision to have a second child. The treatment group comprises families where the parent experienced a health shock after the first child's birth but before the second child's birth. The empirical results in Table 5-B reveal that parental health shocks significantly influence the decision to delay the age of having a second child and reduce the birth age, with statistical significance at the 1% level. Notably, unlike the findings in Table 5-A, the impact of health shocks before the second child's birth has a more substantial effect on delaying childbearing age, as evidenced by both column sets (1)-(3) and (4)-(6). Additionally, the effect of having a second child on women's age is more significant than that of men. One plausible explanation for this finding is that women, having fulfilled their family reproductive duties after the first child, are more involved in work and have more choices when an economic shock like a health shock occurs. As a result, they are more likely to work and share the family's financial burden, which leads to a more considerable delay in the childbearing age. Furthermore, the decision to give birth after the first child may differ significantly in the event of an economic shock.

Table 6-C provides the estimated results of the impact of parental health shocks on adult children's decision to have a third child. The treatment group consists of families where the parent experienced a health shock after the birth of the second child but before the birth of the third child. In contrast, the control group comprises families where the parent did not suffer a health shock, and the children had two or more offspring. Table 5-C provides the estimated results of the impact of parental health shocks on adult children's decision to have a third child. The treatment group consists of families where the parent experienced a health shock after the birth of the second child but before the birth of the third child. In contrast, the

control group comprises families where the parent did not suffer a health shock, and the children had three or more offspring. Importantly, the delay in childbearing age for the third child is even more significant than for the second child. Moreover, the parental health shock significantly reduces the likelihood of the family deciding to have a third child, and this impact is also significantly higher than when the health shock occurred after the birth of the second child.

Altogether, the estimated results suggest that the economic shocks' influence on fertility decisions becomes more evident as the number of children in the family increases. These results provide crucial insights into the complex interplay between health shocks and fertility decisions, underscoring the need for policymakers to design effective policies that mitigate the impact of economic shocks on fertility behavior.

Table 6

The impact of health shocks on the fertility choices (additional child) of adult children (health shocks occurred prior to birth).

	(1)	(2)	(3)	(4)	(5)	(6)
A First child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	0.436*** (0.087)	0.824*** (0.096)	-0.004 (0.043)	0.260*** (0.085)	0.590*** (0.093)	0.013 (0.045)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	25.982*** (0.433)	27.450*** (0.478)	-2.028*** (0.429)	25.000*** (0.478)	27.057*** (0.524)	-1.100** (0.487)
Observations	27800	27800	6487	27717	27717	6461
B Second child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	1.119*** (0.209)	0.629*** (0.220)	-0.853*** (0.074)	1.126*** (0.206)	0.684*** (0.219)	-0.686*** (0.077)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	31.110*** (1.429)	31.291*** (1.503)	-0.870*** (0.038)	32.712*** (1.452)	32.636*** (1.539)	0.234*** (0.066)
Observations	22214	22214	6604	22146	22146	6580
C Third child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	3.926*** (0.593)	3.218*** (0.583)	-1.274*** (0.191)	4.365*** (0.599)	3.653*** (0.585)	-1.197*** (0.195)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	35.391*** (0.351)	36.283*** (0.345)	-0.699*** (0.115)	36.521*** (0.472)	36.510*** (0.460)	-0.366** (0.143)
Observations	3599	3599	2409	3568	3568	2161

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

To ensure accuracy in our analysis, we have refined our approach to consider the timing of health shocks in relation to conception. We utilized survey questions that record the age of initial diagnosis to determine the occurrence of parental health shocks. By focusing on the

diagnosis year, we aim to capture the effects of health shocks that occurred prior to conception, offering a more precise understanding of their impact on fertility decisions. In addition, We understand the importance of considering Induced abortions that occurred after health shocks. However, information on abortions is scarce.

Table 7 shows the estimated results of the pre-conception parental health shocks and the adult children's decision to have an additional child. For the first child (Panel A), parental health shocks display a positive and statistically significant relationship with the birth age of both male and female adult children, and the 'Give birth' variable is negatively influenced by health shocks, implying that such shocks may reduce the likelihood of having an additional child. In the context of deciding on a second child (Panel B), health shocks demonstrate mixed results. While the birth age of female adult children seems to be significantly affected, the birth age of male adult children is not affected. 'Give birth' variable once again indicates a negative relationship, reinforcing the hypothesis of parental health shocks possibly deterring subsequent childbirth. For the third child (Panel C), the magnitude of parental health shocks' impact is the most pronounced. The coefficients suggest that health shocks are highly influential at this stage, affecting both age and the decision to give birth. The strong negative relationship for the 'Give birth' variable here is particularly noteworthy.

Table 7

The impact of health shocks on the fertility choices (having an additional child) of adult children (health shocks occurred prior to conception).

	(1)	(2)	(3)	(4)	(5)	(6)
A First child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	.715*** (.088)	.979*** (.099)	-.16*** (.041)	.363*** (.086)	.534*** (.096)	-.065 (.044)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	23.549*** (.087)	24.774*** (.097)	-.001 (.039)	22.953*** (.242)	25.907*** (.268)	.353*** (.114)
Observations	17099	16925	4633	16892	16892	4552
B Second child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	.94*** (.214)	.311 (.23)	-.866*** (.077)	.941*** (.213)	.256 (.229)	-.701*** (.081)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	27.088*** (.113)	28.395*** (.12)	-.579*** (.037)	26.614*** (.252)	28.529*** (.271)	-.039 (.084)
Observations	16070	16051	5090	16036	16036	5045
C Third child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	4.503*** (.764)	3.333*** (.715)	-1.58*** (.23)	4.642*** (.773)	3.529*** (.715)	-1.447*** (.24)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES

Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	29.247*** (.29)	30.872*** (.271)	-.989*** (.097)	31.348*** (.526)	34.416*** (.487)	-.355** (.181)
Observations	2286	2286	2095	2282	2282	1753

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

Our study primarily focused on the immediate economic implications of the parental health shock diagnosis. We represented these parental health shocks as a binary variable, reflecting either the occurrence or non-occurrence of the shock. The selection of these specific illnesses is predicated on their characterization as long-term chronic conditions with no elevated mortality risk. These ailments substantially influence day-to-day life. It is pertinent to note that the samples presented in Table 6 exclusively comprise individuals who have not succumbed to these conditions. Although our approach effectively captures the sudden onset of these health shocks, we acknowledge the necessity of examining the extended trajectory of these diseases and their diverse economic repercussions. We then isolated samples that experienced mortality following these chronic illnesses mentioned above. Table 8 shows the result of the impact of health shocks on the fertility choices of adult children (health shocks occurred prior to birth and then progress to death).

The estimated results in Table 8 signify a strong correlation between parental health shocks diagnosed prior to birth and subsequently resulted in death and the fertility choices of adult children. For the first child (panel A), the occurrence of health shocks is positively correlated with the age of both the male and female adult children, indicating that parental health shocks might lead to a delay in childbirth decisions. For the choice to give birth, the coefficients are positive, implying that health shocks might increase the probability of having a child. For the second child (panel B), health shocks show a more profound impact. Here, the negative coefficient in the "Whether give birth" column suggests a reduced likelihood of having a second child upon experiencing health shocks that occurred prior to birth and then progress to death. For the third child (panel C), parental health shocks are positively associated with the age of the male and female adult children, the decision to give birth has a negative coefficient. This reveals a pronounced adverse effect of health shocks on the decision to have a third child. The empirical findings in Table 8 suggest that parental health shocks have a more pronounced effect on the decision to have a second or third child compared to the first. The relatively smaller effect on the first child can be attributed to the cultural importance of having at least one child in Chinese society, in the context of the historical one-child policy. However, for subsequent children, the financial and care-taking considerations, including those spurred by parental health shocks, become increasingly

significant. These economic constraints are pivotal in postponing or deciding against additional childbearing.

Table 8

The impact of health shocks on the fertility choices (having an additional child) of adult children (health shocks occurred prior to birth and then progress to death).

	(1)	(2)	(3)	(4)	(5)	(6)
A First child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	.781*** (.168)	.913*** (.198)	.03 (.068)	.594*** (.165)	.55*** (.195)	.197*** (.071)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	23.355*** (1.371)	30.828*** (1.615)	-.227*** (.03)	24.731*** (1.347)	32.818*** (1.586)	.856*** (.088)
Observations	8296	8271	2517	8254	8254	2499
B Second child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	2.101*** (.338)	1.557*** (.358)	-.634*** (.095)	1.854*** (.326)	1.284*** (.35)	-.446*** (.1)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	27.338*** (.476)	29.855*** (.504)	-1.089*** (.173)	27.92*** (.486)	31.091*** (.521)	.033 (.197)
Observations	8835	8828	3026	8808	8808	2944
C Third child	Age of woman	Age of man	Whether give a birth	Age of woman	Age of man	Whether give a birth
Health shocks	2.821*** (.74)	1.747** (.681)	-1.107*** (.181)	3.084*** (.736)	1.791*** (.694)	-.98*** (.208)
Variable controls	NO	NO	NO	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	29.722*** (1.71)	30.663*** (1.573)	-1.018*** (.098)	29.51*** (1.721)	30.6*** (1.622)	-.526*** (.149)
Observations	1310	1310	1080	1289	1289	1007

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

5.3 The impact of health shocks on hours cared for the offspring of adult children

Table 9 presents the results of empirical outcomes of our investigation into the repercussions of parental health shocks on the caregiving time allocations of adult offspring, as well as the implications for cross-generational care provisions. Here, 'cross-generational care time' is defined as the duration dedicated by grandparents for their grandchildren's caregiving and the time spent by adult offspring in caring for their own children. Specifically, we hypothesize that a parental health shock increases the childcare responsibilities of adult children, making them spend more time caring for their children for the decrease in the time parents can dedicate to cross-generational care, which may necessitate them to reconsider family expansion plans.

We operationalize ' Adult children's childcare time commitments ' as the daily average hours an adult child spends caring for their own children aged 0-6, based on responses to two questions in the China Health and Nutrition Survey: "Did you take care of your own children under 6 years old at home last week?" and "How long did you spend feeding, bathing, dressing, and taking care of children last week? (Hours)". And ' Parents' childcare time commitments ' is defined as daily average hours the parents of the adult children spends caring for their grandchildren aged 0-6.

The evidence robustly corroborates our propositions. There's a marked surge in the childcare hours for adult offspring—irrespective of gender—in the aftermath of a parental health shock. Specifically, the coefficient estimates for male and female are .126 ($p < .01$) and .378 ($p < .01$) respectively, translating to an uptick of about .126 hours/day for male adult children and .378 hours/day for their female counterparts in childcare commitments. An increase of 0.12 hours in childcare time, while seemingly small, represents a significant deviation from the mean child care time reported in our sample. This underscores the tangible impact of parental health shocks on the daily routines and responsibilities of adult children.

Simultaneously, we note a pronounced decrement in both the maximum and average durations parents can allocate to cross-generational care. The inferred coefficients stand at -.333 ($p < .01$) and -.329 ($p < .01$) respectively, signifying that a parental health shock trims the cross-generational care hours by nearly .333 and .329 hours. Collectively, these insights insinuate a considerable reallocation of caregiving roles within the family following parental health adversities, as adult children assume heightened childcare responsibilities, while grandparents' involvement in cross-generational care dwindles. Furthermore, there's a discernible economic impact. The average income of adult children decreases by approximately -2328.784 ($p < .05$) post the parental health shock, underscoring the economic toll of the augmented caregiving responsibility.

Collectively, these findings underscore the multifaceted implications of parental health adversities: they not only catalyze a redistribution of caregiving roles within families but also exert economic strains on adult children due to increased care responsibilities and reduced income-generating capacities.

Table 9

The estimate of the effect of parental health shocks on cross-generational care time and income of the adult children

Adult children' childcare time commitments		Parents' childcare time commitments		Income of the adult children
Male	Female	Max time	Mean time	Average income of the adult couple

Health shocks	.126***	.378***	-.333***	-.329***	-2328.784**
	-0.042	-0.099	-0.069	-0.064	-1012.91
Constant	.116***	.394***	.541***	.496***	-2874.075***
	-0.005	-0.013	-0.028	-0.026	-641.046
Time fixed effect	YES	YES	YES	YES	YES
Region fixed effect	YES	YES	YES	YES	YES
Observations	18425	24471	8798	8798	42047

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

In this study, we conceptualize "intergenerational families" as familial units in which various generations maintain economic linkages, irrespective of their residential status. Such a definition mirrors the structure of many Chinese households, where adult offspring commonly render both financial and emotional backing to their aging parents, irrespective of whether they share a residence.

For analytical purposes, our sample encompasses both co-residing parent-child dyads and those without intergenerational co-residence. Nonetheless, a salient methodological query emerges: To what extent do families with joint intergenerational co-residence diverge from those lacking such an arrangement, and what implications might this hold for the study's external validity? To bolster the robustness of this study, it becomes imperative to introduce a metric gauging the geographical proximity between parents and their adult children. The reasoning behind this addition is that the magnitude and nature of "intergenerational economic spillover" may be influenced by this spatial dimension. Table 10 presents the estimate of the difference in the effect of parental health shocks in families living under intergenerational co-residence and not living under intergenerational co-residence, and Table 11 presents the estimate of the proximity (KM) on birth age of female/male adult children.

Table 10 shows that parental health shocks display varying magnitudes of effect based on co-residential status. Notably, for families with intergenerational co-residence, a parental health shock exhibits a positive correlation with the adult children's birth age. Contrarily, in families without such co-residence, this relationship is either negative or statistically non-significant. This suggests that co-residential status plays a pivotal role in mediating the impact of health shocks on economic factors. In Table 11, the results are less pronounced, oscillating near zero across all age categories. This could be due to the non-significance in the effect of parental health shocks in families without such co-residence.

Table 10

The estimate of the differential impact of parental health shocks based on intergenerational co-residence

	intergenerational co-residence	not co-residence
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	W_age_1	W_age_2	W_age_3	W_age_1	W_age_2	W_age_3
Health shocks	.857** (0.371)	1.797* (1.075)	6.931** (3.215)	-0.555 (0.545)	-1.916 (2.429)	
Constant	23.098*** (0.118)	27.105*** (0.333)	28.87*** (0.858)	22.652*** (0.215)	28.671*** (0.753)	35.632*** (0.907)
Observations	4051	1380	203	967	299	22

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

Table 11

The estimate of the proximity (KM) on birth age of Female/Male adult children

	the distance(KM) of Female adult child's parents			the distance(KM) of Male adult child's parents		
	W_age_1	W_age_2	W_age_3	W_age_1	W_age_2	W_age_3
Distance (KM)	0.003 (0.002)	-0.001 (0.004)	0.006 (0.005)	0.001 (0.002)	-0.001 (0.003)	0 (0.004)
Constant	23.468*** (0.348)	26.258*** (0.580)	31.129*** (0.814)	23.919*** (0.269)	27.431*** (0.416)	30.288*** (0.752)
Observations	431	290	125	726	534	209

	the distance(km) of Female adult child's parents			the distance(km) of Male adult child's parents		
	W_age_1	W_age_2	W_age_3	W_age_1	W_age_2	W_age_3
Distance (KM)	0.003 (0.002)	-0.001 (0.004)	0.006 (0.005)	0.001 (0.002)	-0.001 (0.003)	0 (0.004)
Constant	23.468*** (0.348)	26.258*** (0.580)	31.129*** (0.814)	23.919*** (0.269)	27.431*** (0.416)	30.288*** (0.752)
Observations	431	290	125	726	534	209

5.4 The impact of health shocks on families with different economic security

This section presents the estimated results of parental health shocks on fertility decisions of adult children under different income statuses, as shown in Table 12. We selected high-income and low-income families for comparative analysis, controlling for fixed effects such as urban and rural areas, provinces, and years. The empirical findings in Table 12 suggest that parental health shocks negatively affect the childbearing age of the first, second, and third children of adult children from both high- and low-income families. However, high-income families (columns (1)-(3)) are less affected by parental health shocks than low-income families (columns (4)-(6)).

Specifically, the impact of health shocks on the second child's childbearing age is statistically insignificant, and the effect on the third child is significant only at the 10% level for high-income families. In contrast, the effect of parental health shock on the second and

third childbearing age of adult children from low-income families is significant at the 1% level, and the impact is much more substantial than that observed for high-income families. These results highlight that the family's self-financing ability plays a critical role in mitigating the impact of economic shocks on fertility decisions. In other words, the stronger a family's financial position, the smaller the impact of economic shocks on their fertility decisions. Overall, these results have significant implications for policymakers designing effective measures to support vulnerable families during times of economic uncertainty.

Table 12
Effects of health shock on different family income levels

	High-income family			Low-income family		
	First child	Second child	Third child	Frist child	Second child	Third child
Health shocks	0.522*** (0.111)	0.349 (0.285)	1.802* (1.046)	0.461*** (0.126)	2.003*** (0.262)	3.577*** (0.764)
Constant	23.125*** (0.704)	29.729*** (0.259)	33.236*** (0.596)	24.583*** (0.599)	32.124*** (2.530)	34.859*** (0.579)
Observations	26826	10706	2141	27664	12136	2652
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

This section presents the estimated results of parental health shocks on fertility decisions of adult children under different medical insurance statuses, as shown in Table 13. The analysis controls for fixed effects such as urban and rural areas, provinces, and years. The empirical results in Table 13 reveal that regardless of whether the parents have medical insurance or not, it does not change the delaying effect of parental health shocks on the first childbirth age. However, the effect is more significant for families without medical insurance.

Furthermore, the effect of parental health shocks on the childbearing age of the second child is not statistically significant for families with medical insurance. In contrast, the impact is significant at the 1% level for families without medical insurance. These findings suggest that medical insurance has a considerable impact in reducing the effect of economic shocks on family fertility decisions. Specifically, the results show that medical insurance can mitigate the impact of economic shocks on the second child's childbearing age, which is particularly important given the significant impact of economic shocks on the decision to have a second child observed in previous sections. Overall, these results provide essential insights into the role of medical insurance in mitigating the impact of economic shocks on fertility behavior and underscore the importance of policies that increase access to medical insurance to support vulnerable families during times of economic uncertainty.

Table 13

Effects of health shock on different health insurance status

	With health insurance			Without health insurance		
	Frist child	Second child	Third child	Frist child	Second child	Third child
Health shocks	0.419*** (0.101)	0.284 (0.252)	2.001** (0.834)	0.623*** (0.134)	1.972*** (0.290)	4.363*** (0.912)
Constant	24.490*** (0.412)	31.719*** (1.823)	35.809*** (0.828)	24.937*** (2.866)	30.045*** (0.243)	34.554*** (0.573)
Observations	24275	8290	1186	29566	12377	2365
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

This section investigates the impact of working in the public sector on fertility decisions in the context of health shocks. In China, people working in the public sector enjoy better employee safeguards and stability compared to those in the non-public sector (Liu et al., 2016). As such, they have more robust risk resilience capabilities in the face of health shocks. We selected government agencies, public institutions, state-owned enterprises, and research institutes as public sector samples and private enterprises and foreign-funded enterprises as non-public sector samples.

The estimated results in Table 14 suggest that when there is a parental health shock, the childbearing age of adult children on the first child is significantly delayed, regardless of the sector of employment. However, the impact of health shocks on the second and third births is significantly lower for adult children working in the public sector than those in the non-public sector. In contrast, the effect on the second and third births in the non-public sector is statistically significant at the 1% level. These findings highlight that working in the public sector significantly improves a family's ability to cope with economic shocks and reduces the impact of such shocks on family fertility decisions.

Table 14

Effects of health shock on different working sectors

	Frist child	Public sectors		First child	Non-public sectors	
		Second child	Third child		Second child	Third child
Health shocks	0.522*** (0.111)	0.349 (0.285)	1.802* (1.046)	0.461*** (0.126)	2.003*** (0.262)	3.577*** (0.764)
Constant	23.125*** (0.704)	29.729*** (0.259)	33.236*** (0.596)	24.583*** (0.599)	32.124*** (2.530)	34.859*** (0.579)
Observations	26826	10706	2141	27664	12136	2652
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)

5.4 The dynamic effect of parental health shocks.

In this part, we employ an event study methodology to estimate the dynamic effect of parental health shocks. An array of existing literature substantiates the efficacy of event studies as a reliable tool for discerning the effects of exogenous shocks (Naidu and Ranjeeni, 2021; Heyden and Heyden. 2021). This approach facilitates the elucidation of both immediate and enduring repercussions of parental health shocks on fertility outcomes, whilst incorporating controls for unobservable factors invariant over time and potential confounding elements.

To explore the dynamic consequences of a health shock on the reproductive choices of adult offspring, we undertake an evaluation of various temporal periods, using the regression outcomes as the foundation for this examination. The analytical framework is formalized in the ensuing regression equation:

$$\begin{aligned} birthage_{it} = & \alpha_0 + \alpha_1 * Shock_{it}^{-6} + \alpha_2 * Shock_{it}^{-5} + ... + \alpha_{12} * Shock_{it}^6 x_{it} \\ & + A_i + B_t + \varepsilon_{it} \# (8) \\ i = & 1, ..., N; t = 1993, ..., 2015 \end{aligned}$$

Where $birthage_{it}$ is the age at which the woman/man adult child i gives birth/parents her/his first/second/third child ($W_age_1/M_age_1/ W_age_2/M_age_2/ W_age_3/M_age_3$) in year t . $Shock_{it}^{-j}$ equals one for samples in the j^{th} period before the reported health shock, while $Shock_{it}^{+j}$ equals one for samples in the j^{th} period after the reported health shock. In other periods, the $Shock_{it}$'s variable takes the value of zero.

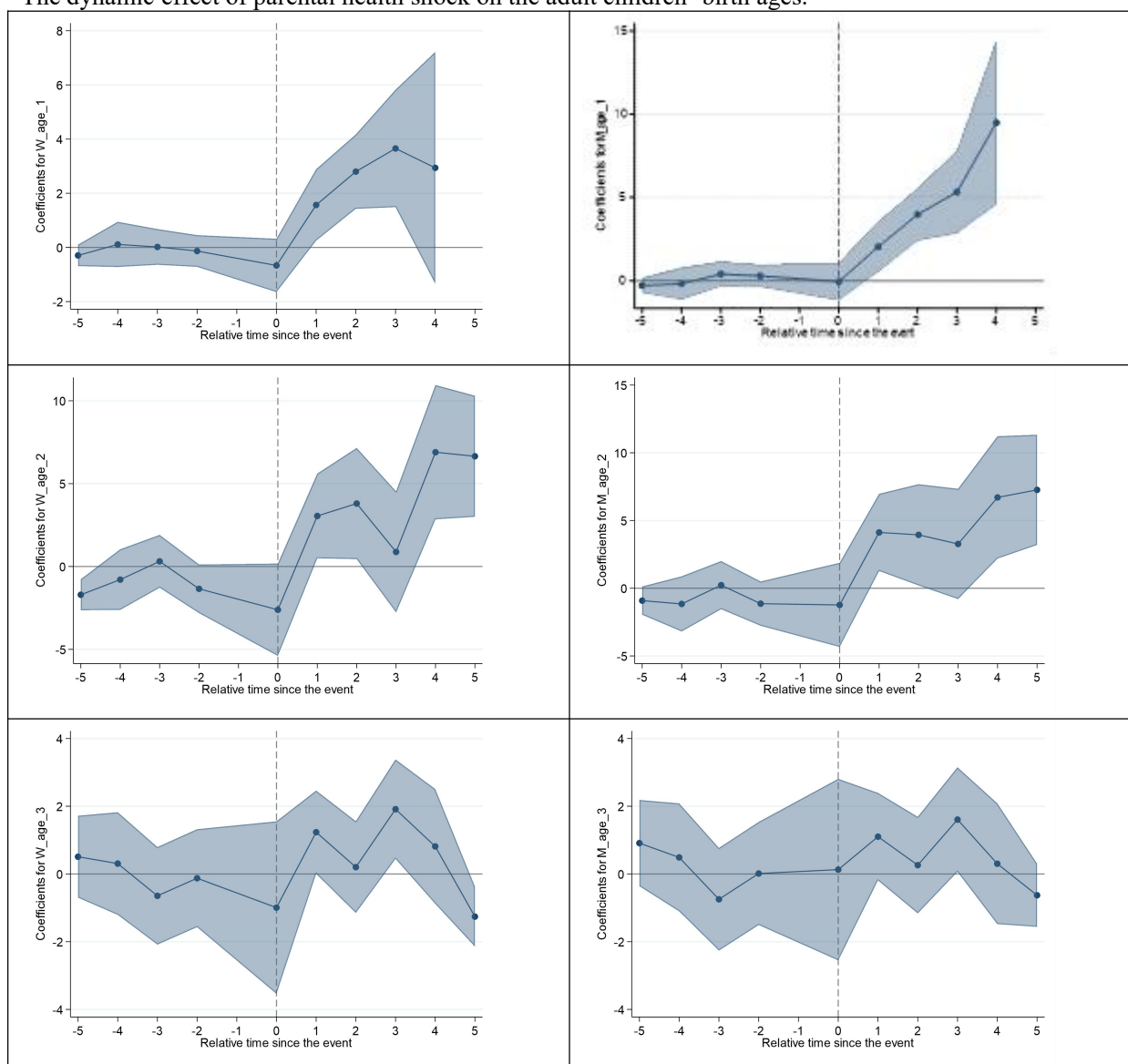
To gauge the temporal dynamics of the health shocks, we segment the periods into three-year intervals. We define relative periods of three years to estimate the dynamic effects of parental health shocks on the relative birth ages, with the first period before the shock ($Shock_{it}^{-1}$) defined as the three-year period before the shock, and ($Shock_{it}^{-2}$) defined as the period starting from six years before the shock to three years before the shock. The shock period is the next three years after the shock, and ($Shock_{it}^1$) is defined as the three-year period after the shock period.

While we recognize the potential for the economic effects of health shocks to dissolve over time, the estimate from the event study methodology in Figure 1 indicates that these effects can be long-lasting. Figure 1 graphically presents the impact of parental health shocks on fertility age, represented by a series of interconnected circles. The estimated coefficients extracted from these figures show minimal variation around zero prior to the shock period, transitioning to substantial positivity following the shock. This observation revealed significant disparities in fertility decision-making even 10-15 years after the health shock.

This finding underscores the lasting impact of economic constraints on fertility behavior, suggesting that the repercussions of health shocks can influence decisions throughout an individual's life cycle. This underscores that economic constraints are pivotal in driving down fertility behavior among adult children and can influence their entire life cycle.

Figure 1

The dynamic effect of parental health shock on the adult children's birth ages.



6. Conclusions and discussion

The falling birth rate in China is viewed with concern in policy circles. Recently President Xi Jinping has called for a ‘new trend of family’³. Various policies have been rolled out at local level to encourage families to have more children from tax incentives, maternity benefits, and housing subsidies⁴. The economic impact of parental health shocks on fertility decisions in China has not been recognized as a causative factor. The unique demographic transition and family structure in China, combined with the absence of a comprehensive social security system, means that adult children often bear most of the financial burden of caring for their elderly parents. This financial burden can have a profound impact on fertility decisions, exacerbating the challenges faced by families in caring for elderly members and creating a vicious cycle of intergenerational poverty.

Using one of the most consistent longitudinal datasets focused on households in China, we find evidence of adverse impact of parental health shocks on family fertility decisions. We separately analyze the impact of health shocks on the father, mother or both sets of parents. We also separate fertility decisions as the gender of the adult children. Based on the dual robust CEM-PSM estimation strategy, we built the fixed effects regression model for the fundamental analysis.

The results of this study provide important insights into the complex relationship between parental health shocks and fertility behavior in China. The study finds that parental health shocks have a significant negative impact on the number of children born and delay the reproductive age of adult children. The impact is more significant on the father's childbearing age than on the mother's, reflecting the greater financial burden borne by men in China. In addition, the delay in childbearing age is more substantial for the second and third children.

The study reveals that the impact of health shocks on fertility is more evident as the number of children in the family increases. Unsurprisingly we find that high-income families are less affected by parental health shocks than low-income families. The self-financing ability of families plays a critical role in mitigating the impact of economic shocks on fertility decisions. Medical insurance can significantly mitigate the impact of economic shocks on fertility decisions, especially for the second child's childbearing age.

If the falling birth rate is a policy issue for China, then this study strikes a strong policy resonance. At the heart of the issue is the lack of a universal social security system that

³[Xi urges women to have more babies as China battles record low birth rate \(telegraph.co.uk\)](https://www.telegraph.co.uk/news/2016/05/20/xi-urges-women-to-have-more-babies-as-china-battles-record-low-birth-rate/)

⁴[How China is seeking to boost its falling birth rate | Reuters](https://www.reuters.com/article/china-birth-rate/2016/05/20/how-china-is-seeking-to-boost-its-falling-birth-rate-idUSKCN0ZL001/)

provides comprehensive medical insurance. Of relevance are policies that target the needs of low-income families, as they are more severely impacted by parental health shocks. This could include financial assistance, access to affordable healthcare and increased medical insurance.

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Appendix

This appendix provides additional information on the numerical solutions as well as a linear approximation to theoretical model in section 1 and section 2. In section 3 we provide the logit regression on the relationship between individual/family observable characteristics and parental health shocks,

1 The solutions to the fertility model

1.1 The derivation of the optimal values of the number of children for adult children in different scenarios, given the health shock to their parents.

The Lagrangian is given by equation (1a):

$$\begin{aligned} \mathcal{L} = & \frac{c_{k,t}^{1-\delta}}{1-\delta} + \varphi(L_k) + nY_{k,t}V_{k,t}(q) \\ & + \lambda \left(\omega_k + I_t(1-B) - c_{k,t} - n\pi q - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t}(1-B)) \right) \\ & + \mu \left(T_{k,t} + Q_{k,t} + L_k - Q_{0,t}(1-B) - 1 \right) \quad (1a) \end{aligned}$$

where λ and μ are the Lagrange multipliers for the budget constraint and the time constraint, respectively.

Taking the first order conditions, we obtain:

$$\frac{\partial \mathcal{L}}{\partial c_{k,t}} = c_{k,t}^{-\delta} - \lambda = 0 \quad \Rightarrow \quad c_{k,t} = \left(\frac{1}{\lambda} \right)^{\frac{1}{\delta}} \#(2a)$$

$$\frac{\partial \mathcal{L}}{\partial L_k} = \varphi'(L_k) - \lambda\omega_k + \mu = 0 \quad \Rightarrow \quad \varphi'(L_k) = \lambda\omega_k - \mu \#(3a)$$

$$\frac{\partial \mathcal{L}}{\partial q} = nY_{k,t} \frac{\partial V_{k,t}(q)}{\partial q} - \lambda n\pi = 0 \quad \Rightarrow \quad \frac{\partial V_{k,t}(q)}{\partial q} = \frac{\lambda\pi}{Y_{k,t}} \#(4a)$$

$$\frac{\partial \mathcal{L}}{\partial n} = Y_{k,t}V_{k,t}(q) - \lambda\pi q = 0 \quad \Rightarrow \quad \lambda = \frac{Y_{k,t}V_{k,t}(q)}{\pi q} \#(5a)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \omega_k + I_t(1-B) - c_{k,t} - n\pi q - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t} * Q_{0,t}(1-B)) = 0 \#(6a)$$

$$\frac{\partial \mathcal{L}}{\partial \mu} = T_{k,t} + Q_{k,t} + L_k - Q_{0,t} * (1-B) - 1 = 0 \#(7a)$$

Rearranging the terms of equation (6a), we get:

$$n = \frac{\omega_k + I_t(1-B) - c_{k,t} - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t}(1-B))}{\pi q} \#(8a)$$

Substituting the expression for $c_{k,t}$ from equation (2a), we get:

$$n^* = \frac{\omega_k + I_t(1-B) - \left(\frac{1}{\lambda} \right)^{\frac{1}{\delta}} - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t}(1-B))}{\pi q} \#(8b)$$

Finally, we can substitute the expression for λ in terms of $Y_{k,t}$ and $V_{k,t}(q)$ from equation (5a), and simplify:

$$n^* = \frac{\omega_k + I_t(1 - B) - \omega_k L_k - \omega_k(Q_{k,t} - Q_{0,t}(1 - B))}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t} V_{k,t}(q)} \right]^{\frac{1}{\delta}} \#(9a)$$

This expression for n^* represents the optimal number of children that the adult children should have, given their preferences, budget constraint, and parental altruism. Note that this is subject to the assumption that the first-order condition for n holds, which is that the marginal utility of having an additional child equals the marginal cost.

1.2 Proof that the optimal number of children following a parental health shock ($B=1$) is strictly greater than the optimal number in the absence of a parental health shock ($B=0$).

For the case when $B = 0$, from equation (9a):

$$n_{B=0}^* = \frac{\omega_k + I_t - \omega_k L_k}{\pi q} - \frac{\omega_k(Q_{k,t} - Q_{0,t})}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}} \#(10a)$$

when $B = 1$, we have:

$$n_{B=1}^* = \frac{\omega_k - \omega_k L_k}{\pi q} - \frac{\omega_k Q_{k,t}}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} \#(11a)$$

$$\begin{aligned} \Delta n^* &= n_{B=0}^* - n_{B=1}^* \\ &= \frac{I_t + \omega_k Q_{0,t}}{\pi q} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}} \\ &\quad + \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} \end{aligned} \quad (12a)$$

For the first term of equation (12a), note that I_t and $Q_{0,t}$ are both non-negative, so the numerator of the first term is non-negative. Also, since π , q , and ω_k are positive, the denominator of the first term is positive. Therefore, the first term is non-negative.

For the second and third term of equation (12). Since the value of $Y_{k,t}$ is negatively correlated with the number of children and the cost of having each child, but positively correlated with the amount of childcare that can be shared with their parents, and $V_k(q)$, $\frac{1}{\delta}$ as well as πq are positive. Therefore, $Y_{k,t}(B=1) < Y_{k,t}(B=0)$, and we have:

$$\frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} > \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}} \#(13a)$$

Therefore, Δn^* itself is positive. This result holds under the assumption of parental altruism and the assumptions for the fertility preferences, budget constraint, and utility function of the adult children.

1.3 Proof that a parental health shock has a negative impact on adult children's choice to have another child, with the impact increasing with each successive child.

From the expression for Δn^* , we know that it depends on the cost of having each child πq , the transfer payment to support parents I_t , the amount of time available for childcare $Q_{0,t}$, the fertility preferences $Y_{k,t}(B=0)$ and $Y_{k,t}(B=1)$, and the quality of children $V_k(q)$.

If the cost of having each child, transfer payments, and childcare time are the same for each child, the main factor that influences Δn^* is the fertility preference. Specifically, the optimal number of children is determined by the trade-off between the marginal benefits and costs of having an additional child, which depend on the fertility preference.

If the fertility preference is higher, the marginal benefit of having an additional child is higher, which increases the optimal number of children. On the other hand, if the fertility preference is lower, the marginal benefit of having an additional child is lower, which decreases the optimal number of children.

At the beginning of each period, the cost of having each child πq is given. The fertility preference of adult children is influenced by the number of children they have before period t . Specifically, if they have 0, 1, or 2 children before period t , their fertility preference is $Y_{k,t}(\alpha, B)$, $Y_{k,t}(\beta, B)$, and $Y_{k,t}(\gamma, B)$, respectively, where the value of B is the same. Since the fertility preference decreases with the number of children, we can assume that $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$. This means that the marginal benefit of having an additional child is highest when there are no children (i.e., $Y_{k,t}(\alpha, B = 0)$ is the highest) and decreases with each successive child. Therefore, the impact of a parental health shock on the optimal number of children is expected to be the highest when there are no children and decreases with each successive child.

We can use the derived expression for Δn^* from equation (12a) to show that it is increasing as the fertility preference decreases. Specifically, we need to show that:

- 1) The numerator $I_t + \omega_k Q_{0,t}$ is fixed and positive.
- 2) The denominator πq is fixed and positive.
- 3) The term $\frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=1) * V_k(q)} \right]^{\frac{1}{\delta}} - \frac{1}{\pi q} \left[\frac{\pi q}{Y_{k,t}(B=0) * V_k(q)} \right]^{\frac{1}{\delta}}$ is decreasing as the fertility preference increases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$.

The first two conditions are trivially satisfied. For the third conditions, note that: $\frac{1}{\delta} < 1$, so raising a positive number to a power less than 1 makes it larger.

To prove that n^* is decreasing as the fertility preference increases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$, we need to show that:

$$\begin{aligned} \frac{\partial \Delta n^*}{\partial Y_{k,t}(\alpha, B)} &\leq 0, \frac{\partial \Delta n^*}{\partial Y_{k,t}(\beta, B)} \leq 0, \text{ and } \frac{\partial \Delta n^*}{\partial Y_{k,t}(\gamma, B)} \leq 0 \quad \#(14a) \\ \frac{\partial \Delta n^*}{\partial Y_{k,t}(\alpha, B)} &= -\frac{1}{\delta} \left[-\frac{1}{Y_{k,t}(B=0)} \right]^{\frac{1}{\delta}-1} \frac{\partial}{\partial Y_{k,t}(\alpha, B)} (Y_{k,t}(\alpha, B)) \\ &\quad + \frac{1}{\delta} \left[\frac{1}{Y_{k,t}(B=1)} \right]^{\frac{1}{\delta}-1} \frac{\partial}{\partial Y_{k,t}(\alpha, B)} (Y_{k,t}(\alpha, B)) \\ &= \frac{1}{\delta} \left[\frac{1}{Y_{k,t}(B=1)} \right]^{\frac{1}{\delta}-1} \left[\left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{1}{\delta}-1} - \left(\frac{1}{Y_{k,t}(B=0)} \right)^{\frac{1}{\delta}-1} \right] \quad (15a) \end{aligned}$$

Since $\frac{1}{\delta} > 1$, we have $\frac{1}{\delta} - 1 < 0$, which means that both terms inside the square brackets are decreasing functions of $Y_{k,t}(\alpha, B)$. Therefore, to prove that $\frac{\partial \Delta n^*}{\partial Y_{k,t}(\alpha, B)} \leq 0$, it is sufficient to show that:

$$\left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{1}{\delta}-1} \leq \left(\frac{1}{Y_{k,t}(B=0)} \right)^{\frac{1}{\delta}-1} \quad \#(16a)$$

Taking the reciprocal of both sides, we get:

$$(Y_{k,t}(\alpha, B))^{\frac{1}{\delta}-1} \geq (Y_{k,t}(B=0))^{\frac{1}{\delta}-1} \quad \#(17a)$$

Since $\frac{1}{\delta} - 1 < 0$, raising both sides to the power of $\frac{\delta}{\delta-1}$, we get:

$$Y_{k,t}(\alpha, B) \leq Y_{k,t}(B = 0) \quad (18a)$$

But we know that $Y_{k,t}(\alpha, B) > Y_{k,t}(B = 0)$, which means that $\frac{\partial \Delta n^*}{\partial Y_{k,t}(\alpha, B)} \leq 0$.

Now, let's look at the second derivative:

$$\begin{aligned} \frac{\partial^2 \Delta n^*}{\partial Y_{k,t}(\alpha, B)^2} &= -\frac{1}{\delta} \left[\frac{1}{Y_{k,t}(B = 1)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{\delta} - 1 \right) \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \frac{\partial}{\partial Y_{k,t}(\alpha, B)} (Y_{k,t}(\alpha, B)) \\ &\quad - \frac{1}{\delta} \left[-\frac{1}{Y_{k,t}(B = 0)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{\delta} - 1 \right) \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \frac{\partial}{\partial Y_{k,t}(\alpha, B)} (Y_{k,t}(\alpha, B)) \\ &= -\frac{1}{\delta^2} \left[\frac{1}{Y_{k,t}(B = 1)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\left(\frac{2\delta-1}{\delta} \right) - \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\ &\quad + \frac{1}{\delta^2} \left[-\frac{1}{Y_{k,t}(B = 0)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\left(\frac{2\delta-1}{\delta} \right) - \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\ &= -\frac{1}{\delta^2} \left[\frac{1}{Y_{k,t}(B = 1)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\left(\frac{2\delta-1}{\delta} \right) - \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\ &\quad + \frac{1}{\delta^2} \left[-\frac{1}{Y_{k,t}(B = 0)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\left(\frac{2\delta-1}{\delta} \right) - \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\ &= -\frac{1}{\delta^2} \left[\frac{1}{Y_{k,t}(B = 1)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\frac{\delta-1}{\delta} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} - \frac{2\delta-1}{\delta} \right] \\ &\quad + \frac{1}{\delta^2} \left[-\frac{1}{Y_{k,t}(B = 0)} \right]^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\frac{\delta-1}{\delta} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} - \frac{2\delta-1}{\delta} \right] \\ &= -\frac{1}{\delta^2} \left(\frac{1}{Y_{k,t}(B = 1)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\frac{2\delta-3}{\delta} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} - \frac{2\delta-1}{\delta} \right] \\ &\quad + \frac{1}{\delta^2} \left(\frac{1}{Y_{k,t}(B = 0)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \left[\frac{2\delta-3}{\delta} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} - \frac{2\delta-1}{\delta} \right] \\ &= \frac{1}{\delta^3} \left(\frac{1}{Y_{k,t}(B = 1)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{3\delta-1}{\delta}} \left[3\delta - 2 - 2 \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\ &\quad + \frac{1}{\delta^3} \left(\frac{1}{Y_{k,t}(B = 0)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{3\delta-1}{\delta}} \left[3\delta - 2 - 2 \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \end{aligned}$$

$$\begin{aligned}
&= \frac{1}{\delta^3} \left(\frac{1}{Y_{k,t}(B=1)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{3\delta-1}{\delta}} \left[3\delta - 2 - 2 \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{\delta-1}{\delta}} \right] \\
&\quad \times \left[1 - \left(\frac{Y_{k,t}(B=0)}{Y_{k,t}(B=1)} \right)^{\frac{1}{\delta}-1} \left(\frac{Y_{k,t}(\alpha, B)}{Y_{k,t}(B=1)} \right)^{\frac{3\delta-1}{\delta}} \right] \quad (19a)
\end{aligned}$$

Since $\frac{1}{\delta} > 1$, we know that $3\delta - 2 > 2\delta - 1$, which means that the expression inside the square brackets is positive. Therefore, the sign of the second derivative is determined by the expression in the first pair of square brackets.

Since $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$, we have:

$$Y_{k,t}(B=0) < Y_{k,t}(\gamma, B) < Y_{k,t}(\beta, B) < Y_{k,t}(\alpha, B) < Y_{k,t}(B=1) \quad (20a)$$

Substituting these values into the expression inside the first pair of square brackets, we get:

$$\frac{1}{\delta} - 1 < 0 \quad (21a)$$

so:

$$\left(\frac{1}{Y_{k,t}(B=1)} \right)^{\frac{1}{\delta}-1} > \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{1}{\delta}-1} > \left(\frac{1}{Y_{k,t}(B=0)} \right)^{\frac{1}{\delta}-1} \quad (22a)$$

Therefore,

$$\left(\frac{1}{Y_{k,t}(B=1)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} > \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{3\delta-1}{\delta}} > \left(\frac{1}{Y_{k,t}(B=0)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \quad (23a)$$

Since $\frac{2\delta-1}{\delta} > 1$, we know that:

$$\left(\frac{1}{Y_{k,t}(B=1)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} > \left(\frac{1}{Y_{k,t}(B=0)} \right)^{\frac{1}{\delta}-1} \left(\frac{1}{Y_{k,t}(\alpha, B)} \right)^{\frac{2\delta-1}{\delta}} \quad (24a)$$

Therefore, $\frac{\partial^2 \Delta n^*}{\partial Y_{k,t}(\alpha, B)^2} > 0$.

Since the second derivative is positive and the first derivative is non-positive, we know that the function Δn^* is a concave function of $Y_{k,t}(\alpha, B)$. Therefore, the maximum value of Δn^* is achieved when $Y_{k,t}(\alpha, B)$ is at its lowest value, i.e., when fertility preference is $Y_{k,t}(\gamma, B)$. Thus, we have shown that Δn^* is decreasing as the fertility preference increases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$.

Therefore, we have shown that Δn^* is increasing as the fertility preference decreases in the order of $Y_{k,t}(\alpha, B) > Y_{k,t}(\beta, B) > Y_{k,t}(\gamma, B)$. This means that a parental health shock has a stronger negative impact on adult children's choice to have another child as the fertility preference decreases, which is consistent with the notion of diminishing marginal utility of children. As the number of children increases, the marginal benefit of having an additional child decreases, and a negative shock to parental health further reduces the marginal benefit, leading to a lower optimal number of children.

2 A linear approximation for the utility function

In this section, we insert a discussion on the effectiveness of linear approximation for the optimal fertility number, n^* . This can be done by replacing the non-linear terms in the utility function with their first-order Taylor series approximations around some point.

Firstly, we can apply linear approximation to simplify the analysis of the consumption utility function $\frac{c^{1-\delta}}{1-\delta}$. Assuming that the consumption level c is close to a benchmark value

c_0 , we can linearly approximate the utility function at c_0 using a first-order Taylor expansion, which yields a linear function:

$$U(c) \approx U(c_0) + U'(c_0)(c - c_0) \quad (25a)$$

Where $U'(c_0)$ is the derivative of the utility function at c_0 .

Next, we apply linear approximation to the fertility preference of adult children $Y = Y(n, \pi q, B)$. Given a fixed number of children n and the availability of parenting assistance B , we can linearly approximate the fertility preference Y with respect to the cost of raising children πq around a benchmark value πq_0 using a first-order Taylor expansion:

$$Y(n, \pi q, B) \approx Y(n, \pi q_0, B) + \frac{\partial Y}{\partial(\pi q)} \Big|_{\pi q = \pi q_0} (\pi q - \pi q_0) \quad (26a)$$

where $\frac{\partial Y}{\partial(\pi q)}$ is the partial derivative of the fertility preference Y with respect to the cost of raising children πq .

By substituting these two linear approximation formulas into the optimization problem, we can simplify the utility function of adult children in period t . Specifically, we substitute the linearly approximated consumption utility function and fertility preference Y into the original utility function, which yields:

$$\begin{aligned} \max_{c, n, q, l} U_{k,t}(c, l, V) \\ \approx \frac{c_{k,t}^{1-\delta}}{1-\delta} \Big|_{c_{k,t}=c_0} + U'(c_0)(c - c_0) + \varphi(L_k) + Y(n, \pi q_0, B) \\ + \frac{\partial Y}{\partial(\pi q)} \Big|_{\pi q = \pi q_0} (\pi q - \pi q_0) \end{aligned} \quad (27a)$$

We can then solve this simplified optimization problem to obtain the optimal decisions with respect to the number of children n , the cost of raising children πq , and the availability of parenting assistance B . By taking the derivative of the simplified utility function and setting it equal to zero, we can obtain a simpler closed-form solution that describes the optimal decision for the number of children n^* .

3 The relationship between individual/family observable characteristics and health shocks.

Table 1 presents the results from our logistic regression analysis investigating the relationship between individual/family observable characteristics and health shocks, conditional on cohort fixed effects.

The Key Findings are:

Parents' Age (P_age): A one-unit increase in age is associated with a statistically significant increase in the likelihood of experiencing a health shock by 5.2 percentage points ($p < 0.01$). The estimated coefficient is 0.052 with a 95% confidence interval of [0.037, 0.066].

Parents' Education (P_edu_hat): The predicted value of education (P_edu_hat) shows a positive and statistically significant association with health shocks. A one-unit increase in the predicted value of education raises the likelihood of a health shock by 63.9 percentage points ($p < 0.01$). The confidence interval for this coefficient ranges from 0.411 to 0.867.

Household Income (hh_income): There's a significant positive relationship between household income and health shocks. A unit increase in household income increases the likelihood of health shocks by 212 percentage points ($p < 0.01$). This estimate lies within the 95% confidence interval of [0.789, 3.452].

Whether the parents work in the public (P_public): Receiving public assistance is associated with a decrease in the likelihood of a health shock by 57 percentage points ($p < 0.01$), with a 95% confidence interval of [-0.942, -0.199].

Whether the parents have medical insurance (P_med_insur): Having medical insurance seems to reduce the likelihood of health shocks by 46 percentage points, though this relationship is significant only at the 10% level ($p = 0.063$). The confidence interval for this coefficient is [-0.945, 0.025].

Cohort Fixed Effects: Among the cohort fixed effects, the years 2004, 2009, and 2011 show a statistically significant positive association with health shocks at the 5% level. The other years are not statistically significant at conventional levels.

Table 1

Logistic regression of individual/family observable characteristics and parental health shocks.

treatment	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
P_age	.052	.007	7.11	0	.037	.066	***
P_edu_hat	.639	.116	5.49	0	.411	.867	***
hh_income	2.12	.679	3.12	.002	.789	3.452	***
P_public	-.57	.189	-3.01	.003	-.942	-.199	***
P_med_insur	-.46	.247	-1.86	.063	-.945	.025	*
T2	-.398	.136	-2.92	.003	-.664	-.131	***
1991b	0
1993	.146	.202	0.72	.47	-.25	.541	.
1997	.284	.209	1.35	.176	-.127	.694	.
2000	.087	.223	0.39	.696	-.351	.525	.
2004	.678	.245	2.77	.006	.199	1.158	***
2006	.375	.275	1.36	.172	-.164	.915	.
2009	.656	.285	2.30	.021	.097	1.214	**
2011	.664	.285	2.33	.02	.105	1.222	**
2015	.604	.324	1.87	.062	-.031	1.238	*
Constant	-10.232	1.694	-6.04	0	-13.553	-6.912	***
Mean dependent var		0.124	SD dependent var		0.330		
Pseudo r-squared		0.100	Number of obs		3511		
Chi-square		263.568	Prob > chi2		0.000		
Akaike crit. (AIC)		2404.993	Bayesian crit. (BIC)		2522.102		

*** $p < .01$, ** $p < .05$, * $p < .1$

4 The estimation of the effect of parental health shock without education as control variable

In China, typically, individuals tend to embark on marriage and childbirth only after completing their education, thus invariably implicating the level of education as a significant determinant of reproductive age. This rationale underscores the necessity of incorporating the offspring's education level as a controlled variable in our baseline regression in our manuscript. However, we also present results devoid of this educational control because individuals may defer their reproductive decisions to acquire education, or the occurrence of parental health shocks could simultaneously shape educational attainment and fertility results. Conducting a comparative analysis of these regression outcomes with our principal results can facilitate a more lucid comprehension.

Here, parental health shocks increase the age at first, second, and third birth both for female adult children (W_age_1 to W_age_3) and male adult children (M_age_1 to M_age_3). These effects are statistically significant at the 1% level, except for M_age_2, which is significant at the 5% level.

Estimated results suggest a positive correlation between the occurrence of health shocks and age of reproduction even without educational control. These regressions do not include variable controls but comprise both region and time-fixed effects. Concluding, these results indicate that parental health shocks significantly postpone the age of reproduction for both

male and female offspring in Chinese households.

Table 2

The effect of parental health shock without education as control variable.

	(1) W age 1	(2) W age 2	(3) W age 3	(4) M age 1	(5) M age 2	(6) M age 3
Health shocks	.61*** (.059)	1.045*** (.155)	3.433*** (.542)	.601*** (.069)	.398** (.163)	1.538*** (.535)
Variable controls	NO	NO	NO	NO	NO	NO
Region fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Constant	24.132*** (.011)	28.107*** (.026)	29.807*** (.076)	25.8*** (.012)	29.348*** (.027)	31.411*** (.075)
Observations	86806	24510	3987	84990	24453	3986

(Note: The robust standard errors are in parentheses.

***, **, and * respectively represent the significance levels of 1%, 5%, and 10%.)