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How private sector participation improves retirement preparation: A case from China

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Abstract This paper shows empirically how private sector participation improves the adequacy and equality of retirement preparation in a three-pillar retirement system. We develop a three-layer replacement rate approach based on the China Health and Retirement Longitudinal Study, a nationwide representative household survey of middle-aged and old aged population. Our empirical evidence shows that private sector participation increased the mean (median) replacement rate in 2013 from 35.4% (15.4%) to 69.8% (48.7%). The evidence also suggests that annuitising home equity is responsible for a large portion of this increase. Surprisingly, private sector participation also mitigates the inequality of retirement preparation between the formal and informal sectors. Our empirical findings emphasise the importance of annuitisable private savings for the retirement income security of the one-fifth of the global population who live in a representatively high-growth and rapidly ageing economy.

Keywords Retirement preparation · Pension · Replacement rate · Adequacy · Equality · China

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Introduction

Longevity and low fertility rates constitute an unprecedented concern for the ageing population in our modern society. Retirement incomes are becoming inadequate for longer retirement periods. Longer retirement periods also result in protection gaps for vulnerable social groups, such as minorities, females and immigrants.[1] Inequality of retirement preparation thus arises. In a classical Bismarck social insurance system, the public pension programme provides a major part of retirement income. However, solely relying on public pension systems may endanger fiscal sustainability, particularly in developing countries such as China.[2]

This paper shows empirically the extent to which private sector participation[3] improves the adequacy of retirement preparation, considering insufficient public pension benefits. We also show to what extent private sector participation mitigates the inequality of retirement preparation resulting from the fragmented public pension system. The previous literature attributes retirement preparation problems to the design of the public pension programme and suggests necessary reforms.[4] Our empirical evidence shows that the lack of private motivation to participate also contributes to the inadequacy and inequality of retirement preparation.

Existing studies on Chinese retirement preparation use macroeconomic statistics to assess public pension programmes, for example Wang et al. (2014a), or use a modelling-simulation approach to derive policy implications on pension reforms, for example Wang et al. (2014b), Song et al. (2015), and Chen and Groenewold (2017).[5] This study is the first to consider preparation for retirement in China at the microeconomic level. We explore the well-established metric of the income replacement rate to assess each individual's economic preparation for retirement and thus to estimate the actual income replacement rates of the Chinese population, incorporating all three pillars of the retirement system (i.e. public pension, employer-provided private pension, and annuitisable private savings).[6] Furthermore,

[1] See Bridges and Choudhury (2009), Neelakantan and Chang (2010), and Knoef et al. (2016) for discussions on the protection gaps of minorities, females, and immigrants, respectively.

[2] Wang et al. (2014a, b) present and discuss the looming financing crisis and the unfairness in the Chinese pension system.

[3] Conventionally, private sector participation in retirement preparation involves Pillar II, i.e. employer-provided private pensions, and Pillar III, which includes individually arranged private pensions and potentially annuitisable private savings. In this paper, we further consider annuitising private savings through the additional premium contribution options in the public pension programme (Resident's Basic Pension Programme, Pillar I) as a special type of private sector participation.

[4] See, e.g. Wang et al. (2014a, b), Song et al. (2015), and Chen and Groenewold (2017).

[5] Two consulting reports in Chinese also contribute to understanding Chinese retirement adequacy (Insurance Association of China 2015; China Center for Insurance and Risk Management of Tsinghua University 2016). Our analyses fundamentally differ from theirs in terms of methodology, sample representativeness, and findings. Feng et al. (2011) explore micro-level data; however, their focus is on the trade-off between public pension and household savings for urban residents.

[6] Monetary transfer and services from children to parents are not included in our replacement rate estimation; rather, we control for these elements in a second-stage regression to reveal the substitution effects between family transfer and pension benefits and savings. We refer to Cai et al. (2006) and Oliveira (2016) for a closer examination of family transfer.



our analyses cover not only the formal sector (i.e. government, public institutions and formally established enterprises) but also the informal sector (i.e. farming, self-employment and other informal businesses).

The replacement rate is defined as the ratio of income after retirement to income before retirement. The replacement rate is the most widely used measure of the relative well-being of retirement income and is a commonly accepted standard of pension systems worldwide, as Yuh (2011) and Knoef et al. (2016) suggest. To separately assess the contribution of each of the three pillars of the pension system, we develop three layers of the income replacement rate in the spirit of Knoef et al.'s (2016) multi-pillar replacement rate approach. This approach disentangles the contributions of public pensions, private pensions (both employer-provided and individually arranged), and annuitisable private savings. This approach also offers useful additional insights in the sense that it quantitatively measures the gaps between each layer and thus facilitates the identification of the source of the protection gap.

We derive our results from an academically recognised and nationally representative household survey (China Health and Retirement Longitudinal Study, CHARLS 2011, 2013, 2014, 2015). This data set is particularly suitable for analysing retirement preparation questions because it focuses on the population aged 45 or older, who are close to or in retirement. Its detailed sampling protocols and effective survey management ensure its nationwide representativeness and data quality. Thus, this data set is widely used in international health and pension economics research, for example by Zhang et al. (2013) and Oliveira (2016), among others.

Several factors account for our choice of China as a case study for this paper. China faces the typical challenges of a developing country, such as limited economic resources, institutional segmentation between the formal and informal sectors, and a rapidly ageing population. Thus, the case of China may yield useful implications for other economies encountering similar challenges. Finally, China is home to one-fifth of the world's population, justifying its importance as a market, but has been much less investigated than the U.S. and Europe by the international retirement research community.

The rest of this paper is structured as follows. We first review the existing literature. Then we describe the Chinese three-pillar retirement system and its evolution. This is followed by a summary of the CHARLS data and our sample. Next, we introduce our methodologies, the three-layer replacement rate approach and the empirical methods. We report the empirical results and discuss the individual choice to contribute additional premiums to a public pension programme. Finally, we conclude with policy implications.

Literature review

The existing literature, for example Brady (2010), Yuh (2011), and Knoef et al. (2016), recognises that retirement preparation decisions involve private investment and savings. From a theoretical perspective, Brown (2003) proves that complete



annuitisation is welfare enhancing in a simple life cycle model with no bequests. Hanewald et al. (2016) find that retirees have utility gains through equity release products. Thus, studies assessing retirement preparation must consider all attainable retirement income resources. From an empirical perspective, Knoef et al. (2016) develop a multi-pillar replacement rate approach for the Netherlands. Their approach successfully captures the marginal contribution of annuitisable private savings to improving the adequacy of retirement income. We further develop the multi-pillar replacement rate approach of Knoef et al. (2016) to separately consider the effects of public pension benefits, private pensions and private savings. Munnell et al. (2006) and Yuh (2011) construct a household replacement rate with income from work and annual return from assets as the denominator, and pension income and annuitised income from assets as the numerator. However, Purcell (2012) suggests that the replacement rate at the individual level captures more accurate information than at the household level. We thus follow Purcell (2012) to construct the replacement rate at the individual level.

Compared to studies in the U.S. and Europe, little is known about retirement preparation in developing economies,[7] particularly when taking Pillars II and III into account. In China, as in many other developing economies, limited public economic resources and a rapidly ageing population have caused an inadequate replacement rate of public pension programmes. Moreover, institutional segmentation between the formal and informal sectors causes inequality between the two sectors. This inequality results from the fragmented public pension system, as suggested by Dessy and Pallage (2003), and Wang et al. (2014a). Cai and Cheng (2014) conduct a literature survey on the challenges and opportunities of the pension system in China and highlight the absence and importance of quantitative analyses using micro-level household databases.

James (2002), and Sun and Suo (2007) note that accumulated savings and private insurance solutions should fill the protection gap of the Chinese public pension, which alone is considered insufficient if the aim is to cover all residents. A few models for analysing reform options for the Chinese public pension system are developed, accompanied by simulations based on macroeconomic statistics, for example Yang (2009), Song et al. (2015), and Chen and Groenewold (2017). Wang et al. (2014b) empirically estimate the (expected) pension fund gap of China in 2013, 2020, and 2050 based on macroeconomic statistics, and highlight the risk of a Chinese fiscal crisis in the long run. All of the above studies are based on macro-level statistics and/or simulations of theoretical models, thus motivating us to explore the micro-level evidence.

From the perspective of Chinese retirement preparation equality, Barr and Diamond (2010) note that Chinese public pension benefits should have a national structure instead of being separate systems with unequal benefits for urban and rural residents. Wang et al. (2014a) develop a fairness coefficient to evaluate the inequality of a pension system and conclude that the pension income across various

[7] Forteza and Ourens (2012) develop an indicator describing the return to contribution of Latin American pension programmes; however, they do not focus on retirement preparation.



Chinese public pension schemes is "absolutely unfair".[8] The "absolutely unfair" public pension programmes suggest that public efforts alone cannot solve the inequality in retirement preparation. We are thus motivated to show for the first time the equality effects of the fragmented public pension system and private sector participation using micro-level evidence.

The Chinese retirement and pension system

The Chinese retirement and pension system consists of three pillars: public pension (Pillar I), employer-provided private pension (Pillar II), and individually arranged private pension and private savings (Pillar III). Following Poterba (2014), we adopt the broad definition of the third pillar that includes not only individually arranged private pensions but also all private savings potentially annuitisable for retirement. This includes, for example, private financial assets and home equity. Figure 1 illustrates the evolution of Chinese public pension programmes (Pillar I) since 1991, when it was announced that the three-pillar framework and coverage for all residents would be pursued.

The Chinese public pension system has been fragmented since its establishment. It targets four exclusive groups of people: employees in formally established enterprises, employees in government and public institutions, other urban residents, and other rural residents. In 2014 and 2015, the four fragmented public pension programmes were merged into two nationwide: the Employee's Basic Pension (mainly for the formal sector) and the Resident's Basic Pension (mainly for the informal sector).[9] The former is compulsory and is funded by a payroll tax paid by both employers and employees. The latter is voluntary and funded by a general tax (i.e. government subsidy) and voluntary individual premium contributions, with several options as guidance.

In parallel, the employer-provided private pension (Pillar II) and the individually arranged private pension and private savings (Pillar III) are developed independently of the public pension programmes. However, by 2013, less than 3% of pension income came from employer-provided private pensions and individually arranged private pensions (see Table 2). Employer-provided private pensions are mostly offered to employees of the government, public institutions, and profitable enterprises as employee benefits. Efforts to annuitise private savings (financial assets and home equities) are highly personalised and underdeveloped. As shown by Zheng (2016), only one insurance company offered a reverse mortgage product for elderly Chinese, and only 63 individuals from 46 households had purchased this product by 2016.

[8] Wang et al. (2014a, p. 25).

[9] The Rural Resident's Basic Pension and Urban Resident's Basic Pension were merged to form the Resident's Basic Pension in China in 2014. Thus, we do not distinguish the detailed differences in the premium contribution and the pension benefits of these programmes but instead aggregate and analyse them as if they had always been one programme, i.e., the Resident's Basic Pension.



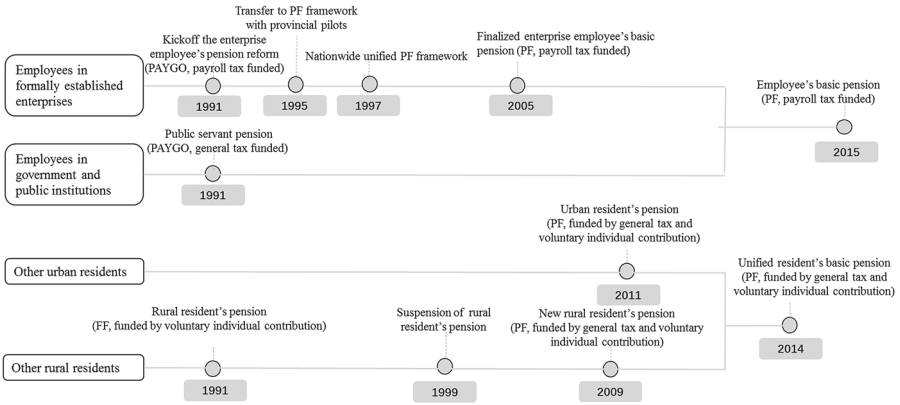


Fig. 1 Chinese public pension system (Pillar I). *Notes:* PAYGO: pay as you go; PF: partially funded; FF: fully funded

Data and sample

CHARLS data set

The CHARLS data set belongs to a family of well-established international health and retirement data sets including, for example, the Health and Retirement Study (HRS) in the U.S., the English Longitudinal Study of Ageing (ELSA) in England, and the Survey of Health, Ageing, and Retirement in Europe (SHARE). CHARLS uses multi-stage stratified probabilities proportional to size (PPS) sampling to survey nationwide respondents aged 45 years or older. The survey follows detailed protocols for sampling, field survey, and data quality verification. The CHARLS national baseline survey was first conducted in 2011 and then again in 2013 and 2015. The second- and third-wave national surveys in 2013 and 2015 aimed to revisit the same respondents sampled in the first wave. CHARLS (2014) is a life history survey that revisits all living respondents from CHARLS 2011, 2013). The information in the CHARLS surveys includes the respondents' pre-retirement income (employment wage and benefits, agricultural revenue and costs, and income from self-employment), post-retirement income (pension benefits), premium contribution to pension programmes, financial assets and home equities, and demographic characteristics. The life history survey in 2014 collected, for example, the respondents' work history, enabling us to estimate the pre-retirement permanent income from all working activities. CHARLS is also optimal for retirement studies because of its focus on senior people, with more than 98% of respondents aged 45 years or older.[10]

We use eight macroeconomic factors to adjust respective pre- and post-retirement income values to the retirement year to estimate the replacement rate. In

[10] The spouse of the primary respondent may be younger than 45 but is also interviewed as a respondent.



addition, we obtain the life expectancies of the Chinese population by gender and birth cohort from the United Nations Population Division (2015), which shows an accelerating increase in longevity. The life expectancy is used to annuitise respondents' assets after retirement. The Online Appendix A summarises the details of the above information.

Sample construct

We construct our sample based on the complete CHARLS (2013) data set in five steps.[11] First, we select respondents with retirement ages between 40 and 70 to maintain consistency with statutory requirements.[12] Second, we select respondents who retired or will retire between 1997 and 2025. China established the nationwide unified Employee's Basic Pension system in 1997. Thus, the assessment of retirement preparation before 1997 is less relevant to current situations. We limit our sample to 2025 because projections of income and pension become less accurate beyond that point. Third, we exclude respondents with missing values in key variables that are used in later regression analyses.[13] Fourth, we truncate the non-zero replacement rate at the 5th and 95th percentiles to exclude extreme replacement rates in the sample.[14] The above four steps generate Sample A, which is used to estimate the pension income replacement rate.[15] In the fifth and final step, we construct a subsample (Sample B) that also excludes observations with missing values in housing rent, home equity and financial assets. Sample B consists of approximately 35% of the observations in Sample A, enabling us to estimate the total income replacement rate.

Table 1 reports the sample summary statistics for CHARLS (2013). The summary statistics for CHARLS (2011, 2015) are shown in the Online Appendix C. We report two mean values of each variable. One is weighted by the inverse probability weights for each respondent to correct for non-responses following Zhao et al. (2016) (thus representing the whole Chinese population), and the other one is

[11] In the main part of the paper, we use CHARLS (2013) to conduct most of our analyses. We repeat all analyses with CHARLS (2011, 2015) in a robustness test, and all results support our conclusions (see the section on robustness tests). CHARLS (2011) contains limited information on the Resident's Basic Pension, which was underdeveloped with a low coverage rate in 2011 and may thus result in sample selection bias. CHARLS (2015) was partially released in May 2017; however, the sub-data set of family information has not yet been released. We would have to approximate the number of children and number of siblings to use CHARLS (2015). In the regression analyses, a full sample result including all three waves is also presented.

[12] The minimum statutory retirement age is 40 for workers involved in unhealthy special activities, and the maximum statutory retirement age is 70 for senior government officials and other senior positions; the regular statutory retirement age is 60 for males, 50 for female workers, 55 for female cadres, and 60 for other females.

[13] Before the third step, we supplement missing values by taking full advantage of information in CHARLS (2011, 2013, 2014 and 2015). For example, we supplement missing values of time-invariant variables in one year with the corresponding values in another year.

[14] Hurd and Rohwedder (2011). Alternatively, we truncate the replacement rate in percentiles of 2.5/97.5 and 1/99. The results are consistent with our conclusions and are available from the authors on request.

[15] The observations dropped from Steps 1, 2, 3, and 4 are 13%, 16%, 47%, and 10% of the previous step sample, respectively.



Table 1 Summary statistics

	Mean (weighted)	Mean	SD	10th	Median	90th
Sample A	*N = 6855*					
Formal sector	0.242	0.180	0.384	0	0	1
Birth year	1953	1953	7.125	1944	1953	1963
Married	0.904	0.911	0.284	1	1	1
Male	0.515	0.511	0.500	0	1	1
Han Chinese	0.924	0.922	0.268	1	1	1
Urban resident (non-agriculture Hukou)	0.265	0.200	0.400	0	0	1
Education[a]	1.742	1.671	1.176	0	2	3
Number of children	2.541	2.630	1.356	1	2	4
Number of siblings	3.296	3.303	1.900	1	3	6
Rely on children for old-age support	0.551	0.601	0.490	0	1	1
Provincial GDP per capita	46,289	44,856	16,125	25,322	38,909	68,805
Sample B	*N = 2372*					
Formal sector	0.339	0.248	0.432	0	0	1
Birth year	1953	1954	7.153	1944	1954	1964
Married	0.908	0.925	0.264	1	1	1
Male	0.510	0.503	0.500	0	1	1
Han Chinese	0.925	0.919	0.273	1	1	1
Urban resident (non-agriculture Hukou)	0.375	0.287	0.452	0	0	1
Education[a]	1.903	1.798	1.172	0	2	3
Number of children	2.445	2.533	1.324	1	2	4
Number of siblings	3.325	3.335	1.939	1	3	6
Rely on children for old-age support	0.467	0.539	0.499	0	1	1
Provincial GDP per capita	47,594	45,913	16,655	30,741	38,909	68,805

[a]0 = no formal education; 1 = can read and write; 2 = elementary school; and 3 = secondary school or above. Each category accounts for approximately 25% of the sample

non-weighted. The discussion below will be based on the weighted mean values and the median values.

Methodology

Three layers of the replacement rate

We estimate three layers of the income replacement rate for each respondent in each year to separately assess the contributions of public pensions, employer-provided and individually arranged private pensions, and potentially annuitisable private savings. The 1-Layer projected replacement rate (1-Layer PR) is the public pension



replacement rate, defined by public pension benefits divided by the pre-retirement permanent income from working activities [Eq. (1)]. The 2-Layer is the all pension replacement rate, defined by public and private pension (both employer-provided and individually arranged) replacing the pre-retirement permanent income from working activities[16] [2-Layer PR, Eq. (2)]. The 3-Layer is the total income replacement rate, which additionally considers the potential income from financial assets and home equity before and after retirement [3-Layer PR, Eq. (3)]. Following Purcell (2012), we assume that respondents voluntarily annuitise 80% of their private savings after retirement via reverse mortgage and/or other private solutions. The estimated income replacement rates capture the percentage of long-term post-retirement income replacing the permanent pre-retirement income for each individual respondent in the sample. The Online Appendix B summarises the details of the replacement rate estimations.

$$1\,Layer\,PR_{i,t} = \frac{Public\ pension\ benefits_{i,t}}{Pre_retirement\ permanent\ income\ from\ work_{i,t}} \tag{1}$$

$$2\,Layer\,PR_{i,t} = \frac{Public\ pension\ benefits_{i,t} + Private\ pension\ benefits_{i,t}}{Pre_retirement\ permanant\ income\ from\ work_{i,t}} \tag{2}$$

$$3\,Layer\,PR_{i,t} = \frac{Pension\ benefits_{i,t} + Post_retirement\ income\ from\ assets_{i,t}}{Pre_retirement\ permanant\ income\ from\ work_{i,t} + Pre_retirement\ income\ from\ assets_{i,t}} \tag{3}$$

Our approach is developed based on the state-of-the-art multi-pillar replacement rate estimation in Munnell et al. (2006), Yuh (2011), Purcell (2012), and Knoef et al. (2016). It advances the extant replacement rate approach in the following aspects. First, we estimate the pre-retirement permanent income based on the 10-year real income stream of each respondent prior to their retirement. Second, we observe the individual retirement age for more than 70% of the respondents in our sample and approximate the rest by the statutory retirement age. Third, we estimate the replacement rate at the individual level instead of the household level. This setup is particularly suitable for developing countries, where the tax and social security systems are based on individuals instead of households. Moreover, the individual replacement rate approach is more suitable for equality analyses among social groups because one couple may belong to different categories.[17]

[16] The three layers of replacement rates are defined differently from the three pillars of the retirement system. The 2-Layer PR includes the public pension (Pillar I), the employer-provided private pension (Pillar II), and individually arranged private pension (a part of Pillar III). The 3-Layer PR additionally includes the annuitisable private savings.

[17] We also calculate the household replacement rate as a robustness test, and the results support our conclusions.

Regression model

We conduct regressions to analyse the drivers of the three layers of replacement rates using Eq. (4). X_i is a vector of control variables including ethnic group, resident's registration status, education, number of children, number of siblings, reliance or lack of reliance on children for old-age support, and provincial GDP per capita. The regression is applied to the 2013 sample, the full sample pooling all three waves, and the subsamples of 2011 and 2015 in the robustness test. We additionally control for the year fixed effect in the pooled full sample.

$$\begin{aligned} Replacement\ rate_i = {} & \beta_0 + \beta_1 Formal\ sector_i + \beta_2 Formal\ sector_i \times Male_i \\ & + \beta_3 Formal\ sector_i \times Birth\ year_i + \beta_4 Male_i + \beta_5 Birth\ year_i \\ & + \beta_6 Income\ group_i + X_i\beta + \varepsilon_i \end{aligned} \tag{4}$$

The advantage of the multiple regression approach is that it captures the net impact of certain factors while controlling for others. We conduct the Ordinary Least Squares (OLS) regression in the core model and the Tobit regression in a robustness test to account for the left censoring at 0 of the replacement rates. The connections of respondents within each community and heterogeneity among communities are further accounted for by the robust standard errors clustered at the community level. Following Zhao et al. (2016), all observations are weighted in the regression using CHARLS inverse probability weights to correct for non-responses. The variance inflation factors for all specifications are below 5, suggesting that multicollinearity is not a major concern.

Gini coefficient

The Gini coefficient (GC) is a powerful tool to assess the equality of income streams as shown in Eq. (5). x_i represents the income stream of individual i in a specific year, and $\bar{x}$ is the average value of x_i. It is worth noting that equality in retirement preparation differs from equality of income or wealth. By contrast, equality in retirement preparation does not necessarily imply that everyone has the same amount of pension, as their pre-retirement incomes might have been very different. Rather, an equal retirement system should mitigate the pre-retirement income and wealth inequality, as reflected in a higher replacement rate for the poor and a lower one for the rich.

$$Gini\ coefficient = \frac{2}{n^2\bar{x}} \sum_{i=1}^{n} i(x_i - \bar{x}) \tag{5}$$

Results

We first discuss the adequacy and equality of Chinese public pension programmes as a baseline scenario. Then we show how private sector participation improves the adequacy and mitigates the inequality of public pension programmes. The results



are presented in Tables 2, 3, 4, 5 and 6. Table 2 summarises the estimated three-layer replacement rates and their key components. Table 3 compares the replacement rates of the formal and informal sectors, and Table 4 presents their distributions. Table 5 presents the regression results showing the determinants of the replacement rates. Table 6 shows the estimated Gini coefficients.

Adequacy and equality of public pension programmes

As shown in Table 2, the weighted average (median) 1-Layer PR was 30.3% (12.9%) in 2013. The very low adequacy of public pensions is driven by the informal sector, i.e. the Resident's Basic Pension (mean 19.0% and median 9.0%, as shown in Table 3). In 2013, 80.7% of Chinese had a public pension replacement rate below 50%. This is the case for most respondents in the informal sector and nearly half of the respondents in the formal sector. Only approximately 12% of respondents reach a public pension replacement rate of 70%. Thus, the public pension alone is far from providing an adequate retirement income to maintain standards of living throughout retirement. Sun and Suo (2007) and Feng et al. (2011) quote a target public pension replacement rate of 58.5% in China for employees in the formal sector. Our estimated median 1-Layer PR for the formal

Table 2 Replacement rates and components

	Mean (weighted)	Mean	SD	10th	Median	90th
Sample A	*N = 6855*					
1-Layer PR	0.303	0.283	0.373	0	0.129	0.792
2-Layer PR	0.308	0.287	0.375	0	0.133	0.805
Public pension benefits	4145	3290	7529	0	660	10,457
Private pension benefits[a]	96	60	1602	0	0	0
Income from working activities	21,924	18,961	40,237	1382	7414	44,854
Sample B	*N = 2372*					
1-Layer PR	0.354	0.320	0.391	0	0.154	0.865
2-Layer PR	0.361	0.324	0.394	0	0.158	0.885
3-Layer PR	0.698	0.661	0.555	0.116	0.487	1.492
Public pension benefits	5460	4375	8487	0	720	13,200
Private pension benefits[a]	187	117	2646	0	0	0
Annuitised income from financial assets	782	588	2879	2.608	30	1282
Annuitised income from home equity	8489	7195	10,889	311.6	3767	16,692
Income from working activities	24,549	21,212	45,037	1694	8640	47,348
Investment return from financial assets	644.5	469.3	2561	2.180	23.13	908.9
Imputed rent from home equity	5200	4659	10,045	174.8	1993	9991

All monetary values are in CNY and adjusted to the respective retirement year of each respondent

[a]Both employer-provided and individually arranged

Table 3 Replacement rates by occupational sector

	Mean (weighted)	Mean	SD	Median	Obs.
Sample A (1-Layer)	*N = 6855*				
Formal	0.659	0.679	0.446	0.592	1232
Informal	0.190	0.197	0.290	0.090	5623
Sample A (2-Layer)	*N = 6855*				
Formal	0.672	0.686	0.445	0.597	1232
Informal	0.192	0.199	0.293	0.091	5623
Sample B (3-Layer)	*N* =2372				
Formal	0.905	0.912	0.493	0.845	589
Informal	0.591	0.578	0.550	0.377	1783

Table 4 Distribution of replacement rates

	PR = 0	0 < PR < 50	50 ≤ PR < 70	70 ≤ PR < 100	100 ≤ PR
Sample A (1-Layer)	*N = 6855*				
Percent	19.88	60.85	7.03	5.73	6.51
Observation	1363	4171	482	393	446
Sample A (2-Layer)	*N = 6855*				
Percent	19.37	61.15	7.05	5.73	6.70
Observation	1328	4192	483	393	459
Sample B (3-Layer)	*N = 2372*				
Percent	0[a]	51.10	12.52	12.98	23.40
Observation	0[a]	1212	297	308	555

[a]All respondents in our sample have at least one type of assets or pension benefits and thus the 3-Layer PR cannot be zero

sector was 59.2% in 2013 (see Table 3). This is very close to the 58.5% target. However, this result does not change the overall inadequacy of the Chinese public pension.

In Table 3, we observe that the weighted average 1-Layer PR gap was as large as 46.9 percentage points in 2013 between the formal sector (one quarter of Chinese) and the informal sector (three quarters of Chinese). Columns 1–2 in Table 5 report the results for the 1-Layer PR as the dependent variable. The coefficients of *Formal sector* in columns 1–2 confirm that the formal sector has a significantly higher 1-Layer PR than the informal sector. The protection gap between the two fragmented public pension programmes was as large as 49.5 percentage points in the 1-Layer PR in 2013. The inequality between occupational sectors does not become narrower for younger generations, as evidenced by the insignificant coefficient of *Formal sector* × *Birth year*. Our survey-based micro-evidence is consistent with the literature discussing the unfairness of the Chinese fragmented public pension programmes based on macro-statistics and predictive modelling, for example Wang et al. (2014a) and Hu and Yang (2012).



Table 5 Regression on replacement rates

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample A: 1-Layer PR		*Sample A: 2-Layer PR*		*Sample B: 3-Layer PR*	
	2011, 13, 15	2013	2011, 13, 15	2013	2011, 13, 15	2013
Employer-provided private pension			0.0745	0.0499	0.112	− 0.00484
			(0.0549)	(0.0683)	(0.0775)	(0.0916)
Individually arranged private pension			0.0114	− 0.0598***	− 0.154**	− 0.167**
			(0.0326)	(0.0212)	(0.0629)	(0.0698)
Value of home equity[a]					1.446***	1.610***
					(0.176)	(0.198)
Value of financial assets[a]					− 0.213	− 0.0438
					(0.214)	(0.0930)
Formal sector	0.506***	0.495***	0.516***	0.513***	0.329***	0.318***
	(0.0326)	(0.0387)	(0.0333)	(0.0397)	(0.0359)	(0.0560)
Formal sector × Male	− 0.0434	− 0.0827**	− 0.0433	− 0.0963***	0.0441	0.0154
	(0.0271)	(0.0328)	(0.0275)	(0.0334)	(0.0327)	(0.0465)
Formal sector × Birth year	− 0.00304	− 0.00334	− 0.00309	− 0.00299	− 0.00208	0.00169
	(0.00256)	(0.00309)	(0.00264)	(0.00312)	(0.00265)	(0.00370)
Male	0.00302	0.00002	0.00411	0.000163	− 0.0179	− 0.0308
	(0.00655)	(0.00782)	(0.00663)	(0.00794)	(0.0138)	(0.0223)
Birth year	− 0.00165**	− 0.00178**	− 0.00152**	− 0.00149*	0.00175	0.00124
	(0.000744)	(0.000877)	(0.000747)	(0.000872)	(0.00164)	(0.00240)
Incomegroup2	− 0.176***	− 0.232***	− 0.174***	− 0.232***	− 0.112***	− 0.155***
	(0.0141)	(0.0176)	(0.0142)	(0.0177)	(0.0280)	(0.0450)
Incomegroup3	− 0.242***	− 0.314***	− 0.239***	− 0.309***	− 0.318***	− 0.400***
	(0.0151)	(0.0186)	(0.0155)	(0.0188)	(0.0276)	(0.0418)

Table 5 continued

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample A: 1-Layer PR		*Sample A: 2-Layer PR*		*Sample B: 3-Layer PR*	
	2011, 13, 15	2013	2011, 13, 15	2013	2011, 13, 15	2013
Incomegroup4	− 0.344***	− 0.417***	− 0.344***	− 0.417***	− 0.536***	− 0.655***
	(0.0152)	(0.0186)	(0.0151)	(0.0185)	(0.0283)	(0.0457)
Incomegroup_highest	− 0.473***	− 0.540***	− 0.478***	− 0.545***	− 0.860***	− 1.032***
	(0.0183)	(0.0206)	(0.0185)	(0.0205)	(0.0401)	(0.0532)
Han Chinese	0.00236	− 0.0135	0.00436	− 0.0102	0.0874***	0.0676*
	(0.0103)	(0.0174)	(0.0104)	(0.0174)	(0.0255)	(0.0368)
Married	0.0136	0.0204	0.0163	0.0206	0.0455	0.0797
	(0.0178)	(0.0231)	(0.0180)	(0.0231)	(0.0406)	(0.0551)
Urban registration resident	0.123***	0.119***	0.123***	0.114***	0.178***	0.201***
	(0.0187)	(0.0214)	(0.0189)	(0.0219)	(0.0273)	(0.0436)
No formal education	− 0.0503***	− 0.0451***	− 0.0518***	− 0.0501***	− 0.0839***	− 0.115***
	(0.0116)	(0.0125)	(0.0120)	(0.0132)	(0.0212)	(0.0365)
Can read and write	− 0.0440***	− 0.0439***	− 0.0443***	− 0.0467***	− 0.0390*	− 0.0691**
	(0.0139)	(0.0148)	(0.0143)	(0.0154)	(0.0222)	(0.0307)
Elementary school	− 0.0488***	− 0.0513***	− 0.0503***	− 0.0547***	− 0.0170	− 0.0300
	(0.0155)	(0.0182)	(0.0159)	(0.0190)	(0.0203)	(0.0332)
Number of children	− 0.00937**	− 0.0150***	− 0.00876**	− 0.00382*	− 0.00310	− 0.00451
	(0.00368)	(0.00519)	(0.00368)	(0.00227)	(0.00721)	(0.0110)
Rely on children for old-age support	− 0.0517***	− 0.0512***	− 0.0557***	− 0.0576***	0.00490	0.0186
	(0.00835)	(0.0103)	(0.00843)	(0.0102)	(0.0154)	(0.0277)
Number of siblings	− 0.00142	− 0.00344	− 0.00208	− 0.00382*	− 0.00246	0.00232
	(0.00199)	(0.00225)	(0.00200)	(0.00227)	(0.00407)	(0.00629)

Table 5 continued

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample A: 1-Layer PR		*Sample A: 2-Layer PR*		*Sample B: 3-Layer PR*	
	2011, 13, 15	2013	2011, 13, 15	2013	2011, 13, 15	2013
Provincial GDP per capita[a]	0.566*	− 0.260	0.629*	− 0.134	0.725	1.449**
	(0.322)	(0.325)	(0.326)	(0.329)	(0.525)	(0.703)
Year 2011	− 0.0708***		− 0.0660***		0.0851***	
	(0.0103)		(0.0106)		(0.0186)	
Year 2013	− 0.00172		0.00006		0.0831***	
	(0.00659)		(0.00688)		(0.0176)	
Observations	19,407	6855	19,407	6855	8062	2372
R^2	0.439	0.468	0.446	0.472	0.404	0.428

The robust standard errors clustered at the community level are provided in parentheses. *, **, and *** indicate that the coefficients significantly differ from 0 at the 10, 5, and 1% levels, respectively. Constants are included in the regression but not reported

[a]Scaled by 1/1000,000

Table 6 Gini coefficients

	Pre-retirement permanent income from work	Public pension benefits	Private pension and annuitised private savings
Sample A	$N = 6855$		
Formal sector	0.523	0.434	N.A.
Informal sector	0.678	0.615	N.A.
Full sample	0.658	0.776	N.A.
Sample B	$N = 2372$		
Formal sector	0.522	0.422	0.551
Informal sector	0.675	0.647	0.634
Full sample	0.644	0.748	0.617

Table 6 reports the estimated Gini coefficients. In both Samples A and B, within the formal sector, the GCs of the Employee's Basic Pension benefits are smaller than those of the pre-retirement permanent income from work. This suggests that the Employee's Basic Pension mitigates income inequality within the formal sector. Similarly, the Resident's Basic Pension mitigates income inequality within the informal sector. This is consistent with the results in Columns 1–2 in Table 5, where we observe that low-income groups have a significantly higher 1-Layer PR than high-income groups.[18] However, if we examine the combined effect for the formal and informal sectors, the GCs of public pension benefits are larger than those of pre-retirement permanent income. This suggests that the fragmented public pension programmes do not mitigate but actually amplify income inequality, which is an unintended and undesirable consequence.

Private sector participation improves retirement income adequacy

The marginal effect of private pensions (employer-provided as Pillar II and individually arranged in Pillar III) is captured by comparing the 2-Layer and 1-Layer PR. The marginal effect of potential private savings annuitisation is captured by comparing the 3-Layer and 2-Layer PR. Thus, the aggregate effect of private sector participation is captured by the difference between the 3-Layer and 1-Layer PR.

Table 2 shows that the 2-Layer PR is slightly larger than the 1-Layer PR, but this difference is statistically insignificant. In Sample B, we compare the 3-Layer with the 2-Layer PR. We find that annuitising financial assets and home equity for retirement improves the weighted average replacement rate from 36.1 to 69.8% (median from 15.8 to 48.7%) in 2013. The potential retirement income stream from annuitised home equity may well exceed the sum of pension benefits and annuitised

[18] Both programmes have a design of income redistribution. The benefits of the Employee's Basic Pension are partially determined based on the average employment income and the years of contribution (the part from the pooling account), while the yearly premium is calculated as a percentage of individual employment income. Thus, for the same amount of benefits, high-income employees contribute a greater premium than low-income employees. The redistribution effect of the Resident's Basic Pension is indirect, as reflected by the general tax subsidy, to which rich people contribute more than poor people.



financial assets for most respondents. This reflects the fact that home equity is the single largest asset for most Chinese households. As shown in Table 4, annuitising private savings eliminates the zero replacement rate group and decreases the size of the underprepared group ($0\% \leq PR < 50\%$). Annuitising private savings also increases the size of categories with higher replacement rates, namely, $50\% \leq PR < 70\%$, $70\% \leq PR < 100\%$, $100\% \leq PR$. These increases are statistically significant, subject to binomial probability tests (p-values < 0.001 for all three cases). In yet another analysis, we confirm that annuitising private savings constitutes a prominent financial source to potentially double the replacement rate for more than 50% of Chinese.[19] Still, the total income replacement rate (3-Layer PR) in China is much lower than in the U.S. and Europe. While only 36% of Chinese had a 3-Layer PR above 70% in 2013, this portion was 56% among U.S. households and 69% in the Netherlands.[20]

Our results show that although the impact of private pensions on retirement income adequacy is minimal, the potential annuitisation of 80% of private savings significantly improves the adequacy. Rational choice theory predicts that households find private annuities attractive as an option for retirement preparation. However, relatively few households choose to annuitise a substantial portion of their wealth, as Benartzi et al. (2011) suggest. Our results provide direct evidence for this annuity puzzle. Annuity providers in some cases lack incentives to offer annuity products because of systematic longevity risk, as Bräutigam et al. (2017) suggest. Pension savers' concerns about the investment risk of annuity products result in the prevailing conservative attitude towards annuity products, as Donnelly et al. (2018) suggest. Considering these difficulties, Bräutigam et al. (2017) and Donnelly et al. (2018) develop algorithms to show that appropriate and innovative annuity products can improve annuity market performance and reduce risks from longevity and investment. These innovations are expected to be more practical in a digital pension world and may significantly reduce the risk concerns in the annuity market. These innovations are potentially relevant to promoting the annuity market in China.

Columns 3–4 in Table 5 report the results for the 2-Layer PR as the dependent variable. We add two dummies in Eq. (4). The results show that neither the *employer-provided private pension nor the individually arranged private pension* has a significantly positive impact on the replacement rate, confirming that the role of private pensions is minimal in China. Columns 5–6 in Table 5 report the results for the 3-Layer PR as the dependent variable. We add two more independent variables to Eq. (4). The *value of home equity* has a significantly positive impact on the 3-Layer PR. This suggests that annuitising home equity will significantly improve the adequacy of retirement preparation. The role of financial assets is,

[19] For 1281 respondents, the 3-Layer PRs are at least twice the 2-Layer PR, among 2372 respondents in Sample B.

[20] Yuh (2011), Knoef et al. (2016). Caution must be observed when comparing these fractions because the replacement rate estimations differ in several aspects. However, the differences do not change the relative positions of the three countries.



however, insignificant.[21] The adequacy improvement effect of private sector participation differs in various social groups. For example, Han Chinese have a significantly larger 3-Layer PR than minorities. This might be because Han Chinese tend to save more than minorities and have a higher income and/or minorities' remote regions have lower-value home equity and a less developed financial system.

Private sector participation mitigates inequality in retirement preparation

Saez and Zucman (2016), and Knight et al. (2016) suggest that wealth inequality is usually larger than income inequality due to the snowballing effect. Thus, one should usually expect that private pension and savings amplify inequality. This is true for the formal sector, where the private pension and annuitised private savings (wealth) have a larger Gini coefficient than that of pre-retirement permanent income ($0.551 > 0.522$) (see Sample B, Table 6).

Table 5 shows that the replacement rate gap between the formal and informal sectors is as large as 49.5% in the 1-Layer regression (Column 2). However, this gap is reduced to 31.8% in the 3-Layer regression (Column 6). This significant reduction (p value of T test < 0.005) supports our claim that private sector participation mitigates the formal vs informal inequality resulting from the fragmented public pension programmes.[22] The GC results in Table 6 corroborate the above findings. The GC of private pensions and annuitised private savings in the full sample (0.617) is much smaller than those of public pension benefits (0.748) and pre-retirement permanent income (0.644). This equality-improving effect of private savings is driven by two factors. One is the large gap in retirement income between the formal and informal sectors due to the fragmented public pension programmes. The other is the remarkably high rate of home ownership in both urban and rural areas compared to most countries, which moderates the wealth inequality.

Examining the control variables in our regression results (Table 5), we observe that older generations have significantly higher 1-Layer and 2-Layer PR than younger generations, as evidenced by the negative coefficients of *birth year* in Columns 1–4 in Table 5. We observe that low-income groups have significantly higher replacement rates than high-income groups. We also note that the 1-Layer and 2-Layer PR decrease with the number of children and negatively correlate with the dummy of relying on children for retirement support. This evidence is consistent with Cai et al.'s (2006) conclusion that some households tend to raise more children for old-age support, accompanied by less motivation to participate in pension programmes.[23] We observe lower replacement rates for those not finishing secondary school, consistent with Hurd and Rohwedder (2011). Urban residents

[21] The coefficient of financial assets remains insignificant in 2013 and in the full sample even if we drop the home equity variable in the regression equation.

[22] We note that this equality-improving effect of private savings does not vary across gender or over generations, as evidenced by the insignificant coefficients of the interaction terms *Formal sector* × *Birth year* and *Formal sector* × *Male* in Column 6, Table 5.

[23] Low fertility rates in recent years may weaken the trend of raising children for old-age support in China. An alternative explanation might be that parents do not have spare money to contribute to pension programmes when they have more children.



remain significantly better prepared than rural residents. However, comparing the coefficient of *Urban registration resident* with that of *Formal sector* in each regression, the scale of registration status impact is much smaller than that of the occupational segments subject to T tests (p-value < 0.005). We do not observe significant inequality between married couples and single respondents or between men and women, whereas significant gaps are typically found in U.S. studies, for example, Liu and Rettenmaier (2003), and Munnell and Soto (2005).

Robustness tests

We conduct the following seven robustness tests. The results are presented in the Online Appendix C and are consistent with our conclusions, except where otherwise noted in our discussion below. First, we repeat our analyses of CHARLS (2011, 2015). All our conclusions hold. The public pension replacement rates improve steadily in the three waves. Second, we estimate the household replacement rate.[24] All results remain consistent except that we cannot investigate the gender effect. Third, we annuitise 50% of private savings (instead of 80%) after retirement, considering the Chinese tradition and preference for leaving bequests to children. The mean 3-Layer PR decreases while all conclusions hold. Fourth, we include the interaction terms *Formal sector* $\times$ *Income group*$_i$ in the regressions and reproduce Table 5. The results suggest that the inequality between the formal and informal sectors becomes smaller in the high-income groups. Several statistical alternatives are analysed, and the results are consistent with our conclusions. Fifth, we use only the observations that record the respondent-reported retirement age without statutory retirement age to supplement missing value. Sixth, we conduct Tobit regression with left-censoring at 0. For the seventh and final test, we use sample B to repeat all our analyses.

Moreover, as an additional but interesting test, we examine how the one-child policy impacts our results. We separate our samples into (1) a one or no child subsample (i.e. those strictly following the one-child policy) and (2) a two or more children subsample (i.e. exceptions from the one-child policy).[25] We also include a dummy with 1 indicating one or no child in our regression analyses. We find that one-child families have higher replacement rates than multi-child families in all three layers. One-child families rely more on the public pension programmes and less on the home equity's contribution in improving the adequacy of retirement preparation. The one-child policy has no significant impact on the equality of retirement preparation between the formal and informal sectors. The detailed analyses and discussions are presented in the Online Appendix D.

[24] Following Yuh (2011), we use the characteristics of the main respondent in one family as the characteristics of that family, including occupational sector, birth year, education, and ethnic group.

[25] The majority is actually the "exception" because the respondents in our sample were mostly born between 1944 and 1964, and thus, their children were mostly born between 1960 and 1995. The one-child policy was formally implemented in the late 1970s, and thus, less than half of the respondents were restricted by this policy. Moreover, exceptions are widely present in rural China, as the one-child policy officially allows for two children for rural residents if the first child is a girl.



Discussion

Our results suggest that the current private pension system and the potential annuitised savings cannot eliminate the problems of a fragmented public pension system. Wang et al. (2014a) attribute the inadequacy of the Resident's Basic Pension—consequently, the inequality between the two public pension programmes—to institutional defects, including "ideational deviation" and "lack of conceptual design".[26] We complement the existing literature by showing how the behavioural element, i.e. the individual choice of additional premium contributions to the Resident's Basic Pension programme, affects retirement preparation.

Participants in the Resident's Basic Pension may choose their own level of annual premium contribution between CNY 100 and 2000. This choice determines the pension benefits they will receive after retirement. This is different from the Employee's Basic Pension, for which the contribution is a fixed percentage of working income. Currently, the amount of government subsidy in the Resident's Basic Pension is either the same or not materially different for all participants in a region. As a consequence, most residents pay the minimum individual premium contribution of CNY 100 as an entrance ticket to obtain most of the government subsidies in premiums and benefits. We simulate how adequacy and equality will change if participants choose higher premium contribution options.

We select the participants of the Resident's Basic Pension programme in Sample A if they report the number of years and the annual amount of premium contribution.[27] This subsample (hereafter Sample C) includes only respondents in the informal sector. We simulate the increments of the Resident's Basic Pension benefits under the following 12 scenarios: the participant contributes an additional CNY 250, 500, 750, or 1000 for an additional 5, 10, or 15 years on top of their reported contribution amount and years. The *simulated increments* are calculated based on the standard formula of the Resident's Basic Pension and adjusted to the value at the retirement year.[28] We then derive the *new 1-Layer PR* for each participant under each scenario with Eq. (6).[29]

$$New\,1-Layer\,PR_{i,t}=\frac{Public\,pension\,benefits_{i,t}+Simulated\,increments_{i,t}}{Pre_retirement\,permanent\,income\,from\,work_{i,t}} \quad (6)$$

[26] Wang et al. (2014a, p. 33).

[27] We exclude from this subsample respondents who retired after the age of 60 because most of them had the Resident's Basic Pension benefits for free, without contributions when the programme was rolled out.

[28] For example, a person who retires at 60 has paid CNY 200 for 12 years as a premium contribution to the Resident's Basic Pension programme. We simulate a scenario in which they would pay an additional CNY 750 a year (i.e. 950 in total) for an additional 10 years (i.e. 22 years in total), and thus, the *simulated increments* are CNY 3817. The calculation formulas and standard tariff are documented in Ministry of Human Resources and Social Security (2014).

[29] Ideally, the net (after-tax) pre-retirement permanent income should decrease as the premium contribution to the public pension programme increases. We, however, do not consider this impact on income. This simplification will not affect our conclusion because a decreasing permanent income will further increase the *new 1-layer PR*, reinforcing our conclusions. We truncate the non-zero replacement rates at the 5th and 95th percentiles (Hurd and Rohwedder 2011).



Table 7 shows that *new 1-Layer PR* increases with premium and year of contribution. If residents in the informal sector[30] all contributed an additional CNY 750 each year for an additional 10 years, the replacement rate in the Resident's Basic Pension programme (mean 64.0% and median 45.0%) would be comparable to that of the Employee's Basic Pension programme (mean 65.9% and median 59.2%).[31] The inadequacy for informal sector residents and the inequality between the formal and informal sectors are thus mitigated. The results suggest that the design of the Resident's Basic Pension programme allows for potentially high replacement rates with optional and additional premium contributions. Such potential is difficult to observe from analyses based on macro-statistics.

The additional premium contribution to the public pension programme can be considered a trade-off between participation in the public pension programme and private savings. Our results suggest that residents in the informal sector strongly prefer private savings. Comparing the *new 1-Layer PR* with the *original 3-Layer PR* of the informal sector, we find that the replacement rate from annuitising via the Resident's Basic Pension is at least as good as annuitising via private solutions such as reverse mortgage.[32] Our evidence and simulation contribute another deviation from the rational choice theory in the sense that even if the public pension is as attractive as private savings for a rational decision maker, most people choose to keep their income as private savings, as suggested by Benartzi et al. (2011).

With this discussion, we show that the lack of a private premium contribution is one of the primary reasons for the inadequacy and inequality of the public pension programmes and thus constitutes one of the major defects in the public pension's design. We emphasise a direction to improve public pension adequacy and equality other than merging the two programmes in one step, which is deemed unrealistic in the near future, as Wang et al. (2014a) suggest. Changing individual behaviour by motivating private participation in public pension programmes is shown to be effective and promising.

Conclusion and policy implications

In this paper, we disentangle the role of private sector participation from public efforts to improve the adequacy and equality of retirement preparation. Specifically, we show how annuitising private savings in private markets and through the public pension system improves retirement preparation adequacy and equality, as

[30] In Sample C, the average yearly premium contribution is CNY 232, and the average number of years of contribution is 7.8.

[31] Participants of the Employee's Basic Pension have, on average, 21 years of contribution in Sample A, a minimum of 15 years of contribution to receive any pension benefits, and a fixed individual payroll tax of 8%. If participants in the Resident's Basic Pension follow the same contribution plan, then the yearly premium contribution should be CNY 988 (8% × CNY 12,354, the average income from work in Sample C). Thus, we simulate the scenario of additional CNY 750 premiums for an additional 10 years, which approximates the 8% contribution for 18 years (between 15 and 21 years).

[32] The comparison is based on the new 1-layer PR scenario with the additional CNY 750 premium contribution for an additional 10 years (mean 64.0% and median 45.0%). The original 3-layer PR for the informal sector in 2013 is 59.1% (mean) and 37.7% (median).



Table 7 New 1-Layer replacement rates

Contribution years	Annual premium contribution	Mean (weighted)	Mean	SD	Median
		Sample C (N =1283)			
+ 0 (original 1-layer PR without simulation)		0.159	0.160	0.152	0.106
+ 5	+ 250	0.284	0.272	0.226	0.196
	+ 500	0.361	0.362	0.296	0.262
	+ 750	0.467	0.452	0.372	0.326
	+ 1000	0.540	0.541	0.450	0.386
+ 10	+ 250	0.361	0.346	0.285	0.252
	+ 500	0.482	0.484	0.394	0.354
	+ 750	0.640	0.621	0.509	0.450
	+ 1000	0.756	0.758	0.627	0.545
+ 15	+ 250	0.453	0.434	0.357	0.316
	+ 500	0.626	0.628	0.512	0.465
	+ 750	0.845	0.822	0.674	0.601
	+ 1000	1.013	1.016	0.839	0.734

measured by replacement rates. We develop a three-layer replacement rate approach adapted to a Chinese sample derived from the China Health and Retirement Longitudinal Study (CHARLS). This paper not only concerns the welfare of the Chinese population but also sheds light on economies under similar circumstances, such as a rapidly ageing population, economic development pressure, a segmented social structure, and fragmented pension programmes.

The empirical evidence suggests that public pension benefits alone are inadequate to maintain standards of living across retirement, yielding a replacement rate below 50% for more than three quarters of the Chinese population. Private sector participation increases the mean (median) replacement rate in 2013 from 35.4% (15.4%) to 69.8% (48.7%). The results also suggest that annuitising home equity constitutes the most prominent financial source and will at least double the replacement rates for more than 50% of the Chinese population. From an equality perspective, we document that the protection gap between the two fragmented public pension programmes (i.e. between the formal and informal sectors) is as large as 49.5 precentage points in terms of replacement rates in 2013. The simulation results suggest that motivating private premium contributions to the Resident's Basic Pension programme is an effective way to potentially eliminate the protection gap between the informal and formal sectors. This alternative annuitisation option is overlooked by the existing literature.

The in-depth reasons for the lack of private sector participation may be on both the supply and demand side. For pension savers, long term uncertainties of private pensions and lack of innovative and attractive solutions lower their overall appetite for annuitisation projects at retirement. Donnelly et al. (2018) suggest that communication with pension savers and long-term uncertainties of private pension investment can be improved considerably in a future digital pension world. They propose an algorithm with upper and lower bounds of final investment wealth to



alleviate the concerns of pension savers about complexity and uncertainty. For annuity providers, systematic longevity risk restrains the development of the annuity market. Bräutigam et al. (2017) suggest that product innovation by, for example the pooled annuity overlay funds and equitable retirement income tontines, should be able to keep down the capital requirements and safety loading of pension providers and thus keep down the overall costs of the pension. This trend is expected to become stronger in a future digital pension world.

Future research may further investigate how financial literacy, myopic behaviour, trust in public programmes, and tax incentives affect retirement preparation decisions. We note the limitations of our income replacement rate approach. One is the lack of agreement on which elements should be considered pre- and post-retirement income. It is thus important to show various specifications of replacement rates in the robustness tests. Consumption is considered to be a more direct measure of living standards. Future studies are encouraged to verify our conclusions with consumption assessments considering changes in healthcare and work-related costs across retirement. Monetary transfer and services from children to parents constitute an additional source of retirement income, in addition to pension benefits and annuitised assets. Future research may also incorporate the family support perspective in the analysis of retirement preparation.

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