北京大学经济学院工作论文系列
Peking University School of Economics Working Paper Series

E-2025-12-2

Health Cost Risk, Informal Insurance, and Pension Decisions

Meitong Ai Ming Gao[1] Ruo Jia[2] Yaojing Wang[3]

This paper provides empirical evidence on how health cost risk affects individuals' pension decisions. We find that health cost risk increases pension participation but decreases the amount of contributions among participants. The substitution effect of informal insurance on pensions leads to this paradox. After accounting for informal insurance, health cost risk has a consistently negative impact on both pension participation and contributions, aligning with the theory. The substitution effect is stronger for households with better-educated children, yet does not vary by children's gender

Keywords： Health cost risk, Annuitization decision, Informal insurance, Annuity puzzle.

[1] School of Economics, Peking University, 5 Yiheyuan Road, Beijing, 100871, P.R. China, gao@pku.edu.cn.
[2] School of Economics, Peking University, 5 Yiheyuan Road, Beijing, 100871, P.R. China, ruo.jia@pku.edu.cn.
[3] School of Economics, Peking University, 5 Yiheyuan Road, Beijing, 100871, P.R. China, wangyaojing@pku.edu.cn.

Health Cost Risk, Informal Insurance, and Pension Decisions

Meitong Ai[a], Ming Gao[b], Ruo Jia[b], Yaojing Wang[b]

[a] School of Insurance, Central University of Finance and Economics, 39 South College Road, Beijing 100081, P.R.China

[b] School of Economics, Peking University, 5 Yiheyuan Road, Beijing, 100871, P.R. China

Abstract: This paper provides empirical evidence on how health cost risk affects individuals' pension decisions. We find that health cost risk increases pension participation but decreases the amount of contributions among participants. The substitution effect of informal insurance on pensions leads to this paradox. After accounting for informal insurance, health cost risk has a consistently negative impact on both pension participation and contributions, aligning with the theory. The substitution effect is stronger for households with better-educated children, yet does not vary by children's gender.

Keywords: Health cost risk; Annuitization decision; Informal insurance; Annuity puzzle

JEL Code: G52, H55, I13

1. Introduction

The annuity puzzle has long been a central topic in household finance (Ameriks et al., 2011; Inkmann, Lopes and Michaelides, 2011). The classical annuity demand theory suggests that individuals without bequest motives should fully annuitize their savings when longevity risk is the sole uncertainty (Yaari, 1965). However, elderly people annuitize little of their wealth, if any, to hedge against outliving their income (Benartzi, Previtero and Thaler, 2011). The theory of health cost risk provides one potential explanation for this annuity puzzle. Uninsured medical expenses may motivate individuals to hold liquid assets rather than annuities, reducing annuity demand in early retirement (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017).

However, existing theoretical models and simulations disagree on the direction of this effect. Previous studies suggest that the impact of health cost risk on annuity demand in the early retirement years could be negative (see e.g., Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017), positive (Pang and Warshawsky, 2010), or parameter-sensitive (Pashchenko, 2013). The optimal annuitization decision depends on the timing of the health cost risk and on the availability of alternative assets. On the one hand, uninsured medical expenditures early in life reduce the value of the annuities when compared to alternative assets (e.g., bonds or bank deposits), and thus lead to a lower optimal annuitization level than that later in life. On the other hand, health status is associated with individuals' portfolio allocation (Rosen and Wu, 2004), specifically, health cost risk may drive household portfolios to shift from risky equities to safer assets (e.g., bonds, deposits, annuities), while annuities may eventually dominate due to the embedded survivorship premium that increases with age. Given these conflicting predictions, empirical evidence is critical to reconcile theory with behavior.

This paper empirically investigates the impact of health cost risk on individuals' pension-annuitization decisions. We show that the health cost risk has a negative impact on the pension demand (both participation and contribution), after accounting for child-provided informal insurance and controlling for longevity risk. Informal insurance from children mitigates this effect by alleviating liquidity constraints: parents with two or more children fully offset the negative impact of health cost risk on pension participation, while those with four or more offset it for pension contributions. In China, where the average family has two children, this substitution effect explains why health cost risk increases pension participation (due to informal insurance offsetting) but decreases pension contributions (where the threshold is higher). This divergence resolves the apparent contradiction in prior literature and clarifies the health cost risk-annuitization relationship.

The lack of empirical evidence on how health cost risk affects annuitization decisions stems from two primary challenges. First, in countries with comprehensive health insurance systems, such as those in Europe, out-of-pocket health costs are minimal, leaving little incentive for individuals to account for out-of-pocket medical expenses in their liquidity needs. In contrast, health cost risk is far more salient in developing countries where health insurance systems are less mature. Public health insurance for people in the informal sector in China imposes high copayments,[1] and its scope of coverage is narrow (Yip et al., 2012). The public long-term care insurance was nearly nonexistent during our sample period.[2] Therefore, the out-of-pocket health cost risk is expected to be prominent for individuals in our sample.

Second, empirically distinguishing health cost risk from longevity risk is inherently difficult, as unexpected health shocks both increase medical expenditures and influence life expectancy.

[1] The reimbursement rate of hospitalization expenses is 75%; the rate for out-patient expenses is much lower than 75% and depends on provinces and cities (China State Council, 2016).

[2] The public long-term care insurance pilot programs started in 15 cities and two provinces in 2016.

Leveraging data from the China Health and Retirement Longitudinal Study (CHARLS), we empirically disentangle the impact of longevity risk from that of health cost risk on pension decisions. Longevity risk and health cost risk are the predominate risks that the elderly face concerning optimal financial security in retirement (Peijnenburg, Nijman and Werker, 2017). We measure longevity risk using self-estimated likelihood to live beyond 75 years old, which captures subjective life expectancy independent of health expenditures. The self-estimated life expectancy is an ideal measure to capture longevity risk because it is the subjective belief, upon which individuals make their annuitization decisions (Yogo, 2016). Health cost risk, meanwhile, is proxied by self-reported health status, the number of chronic diseases, and the predicted annual out-of-pocket health cost in five years.

China's Residents' Basic Pension (RBP) program provides an ideal setup for empirically analyzing the annuity puzzle, closely mirroring the assumption that the individual has no bequest motive and the prediction that the individual will fully annuitize, as suggested in Yaari (1965). The RBP program consists of two components: heritable individual accounts funded by participant contributions and non-heritable basic benefits financed through pay-as-you-go general taxation. This design yields three critical features. First, participation decisions are unaffected by bequest motives, as individual contributions remain fully inheritable, functionally equivalent to ordinary savings. Second, rational eligible individuals should participate, given the government's matching subsidies through the pay-as-you-go basic benefits and their exposure to longevity risk. Third, enrolling in the RBP is equivalent to purchasing a life annuity with fixed premiums and lifelong payouts beginning at age 60, with no option for lump-sum withdrawals. Thus, individuals effectively make their annuitization decision at the time of enrollment.

This paper analyzes individuals' pension and annuitization decisions based on the introduction of the RBP program and empirically verifies the health cost risk explanation to the annuity puzzle.

Using nationally representative longitudinal data covering 8,552 informal sector residents (14,324 individual-year observations) who are eligible for the RBP, with 93% residing in rural areas and 7% in urban areas. We find that individuals reporting good or fair health show 2.00 and 1.70 percentage points lower RBP participation probabilities, respectively, compared to those in poor health. Each additional chronic disease increases participation probability by 0.49 percentage points, while a 1% increase in predicted out-of-pocket health cost in five years increases participation by 0.017 percentage points. Contrary to participation patterns, pension contribution levels exhibit an inverse relationship with health cost risk. Participants in fair and good health contribute 2.9% and 10.5% more to the RBP program, respectively, than those in poor health. Each additional chronic disease reduces contributions of RBP participants by 0.94%. A 1% increase in the predicted out-of-pocket health cost in five years decreases contributions of RBP participants by 0.038%.

We explain this apparent contradiction between the impacts of health cost risk on pension participation and on pension contributions through informal insurance. We approximate informal insurance by the number of children in a household and by whether parents rely on their children for old age support (Rossi and Godard, 2022). After accounting for the effect of informal insurance, we find that compared with individuals with higher health cost risk, individuals with lower health cost risk demonstrate greater pension participation and higher contributions when they have no informal insurance, consistent with the mainstream theoretical predictions (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017). As the number of children in a family increases, the impact of health cost risk on pension decisions becomes weaker because parents can rely on children for out-of-pocket health costs; thus, health cost risk becomes less important when making pension decisions. This substitution effect of informal insurance on pensions explains the divergent health cost risk impact on pension participation and contributions, particularly among the healthier individuals.

In addressing potential endogeneity issues in our analysis, we employ a multifaceted approach to test the robustness and reliability of our findings. First, we utilize the panel nature of the data and implement a difference-in-differences strategy, leveraging acute diseases as an exogenous source of variation in health status. Second, to mitigate measurement errors and biased estimates arising from self-reported health assessments, we construct a latent health stock measure based on individuals' health indicators and personal characteristics. Last but not least, we address reverse causality concerns of receiving pension and health status by focusing on a sample of individuals before retirement age, who were not yet receiving pension benefits, thereby excluding the possibility that pension receipt influences health status.

We further show that the substitution effect of informal insurance on pensions is stronger, and thus mitigates the health cost risk impact more pronounced, in households with better-educated children. Child gender shows no differential impact. We rule out income, property ownership, and formal health insurance as explanations for the opposite impact of the health cost risk on the intensive and extensive margins of pension demand. Our results emphasize the importance of informal insurance when analyzing the impact of health cost risk on individuals' annuitization decisions, especially in developing economies with inadequate health insurance coverage and substantial health protection gaps.

Contributions and Relationship to Literature -- Our paper contributes to the literature in two ways. First, we contribute to the understanding of the annuity puzzle and the impact of health cost risk on annuitization decisions. Recent theoretical works considering health cost risk find that partial or no annuitization can be the optimal level (Davidoff, Brown and Diamond, 2005; Reichling and Smetters, 2015). An uninsured health cost risk early in life reduces the value of annuities when compared with alternative assets (e.g., bonds or bank deposits), if it is not possible to sell or borrow against the future payments of the fixed annuity stream while it is possible to do so for the alternative assets (Davidoff, Brown and Diamond, 2005). However, if uncertain health expenses occur later in life, individuals can annuitize all wealth and save money out of the annuity income to build a liquid wealth buffer against the risk (Peijnenburg, Nijman and Werker, 2017). In contrast, Pang and Warshawsky (2010) suggest that there is a positive impact of the health cost risk on annuity demand. Pashchenko (2013) finds that uncertain medical expenses, which are a type of health cost risk, have a very small effect on annuity ownership and the direction of the effect depends on parameters.

To the best of our knowledge, no empirical work has examined the inconsistent theoretical predictions regarding the impact of the health cost risk on annuitization decisions. Our paper fills this gap by providing the first piece of the empirical evidence.[3]

Second, our paper contributes to the literature on informal insurance and its substitution effect on pensions. Informal insurance provided by households and other types of social networks is prevalent in developing economies, where the formal public/private insurance system is underdeveloped (Oliveira, 2016). The demand for social insurance depends on the availability of informal insurance (Bloch, Genicot and Ray, 2008). It is common for couples to have and raise children with a motive of ensuring their security in old age. Children are an important income source in the sense of a family transfer to their parents. Altruism and trust within a household ameliorate the commitment constraints and reinforce the risk-sharing agreements within a household, which forms a potential informal insurance provider and substitutes for a large fraction of the pension scheme (Foster and Rosenzweig, 2001). Having more children to support the parents

[3] Related to our context, Ameriks et al. (2011) and Lockwood (2018) study the joint impact of bequest motives and long-term care considerations on pension and long-term care insurance demand. The health cost risk in our context (and in the health cost risk theories) is short term, unexpected, out-of-pocket medical expenses, which needs for liquid, short-term pre-cautionary savings that cannot be financed by annuitized pension income suggested by Ameriks et al. (2011).

in elderly life provides a more adequate and reliable hedge against longevity risks and thus reduces the demand for annuities.

To the best of our knowledge, the existing literature focuses on bequest motives but overlooks the role of informal insurance as a substitute for pensions when analyzing the role that children play in the impact of health cost risk on annuitization decisions (Davidoff, Brown and Diamond, 2005; Pang and Warshawsky, 2010; Panshchenko, 2013; Reichling and Smetters, 2015). This overlook of informal insurance may well explain the inconsistent directions of health cost risk impacts on annuitization decisions. This paper is the first to examine the pension substitution role that informal insurance plays in the relationship between health cost risk and annuitization decisions.

The rest of the paper is structured as follows. Section 2 introduces the institutional background. Section 3 describes the data and methodology. Section 4 reports our main empirical results. Section 5 conducts additional analyses on the informal insurance effect. Section 6 rules out the alternative explanations and discusses the robustness of the results. Section 7 concludes.

2. Institutional background

2.1 Structure of China's public pension system

Children's responsibility within a household is often an important part of old-age support, especially in developing countries. Many countries, for example, Bangladesh, India, and Singapore, have filial support laws (Serrano, Saltman and Yeh, 2017). The Marriage Law in China codifies the obligation of support from adult children to their elderly parents; the Confucian tradition requires the same. These laws and traditional culture result in a strong informal old-age security system, especially in rural China (Giles, Wang and Zhao, 2010).

In our sample period, China's public pension system (Pillar I) consists of two fragmented programs that are i) Urban Employees' Basic Pension (EBP) and ii) Urban and Rural Residents' Basic Pension (RBP).[4] Below we highlight the difference of the EBP and RBP programs and illustrate how the RBP program used in our paper would be suitable for our analysis.

The EBP is compulsory for urban employees working in the formal sector (e.g. formally established enterprises, public institutions and government) and allows for workers with less formal contracts (e.g., self-employed and temporarily unemployed) to voluntarily participate (China State Council, 1995). For urban employees working in the formal sector, the EBP contribution consists of two parts -- individuals' payroll tax (usually 8% of payroll), which enters into the heritable individual account, and the employers' contribution (usually 16%-20% of the payroll), which enters into the non-heritable general account (i.e. the pay-as-you-go component). For flexible workers, they are required to pay both the employee's and employer's shares of the contribution, totaling around 20% of their income (usually 4% in heritable individual account and 16% in the non-heritable general account). Given the lower income and irregular contributions from flexible workers (including temporarily unemployed), the total amount accumulated in their individual accounts is usually less than that from employees in the formal sector.

2.2 Institutional features of Residents' Basic Pension

The RBP program, that studies in this paper, was first introduced in rural China in 2009, extended to urban areas in 2011, and made available nationwide by 2012. As the first pension plan accessible to most informal-sector workers -- including farmers, the unemployed, and those in

[4] The RBP arose from the merger of two public pension schemes in 2014: the New Rural Basic Pension and the Urban Residents' Basic Pension. The former was launched in 2009 to cover all rural residents, while the latter was launched in 2011 to cover urbanites in the informal sector who were not covered by the EBP. There are few differences in the levels of contributions and pension benefits, retirement age, and other rules between these two short-lived public pension schemes. Thus, we consider them as one RBP program in our analyses and control for the urban or rural registered residence, wherever applicable.

flexible employment -- its simple structure (low contributions and limited benefits) allows for clear observation of annuitization behavior. Unlike the mandatory Employees' Basic Pension (EBP),[5] RBP participation is voluntary, for all urban and rural residents that are not eligible for the EBP (either employed, self-employed, or unemployed), so called informal sector residents (China State Council, 2014). In practice, RBP is a more attractive program for urban flexible workers than the EBP given its lower individual contribution, waiver of employers' contribution, and the government subsidies.

The RBP is a partially funded system. The funding of RBP is composed of individual contributions and government subsidies (China State Council, 2014).[6] The amount of RBP individual contributions is a list of fixed amounts per year, starting from CNY 100, 200, up to 9,000 in our sample. Residents can voluntarily decide to participate in RBP by contributing any amount in the list of options. All individual contributions enter into the heritable individual account. The government subsidies do not enter into the heritable individual account but are paid to individuals as monthly pension benefits after they retire.

The monthly pension benefits of RBP consist of two components, one is the "individual account pension benefits", equal to the total, accumulated amount in the individual account at the time of retirement divided by 139.[7] It is a defined contribution component. The other component is so called "basic pension benefits" that are entirely financed by the government subsidies from general tax. The amount of monthly basic pension benefits varies by province and by year; the lowest standard set by the national regulation was CNY 55 per month in 2011 and 2013 (China

---

[5] The public pension system in China has two schemes: the EBP and the RBP. The EBP is compulsory for employees in the formal sector (i.e., government, public institutions, and formally established enterprises), while the RBP is voluntary and targets informal sector residents who are not covered by the EBP.

[6] Some rich villages may subsidize RBP by contributing to individual accounts, which are however uncommon.

[7] The division factor of 139 months is calculated based on the assumptions of retirement at 60 (China State Council, 2005). The factor was set in 2005 and never changed until now.

State Council, 2009, 2011), CNY 70 in 2015, and CNY 88 in 2018 (Human Resources and Social Security Ministry & Ministry of Finance, 2018). It is therefore a defined benefit component.

Given the general tax funded pension benefits (i.e., the "free" basic pension benefits), it is financially beneficial and attractive for most eligible residents in China to participate in the RBP, compared to saving by oneself, if not considering the near-future liquidity needs due to health cost risk. To receive RBP pension benefits, participants must be at least 60 years old and have contributed for at least 15 years to the RBP scheme. Exceptions are made for participants who were already 60 years old or older, or had contributed for less than 15 years before turning age 60 at the time the RBP was introduced to his/her province. These older participants are entitled to receive pension benefits immediately without any contribution if they are 60 or older and if their eligible adult children have enrolled in the RBP scheme, or they contribute until age 60 and then receive pension benefits.[8] Hence, the residents who were 60 years old or older when the RBP was introduced to his/her province did not make a pension participation decision.

The RBP is a unique program, different from most social security and public pension programs in developed countries, because its participation is voluntary, its contribution is not payroll based, and its benefits consist of both defined contribution and defined benefit components. The advantage of RBP program also lies in that it is a newly introduced program that all eligible residents made an annuitization decision to participate or not; whereas before the RBP introduction, most residents had no access to any pensions. In this sense, the RBP setting also reduces selection bias and offers stronger explanatory power to the general population.

---

[8] Individuals could also decide not to participate at the time RBP was introduced but change their mind and participate at a later stage. Individuals choosing that option would have to contribute for a minimum of 15 years or the difference between the introduction year and the year the individual reached age 60, whichever is smaller. Individuals are also allowed to make a lump sum pension contribution as long as the cumulative payments did not exceed 15 years' worth of contributions. Such a lump sum contribution is higher than the sum of the annual contributions due to the lack of subsidies that are matched to their annual contributions.

The RBP program is essentially a deferred annuity, whereas the pension decision to participate/contribute essentially makes two simultaneous decisions. One is a saving decision -- saving a fixed amount of contribution every year until age 60. The other is an annuitization decision -- receiving a lifetime annuity income starting from 60 that loses the liquidity of withdrawing the savings after participating RBP. Lump-sum withdraw is not allowed either before or after 60 with very few exceptions, which however do not include catastrophic medical expenses.

For RBP decision makers (i.e., those informal sector residents), their consideration of annuitization and liquidity dominates the consideration of saving. This is because RBP pension participation does not meaningfully change one's consumption and savings (See in Appendix D1). In addition, prior literature shows that the alternative to contributing to public pension schemes in China is not consumption but savings mainly in the form of bank deposits or government bonds. Feng, He, and Sato (2011) show that pension reform in urban China is positively associated with household saving. He et al. (2019) find that reductions in pension generosity raise household saving rates. From a cultural perspective, Chan et al. (2022) examine how collectivist cultural values and norms explain why Chinese households exhibit stronger saving behavior relative to more individualistic societies; they argue that cultural predispositions toward thrift, future orientation, and intergenerational responsibility amplify saving motives beyond purely consumption incentives.

Thus, the RBP program, similar to other public or defined-benefit schemes, can be viewed as forms of annuitization, where participation rates and contribution amounts remain suboptimal even when programs are subsidized or offer guaranteed lifetime income. Understanding why individuals underutilize pension and annuity products is therefore critical.

2.3 Bequest motives

The bequest motive is an important, classical explanation for the annuity puzzle, i.e.

individuals decide not to participate in pension schemes as they prefer to leave bequest to heirs when they die before depletion of their own wealth (Yaari, 1965; Pashchenko, 2013). In the RBP system, all individual contributions enter into the RBP individual account, and any remaining balance of the RBP individual account (i.e., individual contribution plus its interests, minus individual account pension benefits received) are heritable. Thus, individuals cannot "lose" in terms of bequest to heirs by participating in the RBP, which exclude the possibility that individuals decide not to participate due to bequest motives. This is a distinguishing characteristic of the RBP.

Appendix A compares the heritable amount between two scenarios: i) participating in and contributing to RBP and ii) not participating in RBP but saving equivalent amount of contributions in a regular bank account. Assuming that the interests provided by RBP individual account always equal to the interests provided by a regular bank account, the heritable amount of participating in the RBP is always equal to or larger than saving in a regular bank account. In this sense, the RPB provides an ideal set up to analyze the annuitization decision free of bequest motives.

3. Data and methodology

3.1 Empirical design

Health cost risk, as suggested by the precautionary saving theory, motivates liquidity needs and thus decreases annuity demand, which is an important explanation for annuity puzzle (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017). However, there is no empirical evidence regarding how health cost risk affects pension demand. To answer this question, we construct the baseline model as follows:

$$Pension\_demand_{it} = \beta_0 + \beta_1 Health\_cost\_risk_{it} + \beta_2 Longevity\_risk_{it} + \beta_3 Informal\_insurance_{it} + \boldsymbol{\lambda X_{it}} + \delta Year_t + \gamma Province_i + \varepsilon_{it}, \quad (1)$$

where the subscripts i and t represent the individuals and survey waves, respectively. *Pension_demand*$_{it}$ is measured by: (i) whether individual *i* participated in the RBP scheme in year t (*Pension_participation*), and (ii) the contributions that individual i paid to the RBP program in year *t* (*Pension_contribution*). We estimate Eq. (1) with a Probit model for the dummy dependent variable *Pension_participation* based on the full sample (i.e., the extensive margin). We estimate an OLS regression for the log form continuous dependent variable Ln(*Pension_contribution*)[9] on a subsample of RBP participants (i.e., the intensive margin).

Health_cost_risk$_{it}$ is captured by: (i) individual *i*'s self-reported health status in year *t*, (ii) individual *i*'s number of chronic diseases in year *t*, and (iii) individual *i*'s predicted out-of-pocket health cost five years into the future. We use these measures for three primary reasons. First, there is a significant correlation between health status and the probability of incurring out-of-pocket medical expenditures (Turra and Mitchell, 2008). Second, future health status can accurately be predicted by the present health status (Yogo, 2016), which can be captured by a self-reported health status and the number of chronic diseases. Third, according to Peijnenburg, Nijman and Werker (2017), health cost risk after approximately five years has little impact on the annuitization decision. Hence, we use five years as a threshold time to project future health cost risk.

Longevity_risk$_{it}$ is captured by individual *i*'s self-estimated likelihood of living beyond 75

[9] We generate the log form continuous variables in this paper based on the equation "Ln(*x*)=ln(*x*+1)" when *x* is positive and the equation "Ln(*x*)=-ln(-*x*+1)" when *x* is negative.

years of age in year *t*.[10] The age of 75 years old is an ideal threshold given that the Chinese life expectancy was 74.83 years old in 2010. The subjective longevity measure is better than any objective mortality measures because individuals make their annuitization decisions based on their perception of their own longevity risk.

We measure $Informal\_insurance_{it}$ by: (i) the living number of children of individual *i* in year *t* (*Number_of_children*), and (ii) as a robustness test, whether an individual relies on his/her children for retirement (*Rely_on_children*). We do not use family transfer to measure informal insurance because our sample consists of individuals who are between 45 and 59 years old and are still working, whose children are at school/university or in an early stage of their careers and most likely have not yet started to transfer income to their elderly parents. Using the number of children to measure informal insurance follows the conventional wisdom of raising children for old-age support (Rossi and Godard, 2022). Children might also be a burden to their elderly parents if the children are not financially independent and continue to rely on their parents after they have grown; this may affect the elderly parent's financial portfolio decisions. Therefore, we use the *Rely_on_children* as an alternative informal insurance measure, which captures an individual's subjective beliefs about the need and the possibility to rely on their children for old-age support.

$\boldsymbol{X}_{it}$ is a vector of control variables representing age, gender, ethnicity, marital status, education, risk attitude, health insurance status, wealth,[11] urban/rural residence, and life satisfaction. We include the province fixed effects, as the policy of the RBP program and its accumulated funds

[10] All respondents under 65 years old were asked "Suppose there are 5 steps, where the lowest step represents the smallest chance and the highest step represents the highest chance. On what step do you think is your chance in reaching the age of 75?"

[11] Alternatively, we replace wealth by income to control for the liquidity for precautionary savings. All results are consistent with our main results. Controlling for wealth or income is also critical to address the concern that some individuals (in particular those without children but with poor health) might be too poor to participate/contribute to the RBP program.

were managed at the provincial level.[12] We also include year fixed effects.

To examine whether and to what extent the substitution effects of child-provided informal insurance on pensions mitigate the impact of health cost risk on pension demand, we include an interaction term between $Informal\_insurance_{it}$ and $Health\_cost\_risk_{it}$, as shown in Eq. (2).

$$\begin{aligned} Pension\_demand_{it} & \\ &= \alpha_0 + \alpha_1 Health\_cost\_risk_{it} \\ &+ \alpha_2 Longevity\_risk_{it} + \alpha_3 Health\_cost\_risk_{it} \times Informal\_insuranc \\ &+ \alpha_4 Informal\_insurance_{it} + \boldsymbol{\theta X_{it}} + \delta Year_t + \gamma Province_i + \varepsilon_{it}. \end{aligned} \tag{2}$$

To reveal the mechanism and heterogeneity of informal insurance's substitution effect on pensions, we estimate Eq. (2) in several subsamples.

3.2 Data and sample

Our data are obtained from the China Health and Retirement Longitudinal Study (CHARLS). CHARLS belongs to the family of well-established international health and retirement surveys, including, for example, the Health and Retirement Study (HRS) in the United States and the Survey of Health, Ageing, and Retirement in Europe (SHARE). CHARLS is nationally representative and involves surveying respondents aged 45 years and older from 450 villages or urban communities from 150 counties or urban districts in China. The national baseline survey was conducted in 2011; this was followed up with surveys in 2013, 2015, and 2018. The latter waves revisit the same respondents as in the baseline survey and recruit new age-eligible respondents to maintain a

[12] We identify the between-group variation, that is, the difference in pension demand between individuals with different health statuses. We do not identify the within-group over-time variation by estimating individual fixed effects because i) pension decisions are made infrequently and although individuals may change their mind over 2011–2018, that is rare; and ii) the sample is heavily unbalanced. Specifically, there are 14,324 individual-year observations for 8,552 individuals. Hence, some individuals appear only once in our sample.

representative sample (Zhao et al., 2020). Interviews ask respondents about their personal information, family structure and family financial support, health status, work, income and assets, and retirement and pension plans, among other things. CHARLS has been widely used in the finance and economic research published in leading academic journals (e.g., Oliveira, 2016; İmrohoroğlu and Zhao, 2018; Cui, Smith and Zhao, 2020).

Using CHARLS (2011–2018), we construct our sample in the following steps. First, we select respondents aged 45 to 59 and are eligible to participate in the RBP scheme. CHARLS specifically targets survey respondents aged 45 and older; respondents aged 60 or older in the survey year should have already been receiving pension benefits and therefore do not need to make pension decisions. Second, we exclude observations with missing variable values. The final sample for our baseline analyses contains 14,324 individual-year observations. Our sample size is comparable to that of relevant studies using CHARLS (e.g., Oliveira, 2016; Cui, Smith and Zhao, 2020). Table 1 presents the summary statistics for our sample.

[Table 1 here]

Pension_participation is a dummy variable that equals 1 when individuals participated in the RBP program, and 0 when an eligible individual did not participate. *Pension_contribution* is a continuous variable representing the annual contributions that individuals paid to the RBP program. Three dummy variables are used to capture the individual's self-reported health status: $Health^{poor}$, $Health^{fair}$, or $Health^{good}$. $Health^{poor}$ equals 1 when the self-reported health status is very poor or poor, and 0 otherwise. $Health^{fair}$ equals 1 when the self-reported health status is fair, and 0 otherwise. $Health^{good}$ equals 1 when the self-reported health status is good, very good, or excellent, and 0 otherwise. *Chronic_diseases* is measured by the number of chronic diseases that the individual has been diagnosed with.[13] *Predicted_health_cost* is an individual's predicted annual out-of-pocket health cost in five years.[14]

Three dummy variables are used to capture the individual's longevity risk: *Unlikely_75*, *Maybe_75*, and *Likely_75*. *Unlikely_75* equals 1 when the individual evaluates his/her chances of reaching the age of 75 as almost impossible or not very likely, and 0 otherwise. *Maybe_75* equals 1 when the individual evaluates his/her chances of reaching the age of 75 as maybe, and 0 otherwise. *Likely_75* equals 1 when the individual evaluates his/her chances of reaching the age of 75 as very likely or almost certain, and 0 otherwise. *Number_of_children* is the number of the individual's living children. *Rely_on_children* equals 1 when the individual expects children to be his/her main financial resource in old-age, and 0 when the individual expects savings, public or private pensions, or other financial resources as the main financial resource for old age. Other variable definitions can be found in Appendix B and in the legend of Table 1.

As Table 1 shows, the average RBP participation rate is 79% over the four waves of surveys during 2011–2018. The high participation rate is driven by heavy general tax subsidies (i.e., government matching funds) to the RBP program that makes the RBP financially attractive to eligible residents. The average annual contribution is CNY 254.1 if including nonparticipants,

---

[13] Chronic diseases, defined in the CHARLS questionnaires, include: (i) hypertension, (ii) dyslipidemia, (iii) diabetes or high blood sugar, (iv) cancer or malignant tumor(s), (v) chronic lung diseases (e.g., chronic bronchitis, emphysema), (vi) liver disease, (vii) heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems, (viii) stroke, (ix) kidney disease, (x) stomach or other digestive disease, (xi) emotional, nervous, or psychiatric problems, (xii) memory-related disease, (xiii) arthritis or rheumatism, and ivx) asthma.

[14] *Predicted_health_cost* is an individual's predicted annual out-of-pocket health cost in five years. We use an individual's annual health cost in 2018 (2015), including medical costs for inpatient care, outpatient treatment, and self-treatment, to approximate his/her future annual health cost when in 2013 (2011). We use an OLS model to estimate the coefficients of the following equation:

$$Health\_cost_{i,t5} = \alpha_0 + \alpha_1 Health\_fair_{it} + \alpha_2 Health\_good_{it} + \alpha_3 Chronic\_diseases_{it} + \alpha_4 Age_{it} + \alpha_5 Age_{it}^2 + \alpha_6 \mathrm{Ln}(Net\_income_{it}) + \alpha_7 Male_{it} + \alpha_8 Health\_insurance_{it} + \varepsilon_{it}$$

where the subscripts i and t represent the individuals and survey waves, respectively. We then use the estimated coefficients to predict individuals' annual out-of-pocket health cost in five years for each wave in our sample. We also predict individuals' annual total health cost in five years, and the results are robust and upon request.

while it is CNY 323.5 for the RBP participants. 24% of individuals are in poor health, 50% are in fair health, and 26% are in good health. The average number of chronic diseases is 1.47 per person, given the age range of 45 to 59. The average predicted annual out-of-pocket health cost in five years is CNY 2160; 29% of individuals believe that they will not live until 75 years old, 39% think they may, and 32% think it is likely. On average, there are 2.24 living children of an individual, and 73% of respondents think they can financially rely on their children during their old age, suggesting that senior and middle-aged Chinese follow the conventional wisdom of raising children for old-age support.

Overall, the average age of the respondents is 52.5, 47% are male, 11% belong to an ethnic minority, and 95% are married. In terms of educational levels, 16% of respondents are illiterate, 43% have an elementary school education, and 41% have a middle school education or above. Thirty-five percent of respondents have taken at least one physical examination within the past two years and 65% have not taken any physical examinations in the past two years. Ninety-six percent are covered by public health insurance[15], which is consistent with the officially announced high participation rate. The average household wealth per capita is CNY 127,000. Only 7.0% of respondents have an urban registered residence because a large fraction of urban residents is covered by the EBP, and therefore, those residents are ineligible for the RBP; the 93% rural-resident-dominant sample is also favorable because the ideology of raising children for old-age support is more common among rural residents than urban residents. Fourteen percent of individuals are not satisfied with their lives, 56% are somewhat satisfied, and 30% are satisfied.

The average incidence rate of acute diseases (incl. heart attack, stroke and cancer) is 10%. The

[15] Public health insurance includes urban resident medical insurance, new cooperative medical insurance, and urban and rural resident medical insurance. Public health insurance is the only accessible health insurance program for almost all individuals in our sample. The decisions to participate in public health insurance and RBP are independent of each other as they are operated by different institutions.

educational levels of the younger generation are much higher than that of the senior and middle-aged respondents in our sample: Thirty-one percent of respondents' children have completed an advanced education (including an associate's degree, a bachelor's degree, a master's degree, or a doctoral degree).[16] On average, there are 1.18 living sons and 1.07 living daughters of a respondent in our sample. The individual average annual net income and labor income are CNY 8298.6 and CNY 7566.5, respectively. Ninety-eight percent of the respondents own land and/or houses/apartments.[17] Sixty-eight percent of respondents have at least one living parent.

4. Empirical results

4.1 Impact of health cost risk on pension demand

Table 2 presents the results of Eq. (1), which represents the impact of health cost risk on pension demand. Columns (1)–(3) use the full sample to estimate the impact on pension participation (i.e., the extensive margin). Columns (4)–(6) use the sample of pension participants to estimate the impact on pension contributions (i.e., the intensive margin). We report the average marginal effects of the Probit regressions and the coefficients of the OLS regressions. We estimate robust standard errors in our main results.

[Table 2 here]

The results in Columns (1)–(3) of Table 2 show that pension participation increases with the health cost risk when controlling for the longevity risk. When compared with individuals in poor health, individuals in fair or good health have a 1.70 and 2.00 percentage points lower probability of participating in the RBP, respectively. Having one more chronic disease increases the probability

[16] The education of the younger generation has greatly improved. Accordingly, we classify the educational levels of parents and children using different categories.
[17] In CHALRS, 78.8% of respondents own land and 94% of respondents own houses/apartments.

of RBP participation by 0.49 percentage points. A 1% increase in the predicted out-of-pocket health cost in five years increases the probability of RBP participation by 0.017 percentage points. The result contradicts the precautionary savings theory for health cost risk, which predicts that optimal annuitization levels are lower for individuals in poor health than those in good health (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017).

The results in Columns (4)–(6) illustrate that the contributions of RBP participants decrease with the health cost risk, which is the opposite result of the pension participation analyses. When compared with participants in poor health, participants in fair health and those in good health contribute 2.87% and 10.5% more to the RBP program, respectively. Having one more chronic disease decreases the contributions of RBP participants by 0.94%. A 1% increase in the predicted out-of-pocket health cost in five years decreases their contributions of the RBP participants by 0.038%. The results are consistent with mainstream theoretical assertion that a health cost risk early in retirement increases the need for liquidity, and thus lowers the annuity demand (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017).

The longevity risk always has a positive impact on pension demand for both pension participation and pension contributions. As a robustness test, we estimate the impact of health cost risk on pension contributions, including both the pension participants and the nonparticipants in the full sample. The results show that the coefficients on the health cost risk become smaller or insignificant, suggesting that the effect of the intensive margin and that of the extensive margin offset each other (see Section 6.2).

In sum, we document the opposite impacts of health cost risk on pension demand when individuals decide whether to participate in the pension program (i.e., pension participation) and when they determine how much to contribute (i.e., the extent of participation or pension contribution) after they have enrolled in the pension program.

4.2 Substitution effect of informal insurance on pensions

The existing theoretical work has yet to explain the seemingly contradictory results that show health cost risk increases the probability of pension participation but decreases the amounts of pension contributions. In this paper, we consider children as alternative informal insurance to pensions for old-age security (Rossi and Godard, 2022), as children provide financial, physical, and emotional support to the elderly. Given that participation and contributions to the RBP scheme are free of bequest motives, we are able to examine whether, and to what extent, the availability of informal insurance provided by children mitigates the impact of health cost risk on pension demand. Table 3 reports the results.

[Table 3 here]

The $Health^{fair}$ and $Health^{good}$ coefficients are consistently positive and significant for pension participation and contribution decisions. In addition, the *Chronic_diseases* and *Predicted_health_cost* coefficients are consistently negative and significant. These results suggest that individuals with a low health cost risk and with no children are more likely to participate in pensions and contribute more to pensions after enrollment. In other words, health cost risk has a consistently negative impact on pension demand after teasing out the substitution effect of informal insurance on pensions.

Columns (1) and (4) of Table 3 show that the coefficients of the interaction terms between *Number_of_children* and $Health^{fair}$ or $Health^{good}$ are all negative and significant. The coefficients of the interaction terms between the *Number_of_children* and *Chronic_diseases* or *Predicted_health_cost* are all positive and significant, as shown in Columns (2), (3), (5), and (6). When compared with individuals in poor health, having one more child decreases the probability of RBP participation for individuals in fair (good) health by 2.45 (2.95) percentage points. When compared with pension participants in poor health, having one more child decreases the contributions of RBP participants in fair (good) health by 4.36% (4.34%). Having one more child on average mitigates the negative impact of *Chronic_diseases* on the probability of RBP participation by 0.66 percentage points and mitigates its negative impact on the contribution of RBP participants by 1.41%. Having one more child on average mitigates the negative impact of *Predicted_health_cost* on the probability of RBP participation by 0.023 percentage points and mitigates the negative impact on RBP participants' contributions by 0.036%. These results suggest that the informal insurance provided by children mitigates the negative impact of health cost risk on pension demand. Compared with individuals with higher health cost risk, individuals with lower health cost risk are more likely to participate in pensions and contribute more after enrollment when they have little or no informal insurance, and they are less likely to participate and contribute less when they have sufficient informal insurance to substitute for a pension.

Given no informal insurance (i.e., no children at all), our results show that health cost risk has a negative impact on pension demand (see the coefficients of $Health^{fair}$, $Health^{good}$, *Chronic_diseases*, and *Predicted_health_cost* in Table 3), which is true for both decisions of pension participation and pension contribution. This result is consistent with the classical theory in that health cost risk creates liquidity needs in the near future and thus reduces pension demand.

Child-provided informal insurance eases the concern of health cost risk as children can provide financial support to their parents' health problems. Therefore, informal insurance should mitigate the negative impact of health cost risk on pension demand. The impact of health cost risk on pension decisions becomes weaker as a family has more children (see the coefficients of the interaction terms in Table 3), because parents can rely on children for out-of-pocket health costs, and health cost risk thus becomes less important when making pension decisions.

To be more specific, in terms of the pension participation decision, having two or more children can offset the negative impact of health cost risk on pension demand. Regarding the pension contribution decision, having four or more children offsets the negative impact of health cost risk on pension demand. The average number of children in our sample is 2.24. Therefore, the substitution effect of child-provided informal insurance on pensions drives the impact of health cost risk on pension participation positive (Columns (1) - (3), Table 2), while its impact on pension contribution remains negative (Columns (4) - (6), Table 2).

It is the difference in the child substitution rate between pension participation and contribution decisions that leads to the seemingly opposite impact of health cost risk on pension participation and pension contribution. To illustrate the results in Table 3, Figure 1 presents the impact of having one more child on the individuals' pension demand under the poor, fair, and good health statuses, respectively. The better the health status (i.e., the lower the health cost risk), the greater the substitution effect of having one additional child on pensions. It is intuitive that individuals in poorer health need more physical, psychological, and financial support and thus need the support of more children to mitigate the reduction in pension demand. When parents are in good health, the substitution effect per child becomes more profound. We emphasize that the role that informal insurance plays in the impact of health cost risk on annuitization decisions should be considered in the precautionary savings theory and must not be overlooked in theoretical and empirical analyses.

[Figure 1 here]

In a robustness test, we use *Rely_on_children* as an alternative measure of the existence of informal insurance. The results are consistent with our main results using *Number_of_children* and suggest that individuals in better health and who think they can rely on their children for help in their old-age are less likely to participate in and contribute less to a pension (see Section 6.2).

The results in Table 3 explain and reconcile the opposite impacts of the health cost risk on pension participation and contributions shown in Table 2. After a long history of lacking access to formal insurance, the RBP was introduced in areas where informal risk sharing arrangements (e.g., child-provided informal insurance) are prevalent. Relying on children for old-age support squeezes out the demand for formal insurance (Bloch, Genicot and Ray, 2008). Having more children can further mitigate the longevity risk and support the elderly life (Oliveira, 2016), and thus reduce the pension demand, especially for the individuals that are healthier and are therefore less of a responsibility to their children. Our results are consistent with the substitution effect of private family transfers on pension demand (Cai, Giles and Meng, 2006). We enrich the existing evidence by illustrating that the substitution effect of children differs for parents with different health statuses.

One might concern that individuals participate in the RBP program before retirement are influenced not only by their preference for annuitization but also by their ability to make annual contributions; while the classical annuitization decision only involves converting accumulated pension wealth into annuities at retirement. Thus, RBP participation at earlier ages may not fully capture their true annuitization preference. Taking advantage that RBP allows individuals to make a lump sum contribution just before retirement, we restrict the sample to individuals between 55 and 59 years old to more purely capture annuitization decision-making process. The results in Table 4 below remain consistent with those in Table 3.

[Table 4 here]

4.3 Endogeneity

One might worry that individuals' health status could be influenced by unobserved determinants of pension demand, which might then bias our OLS results. We address this potential endogeneity concern on *Health_cost_risk* in following ways.

First, we exploit the panel nature of the data and employ a difference-in-differences strategy to estimate the effect of health cost risk on pension demand, as shown in Equation (3) below. We define $Acute\_disease_{it}$ as a binary variable equal to one if individual *i* ever suffered from at least one acute condition, including heart attack, stroke, or cancer, in year *t* or earlier. These acute diseases are immediate, major health threats, thus providing an exogenous source of variation in health status. In Eq. (3), $Acute\_disease\_wave_i$ is the indicator for the specific survey wave in which individual i first had the acute disease(s). The model adopts a staggered difference-in-differences (DID) approach, where the *treatment* is captured by $Acute\_disease\_wave_i$ and *post* is absorbed by the year fixed effects, meaning the variable $Acute\_disease_{it}$ represents the interaction term between *treatment* and *post*.

$$\begin{aligned} Pension\_demand_{it} \\ &= \beta_0 + \beta_1 Acute\_disease_{it} \\ &+ \beta_2 Acute\_disease_{it} \times Informal\_insurance_{it} \\ &+ \beta_3 Informal\_insurance_{it} + \boldsymbol{\lambda X_{it}} + \zeta\, Acute\_disease\_wave_i \\ &+ \delta Year_t + \gamma Province_i + \varepsilon_{it} \end{aligned} \tag{3}$$

During the sample period, acute diseases are relatively rare and only 5% individuals had experienced them. To mitigate the imbalance in covariates between the treatment and the control groups, we perform propensity score matching methods (PSM) to estimate Equation (3).[18] We first employ the k-nearest neighbors matching method among other specifications. In our main specifications, we match treated individuals (those who experienced acute diseases) with up to four control individuals (those who did not experience any acute disease). We match the control and treated groups based on all our control variables, including number of children, longevity risk, age, gender, ethnicity, marital status, education, risk attitude, health insurance status, wealth, urban/rural

[18] The advantage of PSM-DID lies in its double robustness property. See Bang and Robins (2005) for more details.

residence, life satisfaction, provincial residence, and the survey year. Appendix Table C1 presents the balance tests on the pre-period covariates performed after propensity score matching. The results show that the standardized bias for all covariates is below the conventional threshold of 5%, indicating that the balance between the treated and control groups has been significantly improved. Furthermore, the *t*-tests show no significant differences between the treated and control groups across all covariates, ensuring that their comparability for subsequent analyses.

The results presented in Panel A of Table 4[19] are consistent with our main results in Table 3 in the sense that individuals experienced at least one acute disease with no children are less likely to participate in pensions, and contribute less to pensions after enrollment; having one more child on average mitigates the negative impact of *Acute_disease* on the probability of individuals' RBP participation by 2.40 percentage points and mitigates the negative impact on premium contribution of RBP participants by 9.05%.[20]

In addition, we apply alternative matching techniques including radius, kernel matching, and entropy balancing, for robustness checks (see Appendix Table C2). Moreover, to address the concern that unobserved heterogeneity may generate differential trends between treatment and control groups, we further control for the linear trend, and the results remain robust (see Appendix Table C2).

---

[19] We include province by year fixed effect in Table 4, and the results are robust. The main results presented in Table 3 are also robust when province by year fixed effects are accounted for.

[20] We conduct an event study to validate the parallel trend assumption underlying the DID analysis. Specifically, we estimate the following equation: $Pension\_Demand_{it} = \beta_0 + \sum_{j\neq-1} \mu_j D_{it}^j + \sum_{j\neq-1} \theta_j D_{it}^j \times Informal\_insurance_{it} + \beta_1 Informal\_insurance_{it} + \boldsymbol{\lambda X_{it}} + \zeta Acute\_disease\_wave_i + \delta Year_t + \gamma Province_i + \varepsilon_{it}$, where D_{it}^j is an indicator that equals one if the observation is *j* waves after the individual *i* suffered from the first acute disease. D_{it}^{-1} is omitted from the regression as the benchmark wave just before individual *i* suffering from the first acute disease. As the mean of D_{it}^2 is only 0.0044, we create D_{it}^{1-2} as an "end-cap" variable that equals one if the observation is one wave or two waves after individual *i* suffering from the first acute disease. The results are presented in Appendix Figure C1. The estimates support the parallel trend assumption in the sense that the coefficients of the linear term and the interaction term prior to the first acute disease are all statistically indifferent from zero and exhibit no visible pre-trends. The detailed event study coefficients are provided in Appendix Table C3. The results are similar if we estimate D_{it}^1 and D_{it}^2 separately in the above equation.

[Table 5 here]

We have retained the OLS results as our main results for the following reasons. First, the OLS provides a more intuitive and straightforward interpretation of the average treatment effect (ATE) in our context, while the PSM-DID approach estimates the local average treatment effect (LATE), which applies to specific subpopulations. Therefore, the OLS results are more representative and interpretable for our entire sample, which is representative for the entire Chinese population in respective years. By comparison, the PSM-DID method relies on a reduced sample size due to stricter identification requirements, which limits the generalizability of those findings. Second, the OLS results from our main analyses are consistent with those in Table 4 in terms of both magnitude and significance. This consistency strengthens the reliability of our findings, indicating that endogeneity is unlikely to significantly bias our results.

[Figure 2 here]

Second, to address the concern on the measurement errors and potential biased estimates, caused by different scales assessing their self-reported health, we follow Disney, Emmerson and Wakefield (2006) and Bound, Stinebrickner and Waidmann (2010) to construct a latent health stock measure based on individuals' health indicators and personal characteristics. An individual's true health status is assumed to be determined by a linear combination of exogenous personal characteristics, health indicators, and unobservable variables uncorrelated with the former two. The true health status is not observed, but a self-rated health status is observed and allow us to predict the true health. We construct an ordered probit model and estimate the latent health stock by year:

$$Health_{it} = \gamma_0 + \boldsymbol{\lambda H_{it}} + \boldsymbol{\zeta C_{it}} + +\varepsilon_{it} \quad (4)$$

where $Health_{it}$ is an individual's self-rated health status, $\boldsymbol{H_{it}}$ is a vector of health indicators, including difficulty with dressing, difficulty with doing household chores, difficulty with climbing stairs, difficulty with walking 1 km, hypertension, dyslipidemia, diabetes, cancer, lung diseases, liver disease, heart attack, stroke, kidney disease, stomach disease, psychiatric problem, memory related disease, arthritis, asthma, physical disabilities, brain damage, vision problem, hearing problem, and speech impediment. $\boldsymbol{C_{it}}$ is a vector of personal characteristics, including gender, marital status, age, age square, age cubic, minority, number of children, education, house ownership, household wealth, and province of residence. We then use the estimated parameters to predict the latent health stock and normalize it by subtracting the cohort mean for each year. This helps avoid making additional assumptions about the constant in the separate ordered probit models. Specifically, we define *Health_stock* as the continuous predicted true health status, estimated by a set of health indicator variables and personal characteristics. The results, presented in Panel B of Table 4, are consistent with our main findings in Table 3.

Another common source of endogeneity comes from potential reverse causality, namely, receiving pension benefits may improve an individual's health conditions through better nutrition and access to better healthcare (Cheng et. al., 2018). This reverse causality concern can be fully excluded in our sample of 45–59 year olds because individuals were not receiving pension benefits until age 60.

We also address the potential endogeneity concern of the *Informal_insurance* measure (i.e., *Number_of_children*) in two ways. First, individuals may expect a public pension and thus choose not to have more children. This reverse casualty concern can be rested because individuals in our sample are 45–59 years old and made their fertility decisions 15–40 years ago when the RBP scheme did not exist and when they had neither access to nor expectation of any public pensions.

Second, in the labor economics literature (e.g., Agüero and Marks, 2008), individuals' fertility preferences are considered to be a common omitted variable that causes an endogeneity problem.

In our setup, however, omitting the fertility preference will not cause endogeneity in *Number_of_children* because fertility preference influences individuals' *Pension_demand* (i.e., the dependent variable) only through its impact on the *Number_of_children* (i.e., the explanatory variable of interest). The goal of this paper is exactly to investigate whether and how having and raising (more) children would affect individuals' annuitization decisions provided that children function as an informal insurance for old-age security. Therefore, the potential impact of the fertility preference has already been captured by the *Number_of_children.*

5. Additional analyses on the informal insurance effect

In this section, we conduct additional tests concerning the informal insurance's substitution effect on pensions in relation to children characteristics.

Education is a good measure for the ability of a child to support his or her elderly parents as it is a way to acquire human capital (Cervellati and Sunde, 2005) and a kind of parental human capital investment (Raut and Tran, 2005). In our sample, the respondents are 45 to 59 years old. Their children are still at school/university or have entered the workforce but are in an early stage of their careers, when education plays a greater role than in later career stages. Thus, education offers a reliable indication of the quality of child-provided informal insurance. Therefore, we examine whether better-educated children mitigate more health cost risk impacts on the pension demand of their parents. Table 6 presents the results.

[Table 6 here]

As shown in Table 6, regardless of which health cost risk measures we use, the coefficients of the interaction terms are larger among the well-educated group. Among the less-educated group, when compared with individuals in poor health, having one more child decreases the probability of RBP participation for individuals in fair (good) health by 1.95 (2.06) percentage points (see Panel A, Column (1)). Among the well-educated group, these two numbers are 2.67 and 4.35 percentage points, respectively (see Panel A, Column (2)). Among the less-educated group, having one more child does not have a significantly different impact on the pension contributions of participants in poor, fair, or good health (see Panel A, Column (3)). Among the well-educated group, when compared with participants in poor health, having one more child decreases the contributions of pension participants in fair (good) health by 10.8% (12.3%) (see Panel A, Column (4)). Similar results are shown in Panels B and C, which further confirm the results that the substitution effect of better-educated children on pensions mitigates more of the health cost risk impact.

The gender of the children may be another factor influencing the old-age security they provide, although there is no consensus on the existence of gender differences (see e.g., Xie and Zhu, 2009; Oliveira, 2016; Chew et al., 2018). Traditionally, Sons are believed to take on the responsibility of supporting their elderly parents. With continuous demographic, cultural, and economic changes, daughters are gradually taking on more responsibility than before and providing more financial support to their elderly parents (Xie and Zhu, 2009). To examine whether, and to what extent, sons and daughters mitigate the impact of the health cost risk on pension demand, we divide the *Number_of_children* into the *Number_of_sons* and the *Number_of_daughters*.

Table 7 presents the results of parents' having different-gender children. Both sons and daughters can mitigate the impact of the health cost risk on pension demand. The coefficients of the interaction terms between the health cost risk measures and the *Number_of_sons* as well as that between the health cost risk measures and the *Number_of_daughters* are not significantly different from each other, in most specifications. Our results show that the old-age support provided by children no longer depends on gender (Oliveira, 2016). Sons and daughters are the same now, at least from the perspective of old-age support.

[Table 7 here]

6. Robustness

6.1 Alternative explanations

In this section, we discuss explanations other than child-provided informal insurance to explain the seemingly opposite health cost risk impact on pension participation and contributions. These explanations could include income, property ownership, and formal health insurance.

First, higher net income or net labor income of an individual capture greater competence in the labor market. Since good health increases workers' labor force attachment (Disney, Emmerson and Wakefield, 2006), it is intuitive that individuals in better health and with higher income work longer and are able to better support themselves in their old age, and therefore, have lower demand for pensions. The work-until-not-possible rationale is particularly prominent in rural China, where farmers are not used to stopping work or retiring at a certain age (Giles, Wang and Zhao, 2010).

Second, the income stream from properties also provides a potential substitute for pension income. Farming land is an important and conventional income source that supports farmers' old age in China, which generates income streams, either by land transfers or self-employment. Similarly, individuals who own houses or apartments can rent them out or mortgage them to generate income streams.

Given the above rationales, we analyze the moderating effects of net income, net labor income, and property ownership to determine whether they explain the seemingly opposite health cost impacts on pension participation and contributions. The results presented in Appendix Table D2 show that the interaction terms between the health cost risk and *Ln(Net_income)*, *Ln(Labor_income)*, and *Property_ownership* are insignificant, indicating that net income, net labor income, and property ownership cannot explain the opposite results in Table 2.

The informal insurance function of children cannot be replaced by an individual's labor or property income for three reasons. First, financial exchange or old-age security is an important motive for fertility (Rossi and Godard, 2022), especially when formal pension system is immature, insufficient, and/or difficult to access. Second, children are considered to be a more reliable source of continuous income than an individual's labor, due to age and health differences as well as than property income, as the property market may be illiquid and underdeveloped, especially in rural and other noncity areas. Third, children can provide meaningful physical and psychological support (Foster and Rosenzweig, 2001), in addition to financial income to parents. This is particularly true for the healthier elderly, as they are less of a burden to their children.

In addition, we examine the differences between the pension participants and nonparticipants in these four aspects, given the individual's health status. The *t*-test results in Appendix Table D3 also show that the average *Net_income*, *Labor_income,* and *Rental_income* are not significantly different between the RBP participants and nonparticipants. The rate of house/apartment or land ownership is higher among RBP participants than nonparticipants, which is contrary to the idea that properties can substitute for pensions. The results exclude income and property ownership as alternative explanations for our findings.

Third, formal health insurance plays a role in reducing out-of-pocket medical expenses and thus the health cost risk, which may also explain the seemingly opposite health cost risk impact on pension participation and contributions. The formal health insurance available to people in the informal sector in our sample is the public health insurance program called Residents' Basic Medical Insurance, including its two precursors, New Rural Cooperative Medical Care and Urban Residents' Basic Medical Insurance. Therefore, we add the interaction terms between health cost risk and *Health_insurance*. The results in Appendix Table D4 show that the seemingly opposite impact of health cost risk on pension participation and pension contributions remains and most interaction terms are insignificant, suggesting that health insurance cannot explain the opposite results in Table 2. In some specifications, we observe that having health insurance indeed weakens the impact of health cost risk on pension demand, but this cannot reconcile the opposite impact.

The informal insurance function of children cannot be replaced by formal health insurance for two reasons. First, the Residents' Basic Medical Insurance program has relatively limited coverage and high co-payments, making its protection quality may not be as good as child-provided informal insurance. Second, children not only substitute for formal health insurance but for pensions as well, while formal health insurance does not have the ability to substitute for pensions.

6.2 Other robustness tests

We conduct additional tests using alternative samples/measures or considering additional control variables to verify the robustness of our results. First, we use a full sample including both pension participants and nonparticipants to estimate the impact of health cost risk on pension contributions, in which nonparticipants have zero contributions. Estimating Eq. (1), the coefficients of the health cost risk become smaller or insignificant, suggesting that the positive effect on pension participation (i.e., the extensive margin) and the negative impact on pension contribution (i.e., the intensive margin) offset each other. Estimating Eq. (2) **--** where the impact of informal insurance is teased out **--** the impact of health cost risk on pension contributions is consistently negative as mainstream theory predicts (see Appendix Table D5).

Second, we use *Rely_on_children* as an alternative to measure the existence of informal insurance, which captures an individual's subjective beliefs about relying on their children for old-age support. Regardless of which health cost risk measure we use, the coefficients of the interaction terms between *Rely_on_children* and *Health_cost_risk* are found to be significant and consistent with our primary results in Table 3. The results suggest that individuals in better health and those who think they can rely on their children for their old-age are less likely to participate in and contribute to pensions (see Appendix Table D6 and Figure D1).

Third, we consider that the substitution effect of children on pensions might not be linear; for example, it might marginally decrease for each additional child as elder children are commonly thought to be more capable and thus take more responsibility for their parents than younger children. We use Ln(*Number_of_children*) to capture the marginal decreasing substitution effect of having more children. The results are consistent with our primary results using *Number_of_children* as the informal insurance measure in Table 3 (see Appendix Table D7).

Fourth, an individual's pension participation decision might also be motivated by the bundling policy of parents and children. That is, people aged 60 or older at the time of the RBP introduction can receive pension benefits without any contribution if their eligible children participate in the public pension program. We therefore additionally control a dummy variable, *Living_parent*, indicating whether the respondent has at least one living parent. The results are consistent with our primary results (see Appendix Table D8). Moreover, we estimate Eqs. (1) and (2) using clustered standard errors at the household level. The findings are robust (see Appendix Table D9).

Sixth, age is an important determinant of an individual's health, health cost risk, and thus pension decisions. Therefore, the impact of health cost risk on pension demand may change as age increases. We add an interaction term between health cost risk and age dummies. The results show that the interaction terms are all insignificant, suggesting that age does not change the relationship between health cost risk and pension demand (see Appendix Table D10).

7. Conclusion

The theory of health cost risk explains a large part of the empirically observed annuity puzzle. On the one hand, health cost risk motivates liquidity needs, and thus decreases annuity demand

(Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017). On the other hand, health cost risk may drive household portfolios to shift from risky equities to safer annuities (Pang and Warshawsky, 2010). This paper provides the first piece of empirical evidence regarding the impact of health cost risk on annuitization decisions and pension demand.

We document a seemingly contradictory result: the health cost risk increases the probability of pension participation but decreases the amount of pension contributions. We show that this contradictory result is driven by the effect of child-provided informal insurance. Teasing out the effect of informal insurance, individuals with lower health cost risk and with no children are more likely to participate in a pension and contribute more after enrollment. As the number of children in a family increases, parents can rely on children for out-of-pocket health costs, and thus, health cost risk becomes less important when making pension decisions. In terms of the pension participation decision, having two or more children can offset the positive impact of fair or good health on pension demand. Regarding the pension contribution decisions, having four or more children would offset the positive impact of fair or good health on pension demand. Such difference in child substitution rates between pension participation and contributions leads to the seemingly opposite impact of health cost risk on pension participation and contributions. We rule out income, property ownership, and formal health insurance as explanations for the seemingly opposite impacts of health cost risk on pension participation and contributions.

The substitution effect of informal insurance on pensions mitigates the health cost risk impact more pronounced for households that have better-educated children. However, we observe no gender differences for children who provide informal insurance for their parents. Our finding regarding gender equality is consistent with a recent study showing that male and female children no longer display any significant differences in providing old-age support in China (Oliveira, 2016).

Our results explain the seemingly contradictory result of the health cost risk impact on pension participation and pension contributions. After teasing out the impact of child-provided informal insurance, our results are consistent with mainstream theoretical prediction that health cost risk reduces pension demand (Davidoff, Brown and Diamond, 2005; Turra and Mitchell, 2008; Peijnenburg, Nijman and Werker, 2017). To derive this result, it is important to disentangle the health cost risk from the longevity risk and to fully account for the substitution effect of child-provided informal insurance on pensions. These theoretical predictions are empirically observable and verifiable only when fully considering the heterogeneous substitution effect of informal insurance on pensions among individuals with different health cost risks.

In practice, informal insurance within a household, or within other social networks, is prevalent when the individual has limited access to the formal insurance system, which is common in developing economies and particularly common among people in the informal sector. People are, as empirically observed in this paper, more likely to rely on their existing informal insurance when the old-age support motive remains an important reason for fertility and when public pensions are insufficient. Our results highlight the importance of taking a holistic view on household financial decisions.

Figures and Tables

Figure 1 Substitution effect of informal insurance on pensions in respective health status

Figure 1 presents the impact of having one more child on individuals' pension demand under the poor, fair, and good health statuses (i.e., the average marginal effects of *Number_of_children* at different health statuses after regression reported in Columns (1) and (4), Table 3). *Pension_participation* is the dependent variable in Column (1) of Table 3, which is a dummy variable that equals 1 when individuals participated in the RBP program. *Ln(Pension_contribution)* is the dependent variable in Column (4) of Table 3, which is a log form continuous variable representing the annual contributions that individuals paid to the RBP program. $Health^{poor}$ equals 1 when the self-reported health status is very poor or poor, and 0 otherwise. $Health^{fair}$ equals 1 when the self-reported health status is fair, and 0 otherwise. $Health^{good}$ equals 1 when the self-reported health status is good, very good, or excellent, and 0 otherwise. *Number_of_children* is the number of the individual's living children. As shown in Figure 1, the better the health status (i.e., the lower the health cost risk), the greater the substitution effect of having one additional child on pensions.

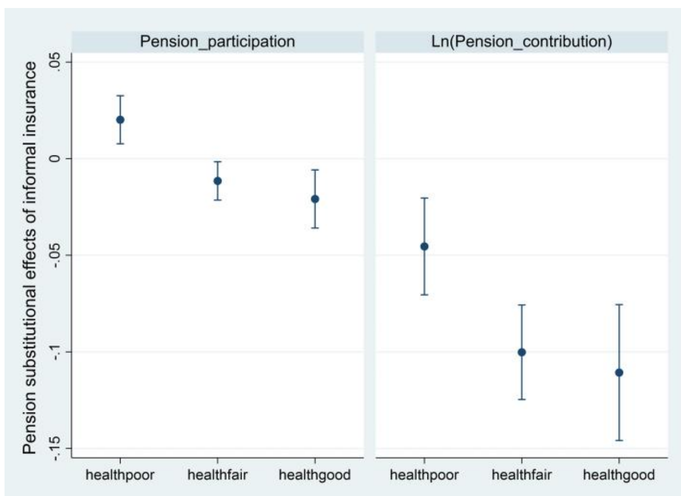

Table 1 Summary statistics

This table presents the summary statistics of our sample. Panel A presents the summary statistics of the key variables. *Pension_participation* is a dummy variable that equals 1 when individuals participated in the RBP program. *Pension_contribution* is a continuous variable representing the annual contributions that individuals paid to the RBP program. $Health^{poor}$, $Health^{fair}$ and $Health^{good}$ are three dummy variables of self-reported health statuses. *Chronic_diseases* is the number of chronic diseases that the individual has been diagnosed with. *Predicted_health_cost* is an individual's predicted annual out-of-pocket health cost in five years. *Unlikely_75*, *Maybe_75* and *Likely_75* equal 1 when the individual evaluates his/her chances of reaching the age of 75 as "almost impossible or not very likely," "maybe," and "very likely or almost certain," respectively. *Number_of_children* is the number of the individual's living children. *Rely_on_children* equals 1 when the individual expects children to be his/her main financial resource in old-age, and 0 when the individual expects savings, public or private pensions, or other financial resources as the main financial resource for old age.

Panel B presents the summary statistics of the control variables. *Age is* the individual's age. *Male* equals 1 when the individual is male. *Minority* equals 1 when the individual is in a minority ethnic group and 0 when the individual is in the majority ethnic group (*Han*). *Married* equals 1 when the individual is married. $Education^{illiterate}$, $Education^{elementary}$ and $Education^{middleabove}$ are three dummy variables of individuals' education levels. *Physical_exam* equals 1 when the individual has taken a physical examination within the past two years. *Health_insurance* equals 1 when the individual has public health insurance. *Wealth* is the household wealth per capita. *Urban* equals 1 when the individual's registered residence (*hukou*) is urban. $Life^{unsatisfied}$, $Life^{somewhat\_satisfied}$ and $Life^{satisfied}$ equal 1 when the individual feels "not at all satisfied or not very satisfied," "somewhat satisfied," and "very satisfied or completely satisfied" with his/her life, respectively.

Panel C presents the summary statistics of the additional variables used in addressing the endogeneity concerns, the heterogeneity analyses and robustness tests. *Acute_disease* is a dummy variable that equals 1 if individuals had ever experienced at least one acute condition (incl. heart attack, stroke and cancer) in year *t* or earlier, and 0 otherwise. *Health_stock* is a measure for individuals' true health status which is estimated from a set of health indicator variables and personal characteristics. Details of the variable construction is described in Section 4.3. $Education^{advanced}_{children}$ equals 1 when the individual's children have an advanced education. *Number_of_sons* and *Number_of_daughters* are the number of the individual's living sons and living daughters, respectively. *Labor_income* is the sum of the individual's wage income, individual-based transfers, net agricultural income per capita, net livestock income per capita, and net income from self-employed activities per capita, noting that it could be negative. *Net_income* includes *Labor_income*, income from a house/apartment and/or land rent per capita, and household public transfer income per capita. *Property_ownership* equals 1 when the individual owns land or a house/apartment. *Living_parent* equals 1 when the respondent has at least one living parent.

	Obs.	Mean	S.D.	Min	Median	Max
Panel A Key variables						
Pension_participation	14,324	0.79	0.40	0	1	1
Pension_contribution (CNY, incl. zero)	13,734	254.1	768.0	0	100	9,000
Pension_contribution (CNY, excl. zero)	10,789	323.5	853.4	100	100	9,000
$Health^{poor}$	14,322	0.24	0.43	0	0	1
$Health^{fair}$	14,322	0.50	0.50	0	1	1

$Health^{good}$	14,322	0.26	0.44	0	0	1
Chronic_diseases	14,323	1.47	1.54	0	1	12
Predicted_health_cost	14,318	2,159.7	1,160.1	725.1	1,845.5	8,797.3
Unlikely_75	14,324	0.29	0.46	0	0	1
Maybe_75	14,324	0.39	0.49	0	0	1
Likely_75	14,324	0.32	0.47	0	0	1
Number_of_children	14,324	2.24	1.01	0	2	10
Rely_on_children	13,894	0.73	0.45	0	1	1
Panel B Control variables						
Age	14,324	52.5	3.97	45	52	59
Male	14,324	0.47	0.50	0	0	1
Minority	14,324	0.11	0.31	0	0	1
Married	14,324	0.95	0.22	0	1	1
$Education^{illiterate}$	14,324	0.16	0.37	0	0	1
$Education^{elementary}$	14,324	0.43	0.49	0	0	1
$Education^{middleabove}$	14,324	0.41	0.49	0	0	1
Physical_exam	14,324	0.35	0.48	0	0	1
Health_insurance	14,324	0.96	0.20	0	1	1
Wealth_per_capita (CNY 10,000)	14,324	12.7	34.6	0.0050	4.59	500.5
Urban	14,324	0.070	0.26	0	0	1
$Life^{unsatisfied}$	14,324	0.14	0.35	0	0	1
$Life^{somewhat\_satisfied}$	14,324	0.56	0.50	0	1	1
$Life^{satisfied}$	14,324	0.30	0.46	0	0	1
Panel C Additional variables						
Acute_disease	4,277	0.10	0.31	0	0	1
Health_stock	10,741	0.075	0.63	-4.40	0.20	1.45
$Education_{children}^{advanced}$	14,123	0.31	0.46	0	0	1
Number_of_sons	14,324	1.18	0.79	0	1	8
Number_of_daughters	14,324	1.07	0.92	0	1	7
Net_income	14,321	8,982.6	15,666.9	-2,000	1,666.7	86,900
Labor_income	14,321	7,566.5	13,574.4	-3,116.7	750	110,000
Property_ownership	14,291	0.98	0.15	0	1	1
Living_parent	14,314	0.68	0.47	0	1	1

Table 2 Impact of health cost risk on annuitization decisions

This table presents the estimation for Eq. (1): the impact of health cost risk on pension demand. Columns (1)–(3) use the full sample to estimate the impact of health cost risk on pension participation and report the average marginal effects of the Probit regressions. Columns (4)–(6) use the sample of pension participants to estimate the impact on pension contributions and report the coefficients of the OLS regressions. The variable definitions can be found in the legend of Table 1. Robust standard errors are provided in parentheses. *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	Pension_participation			Ln(Pension_contribution)		
	(1)	(2)	(3)	(4)	(5)	(6)
Health^{fair}	-0.0170**			0.0287*		
	(0.00802)			(0.0174)		
Health^{good}	-0.0200**			0.105***		
	(0.00998)			(0.0229)		
Chronic_diseases		0.00491**			-0.00935*	
		(0.00220)			(0.00483)	
Ln(Predicted_health_cost)			0.0173**			-0.0384**
			(0.00677)			(0.0157)
Maybe_75	0.0220***	0.0209***	0.0222***	0.0346**	0.0440***	0.0399**
	(0.00761)	(0.00755)	(0.00761)	(0.0169)	(0.0167)	(0.0169)
Likely_75	0.0261***	0.0244***	0.0263***	0.0679***	0.0868***	0.0812***
	(0.00820)	(0.00803)	(0.00816)	(0.0194)	(0.0191)	(0.0193)
Number_of_children	0.00186	0.00160	0.00154	-0.0766***	-0.0773***	-0.0770***
	(0.00326)	(0.00327)	(0.00327)	(0.00780)	(0.00780)	(0.00781)
Age	0.00651***	0.00641***	0.00647***	0.00325*	0.00315*	0.00315*
	(0.000774)	(0.000776)	(0.000774)	(0.00185)	(0.00186)	(0.00186)
Male	-0.0267***	-0.0269***	-0.0244***	-0.0370**	-0.0335**	-0.0389**
	(0.00645)	(0.00644)	(0.00651)	(0.0157)	(0.0157)	(0.0158)
Minority	0.0118	0.0118	0.0111	-0.0415*	-0.0405*	-0.0399*
	(0.0106)	(0.0106)	(0.0107)	(0.0235)	(0.0236)	(0.0236)
Married	0.0538***	0.0535***	0.0534***	0.0619*	0.0597*	0.0602*
	(0.0151)	(0.0151)	(0.0151)	(0.0349)	(0.0351)	(0.0351)
Education^{elementary}	0.00701	0.00652	0.00686	0.0696***	0.0682***	0.0675***
	(0.00922)	(0.00921)	(0.00921)	(0.0189)	(0.0190)	(0.0190)
Education^{middleabove}	0.0232**	0.0223**	0.0231**	0.129***	0.131***	0.129***
	(0.00975)	(0.00975)	(0.00975)	(0.0215)	(0.0215)	(0.0215)
Physical_exam	0.00263	0.00148	0.00142	0.0886***	0.0898***	0.0907***
	(0.00648)	(0.00655)	(0.00654)	(0.0164)	(0.0165)	(0.0165)
Health_insurance	0.300***	0.298***	0.304***	-0.0830	-0.0846	-0.0933
	(0.0205)	(0.0205)	(0.0205)	(0.0600)	(0.0604)	(0.0604)
Ln(Wealth)	0.00907***	0.00889***	0.00897***	0.0271***	0.0284***	0.0280***
	(0.00195)	(0.00194)	(0.00195)	(0.00487)	(0.00486)	(0.00487)
Urban	-0.242***	-0.243***	-0.243***	0.918***	0.921***	0.921***
	(0.0157)	(0.0157)	(0.0157)	(0.0764)	(0.0765)	(0.0765)
Life^{somewhat_satisfied}	0.0202**	0.0184**	0.0200**	-0.0506**	-0.0422**	-0.0452**
	(0.00898)	(0.00889)	(0.00893)	(0.0213)	(0.0210)	(0.0211)
Life^{satisfied}	0.0186*	0.0166*	0.0184*	-0.0352	-0.0161	-0.0204
	(0.00996)	(0.00980)	(0.00984)	(0.0243)	(0.0238)	(0.0240)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,322	14,323	14,318	10,788	10,788	10,786
(Pseudo) R^2	0.185	0.185	0.185	0.215	0.214	0.214

Table 3 Main Results: Impact of health cost risk and substitution effect of informal insurance on pensions

This table presents the estimation for Eq. (2): whether, and to what extent, the availability of informal insurance provided by children mitigates the impact of health cost risk on pension demand. Columns (1)–(3) report the average marginal effects of the Probit regressions. Columns (4)–(6) report the coefficients of the OLS regressions. The standard set of control variables are the same as those in Table 2. The variable definitions can be found in the legend of Table 1. Robust standard errors are provided in parentheses. *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	Pension_participation			Ln(Pension_contribution)		
	(1)	(2)	(3)	(4)	(5)	(6)
$Health^{fair}$	0.0397**			0.132***		
	(0.0193)			(0.0456)		
$Health^{good}$	0.0428**			0.208***		
	(0.0207)			(0.0560)		
Chronic_diseases		-0.0103**			-0.0430***	
		(0.00489)			(0.0126)	
Ln(Predicted_health_cost)			-0.0350**			-0.122***
			(0.0150)			(0.0407)
$Health^{fair}$ × Number_of_children	-0.0245***			-0.0436***		
	(0.00762)			(0.0167)		
$Health^{good}$ × Number_of_children	-0.0295***			-0.0434**		
	(0.00945)			(0.0202)		
Chronic_diseases × Number_of_children		0.00658***			0.0141***	
		(0.00191)			(0.00480)	
Ln(Predicted_health_cost) × Number_of_children			0.0231***			0.0361**
			(0.00589)			(0.0153)
Number_of_children	0.0201***	-0.00857*	-0.209***	-0.0454***	-0.101***	-0.352***
	(0.00635)	(0.00439)	(0.0436)	(0.0128)	(0.0114)	(0.118)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,322	14,323	14,318	10,788	10,788	10,786
(Pseudo) R^2	0.186	0.186	0.186	0.216	0.214	0.214

Table 4 Main Results: Restricting sample to 55-59 years old

This table reports the estimation for Eq. (2), restricting our sample to individuals who are between 55 and 59 years old. The results show whether, and to what extent, the availability of informal insurance provided by children mitigates the impact of health cost risk on pension demand. Columns (1)–(3) report the average marginal effects of the Probit regressions. Columns (4)–(6) report the coefficients of the OLS regressions. The standard set of control variables are the same as those in Table 3. The variable definitions can be found in Appendix B. Robust standard errors are provided in parentheses. *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	Pension_participation			Ln(Pension_contribution)		
	(1)	(2)	(3)	(4)	(5)	(6)
$Health^{fair}$	0.0467			0.201***		
	(0.0296)			(0.0726)		
$Health^{good}$	0.0491			0.220***		
	(0.0311)			(0.0828)		
Chronic_diseases		-0.0114			-0.0323	
		(0.00722)			(0.0209)	
Ln(Predicted_health_cost)			-0.0455**			-0.124*
			(0.0229)			(0.0657)
$Health^{fair}$ × Number_of_children	-0.0274**			-0.0603**		
	(0.0113)			(0.0259)		
$Health^{good}$ × Number_of_children	-0.0282*			-0.0509*		
	(0.0144)			(0.0277)		
Chronic_diseases × Number_of_children		0.00696**			0.0130*	
		(0.00272)			(0.00769)	
Ln(Predicted_health_cost) × Number_of_children			0.0259***			0.0405*
			(0.00862)			(0.0237)
Number_of_children	0.0159*	-0.0140**	-0.223***	-0.0309*	-0.0952***	-0.381**
	(0.00937)	(0.00663)	(0.0576)	(0.0188)	(0.0169)	(0.181)
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,031	5,031	5,029	3,848	3,847	3,847
(Pseudo) R^2	0.195	0.194	0.195	0.220	0.218	0.218

Table 5 Endogeneity concern on health cost risk

This table presents additional results that address the endogeneity concerns of health cost risk. Panel A reports the PSM-DID estimations based on Eq.(3): Columns (1)–(4) use the matched sample without the matching weights, while Columns (5)–(8) use the matched sample with the matching weights. Panel B reports the estimation of Eq. (2) using the latent health stock measure: Columns (1)–(2) reports the average marginal effects of the Probit regressions. Columns (3)–(4) report the coefficients of the OLS regressions. The standard set of control variables are the same as those in Table 2. The variable definitions can be found in the legend of Table 1. Robust standard errors are provided in parentheses. *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	Pension_ participation		Ln(Pension_ contribution)		Pension_ participation		Ln(Pension_ contribution)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A PSM-DID estimations								
Acute_disease	-0.0848**	-0.0627*	-0.195*	-0.216**	-0.0858**	-0.0644*	-0.180*	-0.199**
	(0.0380)	(0.0373)	(0.101)	(0.102)	(0.0395)	(0.0384)	(0.0975)	(0.0940)
Acute_disease ×	0.0240**	0.0210*	0.0905**	0.104***	0.0247**	0.0211*	0.0789**	0.0923***
Number_of_children	(0.0114)	(0.0112)	(0.0372)	(0.0382)	(0.0117)	(0.0114)	(0.0357)	(0.0338)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	No	Yes	No	Yes	No	Yes	No
Year FE	Yes	No	Yes	No	Yes	No	Yes	No
Province × Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Acute disease wave FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,277	4,277	3,376	3,376	4,277	4,277	3,376	3,376
R^2	0.233	0.281	0.198	0.233	0.246	0.293	0.216	0.253
Panel B Latent health stock measure								
Health_stock	0.0264*	0.0256*	0.124***	0.132***				
	(0.0143)	(0.0137)	(0.0336)	(0.0333)				
Health_stock ×	-0.0200***	-0.0189***	-0.0406***	-0.0404***				
Number_of_children	(0.00566)	(0.00548)	(0.0120)	(0.0118)				
Control variables	Yes	Yes	Yes	Yes				
Constant	Yes	Yes	Yes	Yes				
Province FE	Yes	No	Yes	No				
Year FE	Yes	No	Yes	No				
Province × Year FE	No	Yes	No	Yes				
Observations	10,741	10,687	7,979	7979				
(Pseudo) R^2	0.190	0.219	0.213	0.248				

Table 6 Heterogeneous impact of informal insurance (children's education)

This table presents the estimation for Eq. (2) in two subsamples: having children with advanced educations versus having children without advanced educations. The results are based on different health cost risk measures, including self-reported health statuses (Panel A), chronic diseases (Panel B) and predicted health cost (Panel C). Columns (1)–(2) report the average marginal effects of the Probit regressions. Columns (3)–(4) report the coefficients of the OLS regressions. The standard set of control variables are the same as those in Table 2. The variable definitions can be found in the legend of Table 1. Robust standard errors are provided in parentheses. $*$, $**$, $***$ represent statistical significance at the 10%, 5%, and 1% levels, respectively.

	Pension_participation		Ln(Pension_contribution)	
VARIABLES	$Education^{advanced}_{children}$ = 0	$Education^{advanced}_{children}$ = 1	$Education^{advanced}_{children}$ = 0	$Education^{advanced}_{children}$ = 1
	(1)	(2)	(3)	(4)
Panel A Health status				
$Health^{fair}$	0.0212	0.0525	0.0683	0.284***
	(0.0239)	(0.0373)	(0.0508)	(0.104)
$Health^{good}$	0.0294	0.0523	0.122*	0.394***
	(0.0270)	(0.0365)	(0.0640)	(0.120)
$Health^{fair}$ × Number_of_children	-0.0195**	-0.0267*	-0.0170	-0.108***
	(0.00943)	(0.0141)	(0.0183)	(0.0377)
$Health^{good}$ × Number_of_children	-0.0206*	-0.0435**	-0.00650	-0.123***
	(0.0120)	(0.0169)	(0.0233)	(0.0426)
Number_of_children	0.0133*	0.0282**	-0.0556***	-0.0289
	(0.00772)	(0.0116)	(0.0138)	(0.0306)
Observations	9,791	4,325	7,345	3,323
(Pseudo) R^2	0.184	0.199	0.205	0.253
Panel B Chronic diseases				
Chronic_diseases	-0.00915	-0.0114	-0.00484	-0.116***
	(0.00602)	(0.00979)	(0.0135)	(0.0228)
Chronic_diseases × Number_of_children	0.00566**	0.00840**	-0.000797	0.0424***
	(0.00234)	(0.00386)	(0.00488)	(0.00783)
Number_of_children	-0.00949*	-0.00851	-0.0649***	-0.185***
	(0.00564)	(0.00793)	(0.0131)	(0.0217)
Observations	9,792	4,325	7,345	3,323
(Pseudo) R^2	0.183	0.198	0.203	0.255
Panel C Predicted health cost				
Ln(Predicted_health_cost)	-0.0296	-0.0344	-0.0150	-0.336***
	(0.0188)	(0.0275)	(0.0450)	(0.0863)
Ln(Predicted_health_cost)× Number_of_children	0.0202***	0.0265**	-0.00654	0.121***
	(0.00748)	(0.0104)	(0.0169)	(0.0315)
Number_of_children	-0.180***	-0.275***	-0.0159	-1.034***
	(0.0563)	(0.0773)	(0.131)	(0.241)
Observations	9,787	4,325	7,343	3,323
(Pseudo) R^2	0.184	0.199	0.203	0.254
Control variables	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 7 Heterogeneous impact of informal insurance (children's genders)

This table presents the estimation for Eq. (2): whether, and to what extent, sons and daughters mitigate the impact of the health cost risk on pension demand. Columns (1)–(3) report the average marginal effects of the Probit regressions. Columns (4)–(6) report the coefficients of the OLS regressions. The standard set of control variables are the same as those in Table 2. The variable definitions can be found in the legend of Table 1. Robust standard errors are provided in parentheses. *, **, *** represent statistical significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	Pension_participation			Ln(Pension_contribution)		
	(1)	(2)	(3)	(4)	(5)	(6)
Health^{fair}	0.0368*			0.137***		
	(0.0195)			(0.0474)		
Health^{good}	0.0406*			0.221***		
	(0.0209)			(0.0578)		
Chronic_diseases		-0.0105**			-0.0469***	
		(0.00490)			(0.0128)	
Ln(Predicted_health_cost)			-0.0335**			-0.133***
			(0.0151)			(0.0427)
Health^{fair} × Number_of_sons	-0.0180*			-0.0511**		
	(0.0100)			(0.0238)		
Health^{good} × Number_of_sons	-0.0240*			-0.0672**		
	(0.0123)			(0.0286)		
Health^{fair} × Number_of_daughters	-0.0293***			-0.0395**		
	(0.00884)			(0.0175)		
Health^{good} × Number_of_daughters	-0.0336***			-0.0297		
	(0.0111)			(0.0223)		
Chronic_diseases × Number_of_sons		0.00712***			0.0214***	
		(0.00257)			(0.00662)	
Chronic_diseases × Number_of_daughters		0.00629***			0.00952*	
		(0.00226)			(0.00494)	
Ln(Predicted_health_cost) × Number_of_sons			0.0199**			0.0546**
			(0.00780)			(0.0225)
Ln(Predicted_health_cost)× Number_of_daughters			0.0255***			0.0258
			(0.00687)			(0.0158)
Number_of_sons	0.0127	-0.0124**	-0.179***	-0.0478**	-0.126***	-0.505***
	(0.00808)	(0.00595)	(0.0649)	(0.0181)	(0.0167)	(0.174)
Number_of_daughters	0.0253***	-0.00645	-0.229***	-0.0446***	-0.0876***	-0.268**
	(0.00740)	(0.00494)	(0.0515)	(0.0135)	(0.0117)	(0.121)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,322	14,323	14,318	10,788	10,788	10,786
(Pseudo) R^2	0.186	0.186	0.186	0.216	0.215	0.215

References

[1] Agüero, Jorge M., and Mindy S. Marks. "Motherhood and female labor force participation: Evidence from infertility shocks." *American Economic Review* 98.2 (2008): 500 – 504.

[2] Ameriks, John, Andrew Caplin, Steven Laufer, and Stijn Van Nieuwerburgh. "The joy of giving or assisted living? Using strategic surveys to separate public care aversion from bequest motives." *Journal of Finance* 66.2 (2011): 519–561.

[3] Bang, Heejung, and James M. Robins. "Doubly robust estimation in missing data and causal inference models. " *Biometrics* 61.4 (2005): 962–973.

[4] Benartzi, Shlomo, Alessandro Previtero, and Richard H. Thaler. "Annuitization puzzles." *Journal of Economic Perspectives* 25.4 (2011): 143–164.

[5] Bloch, Francis, Garance Genicot, and Debraj Ray. "Informal insurance in social networks." *Journal of Economic Theory* 143.1 (2008): 36–58.

[6] Bound, John, Todd Stinebrickner, and Timothy Waidmann. "Health, economic resources and the work decisions of older men. " *Journal of Econometrics* 156.1 (2010): 106–29.

[7] Cai, Fang, John Giles, and Xin Meng. "How well do children insure parents against low retirement income? An analysis using survey data from urban China." *Journal of Public Economics* 90.12 (2006): 2229–2255.

[8] Cervellati, Matteo, and Uwe Sunde. "Human capital formation, life expectancy, and the process of development." *American Economic Review* 95.5 (2005): 1653–1672.

[9] Chan, Kenneth S., Jennifer Te Lai, and Tingting Li. "Cultural values, genes and savings behavior in China." *International Review of Economics & Finance* 80 (2022): 134-146.

[10] Cheng, Lingguo, Hong Liu, Ye Zhang, and Zhong Zhao. "The health implications of social pensions: Evidence from China's new rural pension scheme." *Journal of Comparative Economics* 46.1 (2018): 53–77.

[11] Chew, Soo Hong, Junjian Yi, Junsen Zhang, and Songfa Zhong. "Risk aversion and son preference: Experimental evidence from Chinese twin parents." *Management Science* 64.8 (2018): 3896–3910.

[12] China State Council. Notice on deepening the reform of the enterprise employees' pension insurance system (in Chinese, 国务院关于深化企业职工养老保险制度改革的通知) (1995)

[13] China State Council. Decision on enterprise employees basic pension (in Chinese, 国务院关于完善企业职工基本养老保险制度的决定) (2005).

[14] China State Council. Guidelines on the implementation of pilot programs for the new rural social pension (in Chinese, 国务院关于开展新型农村社会养老保险试点的指导意见) (2009).

[15] China State Council. Guidelines on the implementation of pilot programs for the urban residents social pension (in Chinese, 国务院关于开展城镇居民社会养老保险试点的指导意见) (2011).

[16] China State Council. Guidelines on the unified urban and rural residents basic pension (in Chinese, 国务院关于建立统一的城乡居民基本养老保险制度的意见) (2014).

[17] China State Council. Opinion on integration of basic medical insurance systems between urban and rural residents (in Chinese, 国务院关于整合城乡居民基本医疗保险制度的意见) (2016).

[18] Cui, Hanxiao, James P. Smith, and Yaohui Zhao. "Early-life deprivation and health outcomes in adulthood: Evidence from childhood hunger episodes of middle-aged and elderly Chinese." *Journal of Development Economics* 143 (2020): 102417.

[19] Davidoff, Thomas, Jeffrey R. Brown, and Peter A. Diamond. "Annuities and individual welfare." *American Economic Review* 95.5 (2005): 1573–1590.

[20] Disney, Richard, Carl Emmerson, and Matthew Wakefield. "Ill health and retirement in Britain: A panel data-based analysis." *Journal of Health Economics* 25.4 (2006): 621–649.

[21] Erdogan, Berrin, Talya N. Bauer, Donald M. Truxillo, and Layla R. Mansfield. "Whistle while you work: A review of the life satisfaction literature." *Journal of Management* 38.4 (2012): 1038-1083.

[22] Feng, Jin, Lixin He, and Hiroshi Sato. "Public pension and household saving: Evidence from urban China." *Journal of Comparative Economics* 39.4 (2011): 470-485.

[23] Foster, Andrew D., and Mark R. Rosenzweig. "Imperfect commitment, altruism, and the family: Evidence from transfer behavior in low-income rural areas." *Review of Economics and Statistics* 83.3 (2001): 389–407.

[24] Giles, John, Dewen Wang, and Changbao Zhao. "Can China's rural elderly count on support from adult children? Implications of rural-to-urban migration." *Journal of Population Ageing* 3.3 (2010): 183–204.

[25] He, Hui, Lei Ning, and Dongming Zhu. The impact of rapid aging and pension reform on savings and the labor supply. International Monetary Fund working paper (2019).

[26] Human Resources and Social Security Ministry & Ministry of Finance. Notice on raising the minimum standard of basic pension benefits for urban and rural residents' basic pension nationwide (in Chinese, 人力资源社会保障部 财政部关于2018年提高全国城乡居民基本养老保险基础养老金最低标准的通知) (2018).

[27] İmrohoroğlu, Ayşe, and Kai Zhao. "The Chinese saving rate: Long-term care risks, family insurance, and demographics." *Journal of Monetary Economics* 96 (2018): 33–52.

[28] Inkmann, Joachim, Paula Lopes, and Alexander Michaelides. "How deep is the annuity market participation puzzle?" *Review of Financial Studies* 24.1 (2011): 279–319.

[29] Lockwood, Lee M. Incidental Bequests and the Choice to Self-Insure Late-Life Risks, *American Economic Review*, 108(9) (2018), 2513–2550.

[30] Oliveira, Jaqueline. "The value of children: Inter-generational support, fertility, and human capital." *Journal of Development Economics* 120 (2016): 1–16.

[31] Pang, Gaobo, and Mark Warshawsky. "Optimizing the equity-bond-annuity portfolio in retirement: The impact of uncertain health expenses." *Insurance: Mathematics and Economics* 46.1 (2010): 198–209.

[32] Pashchenko, Svetlana. "Accounting for non-annuitization." *Journal of Public Economics* 98 (2013):

53–67.

[33] Peijnenburg, Kim, Theo Nijman, and Bas J.M. Werker. "Health cost risk: A potential solution to the annuity puzzle." *Economic Journal* 127.603 (2017): 1598–1625.

[34] Raut, Lakshmi K., and Lien H. Tran. "Parental human capital investment and old-age transfers from children: Is it a loan contract or reciprocity for Indonesian families?" *Journal of Development Economics* 77.2 (2005): 389–414.

[35] Reichling, Felix, and Kent Smetters. "Optimal annuitization with stochastic mortality and correlated medical costs." *American Economic Review* 105.11 (2015): 3273–3320.

[36] Rosen, Harvey S., and Stephen Wu. "Portfolio choice and health status." *Journal of Financial Economics* 72.3 (2004): 457-484.

[37] Rossi, Pauline, and Mathilde Godard. "The old-age security motive for fertility: Evidence from the extension of social pensions in Namibia." *American Economic Journal: Economic Policy* 14.4 (2022): 488–518.

[38] Serrano, Ray, Richard Saltman, and Ming-Jui Yeh. "Laws on filial support in four Asian countries." *Bulletin of the World Health Organization* 95.11 (2017): 788.

[39] Turra, Cassio M., and Olivia S. Mitchell. "The impact of health status and out-of-pocket medical expenditures on annuity valuation," in (John Ameriks and Olivia S. Mitchell, eds.), *Recalibrating Retirement Spending and Saving*, (2008): 227–250, Oxford: Oxford University Press.

[40] Xie, Yu, and Haiyan Zhu. "Do sons or daughters give more money to parents in urban China?" *Journal of Marriage and Family* 71.1 (2009): 174–186.

[41] Yaari, Menahem E. "Uncertain lifetime, life insurance, and the theory of the consumer." *Review of Economic Studies* 32.2 (1965): 137–150.

[42] Yip, Winnie Chi-Man, William C Hsiao, Wen Chen, Shanlian Hu, Jin Ma, and Alan Maynard." Early appraisal of China's huge and complex health-care reforms." *Lancet* 379.9818 (2012): 833–842.

[43] Yogo, Motohiro. "Portfolio choice in retirement: Health risk and the demand for annuities, housing, and risky assets." *Journal of Monetary Economics* 80 (2016): 17–34.

[44] Zhao, Yaohui, John Strauss, Xinxin Chen, Yafeng Wang, Jinquan Gong, Qinqin Meng, Gewei Wang, and Huali Wang. "China health and retirement longitudinal study wave 4 user’s guide." National School of Development, Peking University. (2020).