The Impact of Rapid Aging and Pension Reform on Savings and the Labor Supply: The Case of China[*]

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Abstract

We study, both empirically and quantitatively, the role of savings and the labor supply in self-insurance channels over the life cycle when one faces not only idiosyncratic income risks, but also changes in longevity risk and pension benefits. We pick China as a case study since over the past two decades China has undergone a dramatic process of rapid aging and a tremendous reduction in social security benefits. We find that both savings and the labor supply are quantitatively important self-insurance channels in responding to changes in

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longevity risk and pension benefits, and the responses via adjustment to savings and labor supply have significant macroeconomic implications. Applying the model to China, we find that the pension reform and rapid aging together contribute 55% of the increase in the household saving rate from 1995 to 2009, and they jointly capture about 64% of the drastic increase in the labor supply for the same period.

JEL classifications: E21, E65, H55

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1 Introduction

Since Aiyagari's path-breaking work (Aiyagari 1994), saving has been recognized as an important instrument with which to self insure against idiosyncratic income shocks. The labor supply, as another instrument to self insure against idiosyncratic income shocks, has recently gained attention in the literature. Low (2005) shows that allowing flexible working hours in a rather standard Aiyagari-type heterogenous agent model brings the age profiles of working hours and consumption closer to the data. Flexibility of working hours allows individuals to react to income shocks by changing their hours of work, and thus reducing the cost of uncertainty. Pijoan-Mas (2006) also highlights the self-insurance channel of the labor supply and shows that the labor supply is at least as important as savings when it comes to the instruments with which to insure against income risk.

This paper studies, both empirically and quantitatively, the roles savings and the labor supply play as self-insurance channels over the *life cycle* when one faces not only idiosyncratic income risks, but also changes in longevity risk and pension benefits. These are important risks and uncertainties that an individual faces over the whole life cycle. Theoretically speaking, changes in pension benefits, such as whether or not a pension benefit is linked to an individual's average (life-cycle) wage, e.g., the average index of monthly earnings (AIME) in the US pension system, would have an impact on the individual's savings and labor supply behavior. The linkage of one's working age income to one's retirement benefits extends the idiosyncratic income shocks faced during working years to retirement period. To hedge against an increase in income shocks during one's retirement period, one could start to save more and/or increase one's labor supply during one's working life. On the other hand, changes in pension benefits via reducing the generosity of the pension

system (e.g., the replacement ratio) could also affect a household's savings and labor supply due to consumption smoothing motive. A lower replacement ratio would reduce the available pension wealth after retirement, and hence would encourage an individual to increase saving while working. The empirical literature, e.g., Attanasio and Brugiavini (2003) and Attanasio and Rohwedder (2003), find that this is the case and the substitutability between public pension wealth and private saving is relatively high. Erosa, Fuster and Kambourov (2012) link government programs such as pensions to the labor supply, and find that social security rules account for the bulk of cross-country differences in labor supply late in the life cycle.

By the same token, changes in longevity risk could also affect the labor supply and savings. An increase in longevity would allow an individual to live for a longer time during the retirement period. In order to prepare for that, one could increase savings and/or one's labor supply while working, so as to effectively insure against the change in longevity risk. We call this channel the *life expectancy* effect (see Bloom et al. 2007).

By putting together idiosyncratic income risks, longevity risk, and uncertainties about the pension system, and allowing both savings and the labor supply to insure against those risks, this paper provides a comprehensive view of individual's responses to these risks and uncertainties over the life cycle and investigates the aggregate implications of those responses. This is the main contribution of the present paper.

Empirically and quantitatively testing the importance of savings and labor supply as self-insurance channels in response to changes in longevity risk and pension benefits, however, is quite challenging, since not many countries have experienced significant changes in both longevity risk and pension benefits. In this paper, we choose China as a case study because China has undergone a rapid aging and a radical pension reform *simultaneously* over the past two decades (more details in the Appendix). Therefore, China provides an ideal "natural experiment" to test the impacts of rapid aging and pension reform on savings and the labor supply, both at the household and at the aggregate level. The first research question we ask is: how would changes in longevity risk and pension benefits, such as the ones that China has experienced, quantitatively affect households' savings and labor supply at the aggregate level, and over the life cycle, in the long run? In addition, as shown in more detail in Section 2, both the average household saving rate and weekly working hours per worker have been increasing significantly in urban China since 1997. We therefore ask a further and specific question: to what extent do the rapid demographic changes and the pension reforms mentioned above contribute to the increasing household saving rate and supply of labor in urban China after 1997?

To answer these quantitative questions, we first provide an empirical analysis

showing that the Chinese pension reform indeed had an impact on the saving rate and the labor supply at the household level, using data from the *Chinese Household Income Project Survey* (CHIPS). We use the 2005 Chinese pension reform (for details, see Appendix 7.2) as a quasi-natural experiment to conduct a difference-in-difference (DiD) regression. We find that workers with pension benefits tend to supply less labor and save less, consistent with our theoretical prediction. Households responded to the 2005 pension reform by increasing their savings and labor supply in response to the reduction in the generosity of the pension system. In addition, our empirical analysis shows that the impact of the pension reform was more significant for the saving rate than for the labor supply.

Motivated by our empirical evidence, we then develop a large-scale (70-period) heterogeneous agent overlapping generations general equilibrium model, following the literature such as Auerbach and Kotlikoff (1987), Imrohoroglu, Imrohoroglu, and Joines (1995), Huang, Imrohoroglu and Sargent (1997), and Conesa and Krueger (1999). In the model, an individual faces stochastic income risks up to retirement and a non-borrowing constraint. Individuals have to make decisions on consumption, asset holding, and their labor supply. We calibrate the model to match the Chinese economy before its pension reform and rapid aging took place, by using data from micro-level Chinese household surveys. We then input the exogenous demographic change and the policy changes in pension system into the model. We study the individual's responses to those exogenous changes in longevity risk and pension benefits, and investigate the aggregate implications of these individual responses in the long run. In addition, we also input the demographic change in China into the annual base, together with a carefully modeled "once-for-all" pension reform, and solve the model along a transition path to investigate the *short-run* impact of the pension reform and rapid aging on our variables of interest.

To answer the first question, we find that compared to the benchmark model without changes in longevity risk and pension benefits, a rising longevity risk alone increases the household saving rate by 3.6% and its labor supply by 3.2%. On the other hand, the pension reform as a whole package raises the saving rate by 28.7% and its labor supply by 3.0% in the long run. We also further decompose the changes in the pension system, and find that the reduction of the indexation of pension benefits (i.e., increasing the linkage with the AIME) increases the household saving rate by 18.3% and its labor supply by 1.3% in the long run. In contrast, the reduction of the replacement ratio raises the saving rate by 12.2% and the labor supply by 1.8% in the long run. The magnitude we find here shows that the labor supply as a self-insurance/consumption smoothing mechanism is of the same order of magnitude as savings for insurance against longevity risk. However, changes in pension benefits

seem to affect the saving rate much more significantly than the labor supply in the long run, which is consistent with our empirical analysis.

To highlight the importance of the labor supply as a self-insurance channel in response to uncertainties in longevity risk and pension benefits, we conduct a counterfactual experiment to shut down the flexible labor supply in our benchmark model. We find that the average household saving rate increases by 52% in the long run, compared to 30.2% in the benchmark case. This exercise shows that ignoring the labor supply would lead to a significant over-estimation of the importance of precautionary savings in insuring against uncertainties over the life cycle, not only for idiosyncratic income shocks, as emphasized by Low (2005) and Pijoan-Mas (2006), but also for uncertainties in longevity risk and pension benefits.

As to the life cycle dimension, our simulations show that young people aged 20–35 reduce their savings in responding to rapid aging and pension reform. After age 35, they start to save more. For workers aged 46–60, especially towards the end of the working years, the increase in savings is mostly in reaction to the changes in pension benefits; whereas after age 60, the increase in household savings is mostly driven by rising longevity risk. In other words, the impact of changes in the longevity risk and pension benefits on the household saving rate focuses on relatively older people (aged 45 and older). The impact increases with age. On the other hand, workers of almost all ages (except for young workers aged below 30) increase their working hours by responding to changes in longevity risk and pension benefits, but the impact of pension benefit changes exceeds that of demographic changes after age 55. The magnitude of the adjustment of the labor supply is comparable to that of the saving rate until retirement age. However, after retirement, an individual is not able to use their labor supply as an instrument for self-insurance. But the adjustment via savings still exists after retirement, and increases with age. This is the fundamental reason why the impact of longevity risk and pension reform hits savings more significantly than the labor supply.

To what extent do these two self-insurance channels help to explain the rising household saving rate and labor supply in urban China after 1997? The data show that the average household saving rate increased 12.7 percentage points: from 15.5%, which is the average for 1990–1997, to 28.2% in 2009. Weekly working hours per worker as a fraction of weekly discretionary hours increased about 7.7%: from 0.379 in 1996 to 0.408 in 2010. Our transition path results show that the changes in pension benefits due to the pension reform alone contribute about 41% of the increase in the household saving rate and 41% of the increase in labor supply for the time period. While the rapid aging contributes more to the increase of the labor supply than to the saving rate: it, alone, contributes about 36% of the increase in labor supply but

only 11% of the increase in household saving rate for the time period. Together, the rapid aging and the pension reforms contribute about 55% of the increase in the household saving rate from 1995 to 1999 and 64% of the increase in the labor supply from 1996 to 2010. The exercise shows that the impact of the demographic changes and pension reform on the aggregate household saving rate and the labor supply in urban China is of *first order* importance.

This paper is related to several strands of the literature. First of all, the empirical literature finds mixed evidence for the importance of demographic change on the aggregate saving rate, from only a modest contribution (Deaton and Paxson 2000) to one that is significantly large (Bloom, Canning and Graham 2003 and Bloom et al. 2007). We quantify the importance of the rapid aging for the household saving rate in the present paper, and find that the contribution indeed is modest. This might reflect the fact there are two opposite driving forces in action in our general equilibrium framework. On the one hand, rapid aging shifts the age structure in an economy from young (working age) towards old. Compared to retirees, working-age individuals tend to save more. Therefore the *composition effect* of the demographic change would reduce the household saving rate. On the other hand, the *life expectancy* effect as mentioned above tends to raise the household saving rate. Probably these two counteracting mechanisms offset each other in the model, to generate the modest quantitative results.

This paper also contributes to the literature on pensions and private savings, such as Attanasio and Brugiavini (2003) and Attanasio and Rohwedder (2003). We confirm their finding in the Chinese context by showing that the significant reduction of generosity of pension system could have had a big impact on the household saving rate.

However, the literature has put less emphasis on the importance of changes in demographic structure and the pension system for the aggregate supply of labor. In that sense, we are closely related to Erosa, Fuster and Kambourov (2012). They analyze the link between the labor supply and government programs, and they find that government policies can account for the differences in the labor supply late in the life cycle (age 50+) across European countries. Instead, our focus is to quantify the self-insurance channel that the labor supply actuates to insure against both longevity risk and changes in pension benefits through the whole life cycle. Giavazzi and McMahon (2012) use German microdata and a quasi-natural experiment to provide empirical evidence for how households use both savings and their labor supply to respond to an increase in pension policy uncertainty. We instead use the structural general equilibrium model here for the analysis. Our paper, however, complements their research, by focusing on studying the impact of changes in the pension *benefits*

formula, in terms of both the replacement ratio and the linkage to the AIME, on household savings and labor supply. Similar to their findings, we find that the impact seems to hit savings more.

Although our paper does not aim to solve the "Chinese saving rate puzzle," it does contribute to understanding why the Chinese household saving rate had been rising.[1] Our quantitative exercise shows that the pension reform, which significantly reduced the generosity of pension benefits for urban workers, could be an important driving force behind the rising saving rate over the past two decades. Our paper also contributes to the strand of the literature on quantifying the effects of China's demographic transition on its household savingss rate, such as Choukhmane, Coeurdacier and Jin (2014) and Curtis, Lagauer and Mark (2015). Both papers emphasize the importance of declining fertility due to the "one child policy" in affecting Chinese households' savings behavior. We complement their research by focusing on another end of the demographic change spectrum, namely the rising life expectancy due to rapid aging. In addition, both papers abstract from the impact of demographic change on the aggregate labor supply, which is an important focus of our paper.

This paper is also related to the literature on Chinese pension reforms. Feng, He, and Sato (2011) estimate the impact of the 1997 pension reform and find that empirically the pension reform boosted the household saving rate in 1999 by about 6–9 percentage points for the cohort aged 25–29 and by about 2–3 percentage points for the cohort aged 50–59. We emphasize the importance of the labor supply as another instrument to self-insure against pension benefit uncertainties. Our paper is also closely related to Song, Storesletten, Wang and Zilibotti (2015), who highlight the redistribution channel of social security in a fast growing country and focus on the *optimal* intergenerational redistribution along the transition path of a Chinese economy facing *future* pension reform and demographic transitions. Our focus here is the *current* impacts of the demographic change and pension reforms on the household saving rate and labor supply. In addition, Song et al. (2015) abstract from idiosyncratic risks, whereas how individuals use their savings and labor supply to insure against idiosyncratic risks over life cycle is our main focus.

The rest of this paper is organized as follows. Section 2 provides some stylized facts on the changes in the household saving rate and labor supply in urban China. It also describes the empirical analysis of the impact of the pension reform on the labor supply and the household saving rate, based on Chinese household survey data. Section 3 describes the model. Section 4 illustrates the calibration of the model. Section 5 presents the simulation results after we input rapid aging and the

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[1]For papers specifically aiming at explaining the dramatically rising saving rate in China, see Song and Yang (2010), Chamon and Prasad (2010), and Wei and Zhang (2011).

pension reform into the benchmark model. It also conducts several counterfactual experiments. Finally, Section 6 concludes.

2   Empirical Evidence

In this section, we first provide data describing the evolution of the household saving rate and labor supply over the past two decades. We then go deeper, with the micro-level household survey data, to empirically analyze the impact of the pension reforms on households' saving behavior and labor supply.

2.1   Trend of Household Saving Rate and Labor Supply

What happened to the Chinese economy after the rapid aging and radical pension reform mentioned above? A well known fact is that the household saving rate in China has also been rising very dramatically, making the nation rank the highest in terms of the saving rate among all countries. Figure 1 shows the average urban household saving rate for 1990–2009, which we constructed from the *Chinese Urban Household Survey* (UHS).[2] As shown in this figure, the Chinese urban household saving rate had been fairly stable from 1990 until 1995. It then began to increase very rapidly after 1996. In 2009, the rate exceeded 28%. Compared to its level in 1995, which was about 15.5%, the saving rate had increased by about 12.7 percentage points over these fourteen years.

However, a less known fact about China over the past two decades is that the Chinese also worked much longer than they did before. In Figure 2, we report the average weekly working hours per worker in urban China for 1996–2010 from a micro-level household survey called *Chinese Health and Nutrition Survey* (CHNS).[3] The panel data structure of the CHNS also makes tracking changes in working hours over time more credible. We therefore use the data from the CHNS as our main data source for the labor supply. The most striking pattern from Figure 2 is that urban workers dramatically increased their labor supply after the late 1990s. The average weekly working hours per worker jumped from 42.4 hours in 1996 to 45.9 hours in 2003. To check the robustness of the pattern found in the CHNS data, we also plot the weekly working hours per worker from the *Chinese Household Income Project*

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[2]The average household saving rate in the figure is defined as 1 - the total consumption by household sector/total disposable income by household sector.

[3]We start our data period from 1996 to avoid the inconsistency caused by the policy change from six working-days per week to five working-days per week, which occurred in 1995.
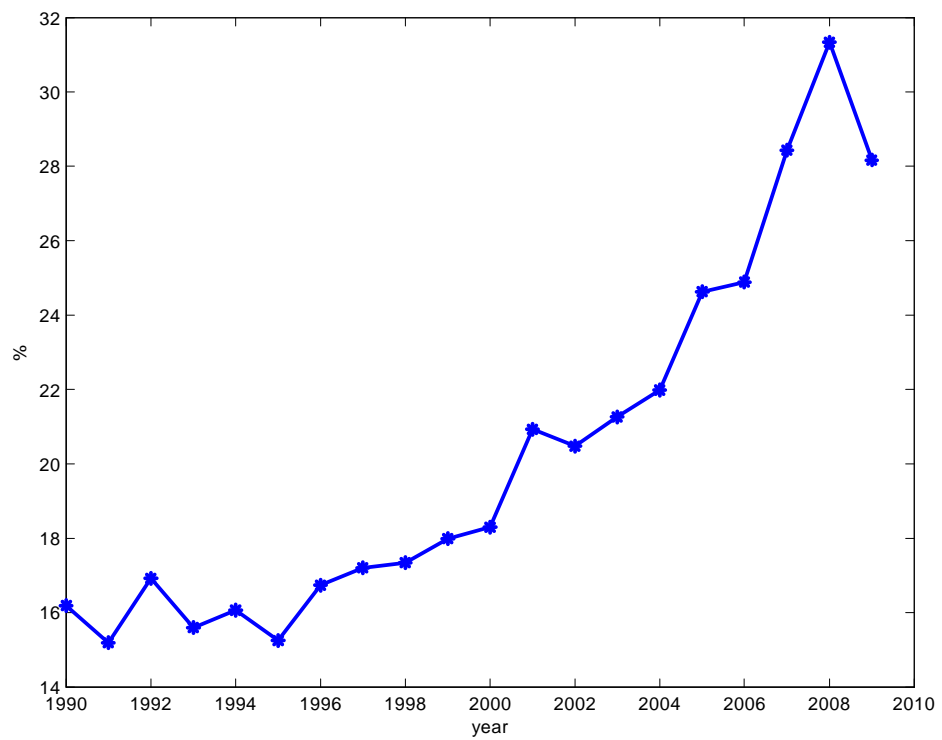
Figure 1: Chinese Urban Household Savings Rate
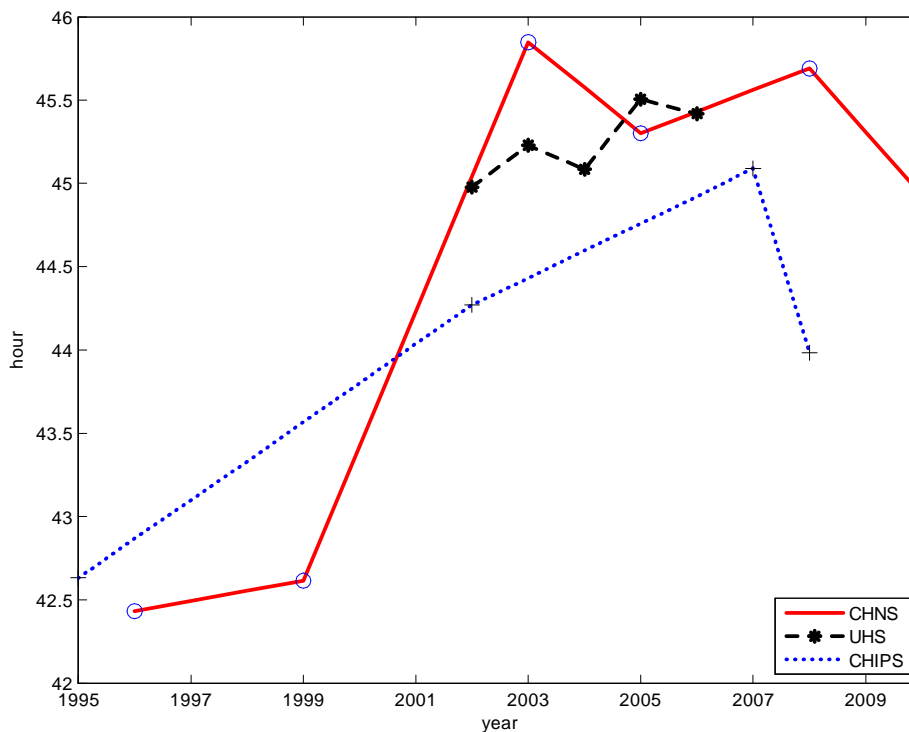
Figure 2: Average Weekly Working Hours in Urban China

Survey (CHIPS) in the same graph.[4] We again see a significant increase in weekly working hours from 1995 to 2007. Finally, the UHS reports the weekly working hours per worker as well, but only for a limited time period from 2002 to 2006. For comparison, we also plot the available data from the UHS in the same figure. The data from the UHS are broadly consistent with the CHNS data on the rising trend even for this limited time period.

2.2   Empirical Analysis Using Micro-level Survey Data

In this section, we provide our empirical analysis of the effect of changes in pension benefits on the labor supply and household saving rate using the CHIPS data.

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[4]Data are from CHIPS 1995, 2002, 2007 and 2008.

2.2.1   The Impact of the Pension Reform on the Labor Supply

We first consider the following regression model for household i to analyze the impact of the changes in pension benefits on the household labor supply:

$$working\ hour_i = \beta_0 + \beta_1 pension_i + \beta_2 X_i + \varepsilon_i \tag{1}$$

where $pension_i$ is a dummy variable that indicates whether household i is enrolled in the pension system or not. X_i is a set of household characteristics including age, age-squared, gender, wage, number of children, family income, spouse's wage, marital status, education, occupation, health status, disability status, ownership of the firm in which the household head is employed, labor contract tenure, industry, and provincial dummies.

We use CHIPS 2002 and 2007 to construct the variables used in the regression. We measure "$working\ hour_i$" by weekly working hours for worker i.[5] We drop working hours < 0 and working hours > 112. *Pension* is a dummy variable for pension status: 1 for having a pension, 0 otherwise.[6][7]

We restrict our sample to those non-government urban workers aged 25–55 for females and 25–60 for males.[8] The reason why we restrict our sample to non-government workers is because the pension reform did not apply to government employees.

Our theory first implies that across individuals, households with pension = 1 tend to work less than households with pension = 0, other things being equal. In other words, our hypothesis 1 is that for a given year t, $\beta_1 < 0$. In addition, as we describe in detail in the Appendix, the pension system in China underwent a significant change

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[5]In CHIPS 2002, we use P147a ("How many working days per month on average? (Excluding weekends)") and P147b("How many hours per working day on average?") to construct the weekly working hours, which is equal to P147b×P147a×(12/365)×7. In CHIPS 2007, we use question C16 ("How many hours on average do you work at your current primary job per week?") to measure working hours.

[6]In CHIPS 2002, there is no direct question about whether a worker has a pension or not. We therefore use A181 ("Contribution to pension fund") to construct the dummy. If A181>0, i.e., the answer is "yes" to A181, then pension = 1. Otherwise, if A181=0, pension = 0. In 2007, we use C03 ("Do you have pension insurance?") to construct the dummy: pension = 1 if an individual chooses either 1) Paid by employer, or 2) Paid by yourself, or 3) Paid by both employer and yourself. But pension = 0 if "none"was chosen.

[7]The reason why we do not use CHIPS 1995 to identify the impact of the pension reforms on the labor supply is because we have very few observations which answered "yes" to question A181. This is evidence that China was still under the "iron rice bowl", and the three-pillar system had not been established as early as 1995.

[8]The average mandatory retirement age for urban workers is 55 for females and 60 for males.

in 2005. The generosity of the pension system was significantly decreased in that year.[9] It thus provides a unique opportunity to conduct a *difference-in-difference* analysis for Equation (1). Compared to workers who do not have a pension (they thus tend to supply more labor), workers with a pension will work significantly fewer hours in 2002. This should be captured in the coefficient $\beta_1^{2002} < 0$. However, in 2007, workers with pension $= 1$, facing much less generous pension benefits in the future, would increase their labor supply to hedge against the change in pension benefits. This implies that the difference in labor supply between workers with and without pensions in 2007 should be smaller compared to the gap in 2002. Therefore, if we run the regression equation (1) for 2002 and 2007 separately, we expect to see $\beta_1^{2002} < \beta_1^{2007} < 0$. And the statistical significance of β_1 might also decrease from 2002 to 2007. This is our hypothesis 2.

We also conduct an alternative empirical specification:

$$\begin{aligned} working\ hour_{it} \ \ = \ \ & \alpha_0 + \alpha_1 year_t + \alpha_2 pension_{it} + \alpha_3 year_t \times pension_{it} \quad (2) \\ & + \alpha_4 X_{it} + \alpha_5 year_t \times X_{it} + \varepsilon_i. \end{aligned}$$

Year_t is a dummy variable which is equal to one if $t = 2007$, and zero if $t = 2002$. Corresponding to hypothesis 1 above, our prediction is $\alpha_2 < 0$, i.e., workers with a pension tend to supply less labor. And probably more importantly, corresponding to hypothesis 2 above, we expect to see $\alpha_3 > 0$. In other words, workers with a pension in 2007 are expected to supply more labor since they face less generous pension benefits in the future.

We also consider two possible alternative explanations for the dramatically rising working hours after 1997 (shown in Figure 2) in our specification. The first one could be that the remaining SOE workers had to take a larger workload after a large-scale layoff of the SOE workers due to the SOE reform the occurred from 1997 to 2001.[10] In addition, another possible alternative explanation could be that the large-scale layoff provides a very strong incentive for the remaining SOE workers to work harder for signalling purposes. We control for those explanations based on the corresponding CHIPS data in the regression.[11]

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[9]As shown in Figure 10, the average replacement ratio decreased from around 64% in 2002 to about 48% in 2007.

[10]See He et al. (2015) for details of the large-scale layoff in the SOE sector and the impact of this layoff on Chinese household savings.

[11]If the first alternative hypothesis ("workload channel") explains a large fraction of the increasing labor supply after the reform, we should expect to see that workers in the firms that have recently changed ownership (so-called "*gai zhi*" in Chinese) would increase their labor supply. We thus control for this by including the "ownership change" dummy variable ($= 1$ if firms changed ownership

Table 1 shows the estimation results for the coefficients of greatest interest, namely β_1, α_2 and α_3, and other selected coefficients. In this table, the first two columns show the results for Equation (1) using the 2002 and 2007 samples separately. $\beta_1^{2002} = -0.982$, meaning that having a pension would reduce an individual's working time by about one hour per week, and $\beta_1^{2007} = -0.238$. We do have $\beta_1^{2002} < \beta_1^{2007} < 0$. And the statistical significance of β_1 does decrease from the 1% level in 2002 to not statistically significant in 2007. Thus hypotheses 1 and 2 are confirmed. In addition, "laid-off before" turns out to be significantly positive. Individuals who had been laid off tend to supply more labor, possibly due to a stronger precautionary motive. However, the workload channel via firm ownership change seems to be not significant.

The third column of Table 1 shows the results for Equation (2): $\alpha_2 = -1.033$ and it is significant at the 1% level. More importantly, the coefficient of the interaction term $\alpha_3 = 0.794$ and it is significant at the 10% level. This shows that individuals did respond to the 2005 pension reform (which further reduced the generosity of the pensions and strengthened the link between the pension benefits and one's own past labor income) by significantly reducing their working time by 0.8 hours per week.

2.2.2 Impact of Pension Reform on the Saving Rate

Next, we would like to empirically identify the impact of the pension reform on the household saving rate. Similar to Equation (1), we consider the following regression model for household i:

$$saving\ rate_i = \beta_0 + \beta_1 pension_i + \beta_2 X_i + \varepsilon_i. \tag{3}$$

We again use CHIPS 2002 and 2007 to construct the saving rate, which is 1 - household consumption/household disposable income. Following Curtis, Lugauer and Mark (2015), we control for gender, age, age-squared, number of children, household income, and education, in X. Besides these, we also control for marital status, share of elderly in the household, firm ownership, working status, province, and household registration ("*hukou*").

Similar to the argument above for the labor supply, our theory implies that workers with a pension tend to save less, other things being equal, i.e., $\beta_1 < 0$. In

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over the past ten years, zero otherwise; the question (P137) is only available for CHIPS 2002) in our regression for 2002. If the second alternative hypothesis ("incentive channel") is the main driving force behind the drastic increase in the labor supply after 1997, we should be able to see that the workers who had been laid off would tend to work longer as a signal to managers, to avoid being laid off. In CHIPS 2002, there is a question (P132b) asking "have you ever been laid off?" We thus include a "laid-off before" dummy variable in our regression for 2002.

Table 1: The Effect of Pension Reform on Labor Supply

Variables	year 2002	year 2007	years 02 & 07
pension	-0.982***	-0.238	-1.033***
	(0.273)	(0.361)	(0.229)
pension×year			0.794*
			(0.441)
male	1.902***	1.694***	1.897***
	(0.255)	(0.263)	(0.217)
age	-0.0931	0.0211	-0.0799
	(0.152)	(0.135)	(0.130)
age^2	0.000585	-0.00117	0.000437
	(0.00183)	(0.00163)	(0.00156)
children	0.967***	0.201	0.648***
	(0.261)	(0.280)	(0.219)
log_wage	0.684***	0.428*	0.444**
	(0.243)	(0.254)	(0.215)
log_HH_income	-0.953***	-0.267	-1.021***
	(0.304)	(0.265)	(0.265)
laid-off before	2.316***		
	(0.383)		
ownership change	0.466		
	(0.297)		
constant	48.42***	40.93***	51.12***
	(5.031)	(4.123)	(4.216)
N	6744	5354	13964
R^2	0.156	0.100	0.126
adj. R^2	0.148	0.089	0.119

Source: CHIPS 2002, 2007.
Note: Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01. The unreported controls include marital status, education level, health status, disability, number of children, firm ownership, occupation, industry, province, and "hukou" dummies.

addition, our DiD approach by comparing 2002 and 2007 also implies that the gap between the saving rate of workers with and without a pension should be smaller (and also might be less statistically significant) in 2007 compared to 2002, i.e., $\beta_1^{2002} < \beta_1^{2007}$.

We also ran an alternative empirical specification to Equation (3):

$$
\begin{aligned}
saving\ rate_{it} \quad = \quad & \alpha_0 + \alpha_1 year_t + \alpha_2 pension_{it} + \alpha_3 year_t \times pension_{it} \qquad (4) \\
& + \alpha_4 X_{it} + \alpha_5 year_t \times X_{it} + \varepsilon_i.
\end{aligned}
$$

We again expect to see $\alpha_2 < 0$ and $\alpha_3 > 0$.

Table 2 presents the results for Equations (3) and (4). In this table, the first two columns show the results for Equation (3) using the 2002 and 2007 samples separately. We find $\beta_1^{2002} = -0.0212$ and it is significant at the 10% level. Having pension benefits would reduce the household saving rate by 2.12% in 2002, other things being equal. However, after the 2005 pension reform, β_1^{2007} is 0.0423. We thus do have $\beta_1^{2002} < \beta_1^{2007}$. And more importantly, β_1^{2007} is not statistically significant. The third column shows the results for Equation (4): $\alpha_2 = -0.0212$ but is not significant, while $\alpha_3 = 0.0618$ and is significant. This means that the 2005 pension reform significantly increased the household saving rate by 6.2%.

In conclusion, our empirical analysis shows that households in urban China did respond to the pension reform by significantly increasing both their labor supply and saving rate. With this strong support from the empirical evidence, we will try to build a theoretical model to analyze an individual's optimal responses to changes in longevity risk and pension benefits, and the aggregate implications of these responses.

3 The Model

In this section, we describe the model economy. The economy is populated with a continuum of many-period lived overlapping generations of individuals. There is a representative firm that uses capital and labor to produce output. The individuals derive utility from consumption and leisure. They supply capital and labor to the firm. The individuals also own the firm. There is a government that imposes payroll taxes to provide social security to retirees. An individual in the economy faces idiosyncratic income risks and lifetime uncertainty. And we assume that the annuity market is missing.

Table 2: The Effect of the Pension Reform on the Savings Rate

Variables	year 2002	year 2007	years 02 & 07
pension	-0.0212*	0.0423	-0.0212
	(0.0123)	(0.0259)	(0.0137)
pension×year			0.0618**
			(0.0262)
male	0.0667***	0.0495**	0.0667***
	(0.0125)	(0.0208)	(0.0139)
age	-0.0156**	0.0143	-0.0156*
	(0.00780)	(0.0112)	(0.00868)
age^2	0.000182**	-0.000191	0.000179*
	(0.0000906)	(0.000132)	(0.000101)
children	-0.0557***	-0.0945***	-0.0557***
	(0.0117)	(0.0216)	(0.0130)
log_HH_income	0.261***	0.571***	0.261***
	(0.0253)	(0.0265)	(0.0282)
constant	-2.240***	-5.853***	-2.240***
	(0.288)	(0.366)	(0.320)
N	4394	2555	6949
R^2	0.149	0.249	0.207
adj. R^2	0.143	0.239	0.200

Source: CHIPS 2002, 2007.

Note: Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01. The unreported controls include marital status, share of elderly in the household, firm ownership, working status, industry, province, and "hukou" dummies.

3.1 Demographic Structure

An individual is born at age $j = 1$ and dies for sure after age J, starting to work from age 1 and retiring at J_R. From age $j - 1$ to j, each individual faces an age-dependent conditional survival probability ψ_j. Therefore, the unconditional survival probability up to age j is $\prod_{i=1}^{j} \psi_i$. The population in the economy grows exogenously at a rate $n > 0$.

Given this information, the fraction of individuals in the population of age j μ_j is

$$\mu_j = \frac{\psi_j}{1 + n} \mu_{j-1} \tag{5}$$

with $\sum_{j=1}^{J} \mu_j = 1$.

3.2 Preferences

An individual maximizes expected, discounted lifetime utility as follows:

$$E \left\{ \sum_{j=1}^{J} \beta^{j-1} \left(\prod_{i=1}^{j} \psi_i \right) u\left(c_j, l_j\right) \right\},$$

where c_j represents consumption and l_j denotes leisure at age j.

At any age j, an individual faces the budget constraint

$$c_j + a_{j+1} = (1 + r) a_j + q_j + b_j + beq, \tag{6}$$

where a_{j+1} is the savings for the next period and r is the interest rate. The labor income at age j q_j is

$$q_j = (1 - \tau_{ss}) w \varepsilon_j \eta_j \left(1 - l_j\right),$$

where τ_{ss} is the social security payroll tax, w is the wage rate, ε_j is the deterministic age-dependent productivity at age j, and η_j is a stochastic idiosyncratic income shock that is an AR(1) process with an i.i.d. innovation as follows:

$$\eta_j = \rho \eta_{j-1} + \xi_j, \xi \sim N(0, \sigma_\xi^2). \tag{7}$$

The social security benefit b_j is determined by

$$b_j = \begin{cases} 0 & \text{if } j < J_R \\ SS_j & \text{if } j \geq J_R \end{cases}.$$

In this economy, the death shock $1-\psi_j$ occurs after an individual makes the decisions as to consumption, asset holding, and labor supply. Therefore, there will be some accidental bequest left over in the economy at the end of each period. We assume that the government collects all these accidental bequests and redistributes them to all the live individuals, in a lump-sum fashion: *beq* describes this lump-sum transfer from the government to individuals.

Although facing a stochastic income risk in every period, an individual is not allowed to borrow, which mimics the severe financial constraint the Chinese consumers face. In other words, we have

$$a_{j+1} \geq 0.$$

There is no private insurance market. Therefore, each individual has to self-insure their risks through asset accumulation. The model thus is in the spirit of the incomplete market model as laid out in Huggett (1993), Aiyagari (1994), and Imrohoroglu, Imrohoroglu, and Joines (1995).

3.3 Social Security

Combining the unique features in the Chinese pension system (for details, see the Appendix), we model the social security system in the economy in the following way. The system is in the spirit of pay-as-you-go (PAYG) in the sense that a working-age individual pays a payroll tax τ_{ss} in exchange for retirement benefits b upon retirement. The defined benefit formula for an retiree of age j who retires at time $t - (j - J_R)$ (and the current calendar time being year t) is given by

$$SS_{j,t} = \theta \left[v\overline{E}_{j,t} + (1-v) Q_j \right], \tag{8}$$

where θ represents the target replacement ratio and

$$\overline{E}_{j,t} = \frac{\sum_{p=1}^{J_R-1} \sum_{\eta} \mu_p w_t \varepsilon_p \eta_p (1-l_p)}{\sum_{p=1}^{J_R-1} \mu_p}$$

captures the *indexed* social average wage at time t. On the other hand, the AIME part of the formula is captured by Q_j, which is given by

$$Q_j = \frac{\sum_{i=1}^{J_R-1} \sum_{\eta} w_{t-j+i} \varepsilon_i \eta_i (1-l_i)}{J_R - 1}.$$

Q_j is the individual's life time average wage. Notice that Q_j is not indexed by age or calendar time, which indicates that once an individual reaches retirement

age, the AIME part of the social security benefits is *fixed* and not indexed at all. The weight υ measures the importance of the indexed social average wage in the determination of the social security benefits. Unlike the government in the US, as described in Imrohoroglu et al. (1995), in this model economy the government can manipulate two policy instruments: θ and υ. Other things being equal, a lower θ can reduce the government's fiscal burden due to the social security. So does a lower υ. Therefore the formula in Equation (8) captures the spirit of the radical pension reforms summarized in Appendix 7.2.

3.4   Production

At each time t, the representative firm produces output Y using aggregate capital K and labor L as inputs according to a constant-returns-to-scale Cobb–Douglas technology

$$Y_t = K_t^\alpha (A_t N_t)^{1-\alpha},$$

where $A_t = A_0(1+g)^t$ represents labor-augmenting technological change at period t and g is the average growth rate of technical change. The capital K follows the law of motion

$$K_{t+1} = (1-\delta)K_t + I_t,$$

where I_t denotes capital investment.

The firm wants to maximize profits, which leads to the following first order conditions that determine the real wage and the net real return to capital.

$$
\begin{aligned}
r_t &= \alpha K_t^{\alpha-1}(A_t N_t)^{1-\alpha} - \delta, &&(9)\\
w_t &= (1-\alpha)\, A_t^{1-\alpha} K_t^\alpha N_t^{-\alpha}.
\end{aligned}
$$

It is easy to show that in this economy, the average growth rate of the real wage is g.

3.5   The Individual's Dynamic Programming Problem

According to the description above, an individual's utility-maximization problem can be expressed as the following (age-dependent) dynamic programming (DP) problem. For an individual of working age ($j = 1, 2, ... J_R - 2$), the DP problem is as follows:

$$V\left(a_j, \eta_j\right) = \max_{a_{j+1}, c_j, l_j} \left\{ u\left(c_j, l_j\right) + \beta \psi_{j+1} E_j V\left(a_{j+1}, \eta_{j+1}\right) \right\} \qquad (10)$$

subject to

$$c_j + a_{j+1} = (1+r)a_j + (1-\tau_{ss})w\varepsilon_j\eta_j(1-l_j) + beq, \tag{11}$$
$$c_j, a_{j+1} \geq 0, a_0 = 0.$$

For an individual prior to retirement $(j = J_R - 1)$, we have

$$V\left(a_j, \eta_j\right) = \max_{a_{j+1}, c_j, l_j} \left\{u\left(c_j, l_j\right) + \beta\psi_{j+1}E_jV\left(a_{j+1}\right)\right\}$$

subject to the same budget constraint as in Equation (11).

However, for a retiree $(j \geq J_R)$, the DP problem changes to

$$V\left(a_j\right) = \max_{a_{j+1}, c_j} \left\{u\left(c_j, 1\right) + \beta\psi_{j+1}E_jV\left(a_{j+1}\right)\right\} \tag{12}$$

subject to

$$c_j + a_{j+1} = (1+r)a_j + SS_j + beq, \tag{13}$$
$$SS_{j,t} = \theta\left[\upsilon\overline{E}_{j,t} + (1-\upsilon)Q_j\right],$$
$$c_j, a_{j+1} \geq 0, a_J = 0.$$

3.6 Stationary Competitive Equilibrium

We define the competitive equilibrium for the model economy in a steady state. The equilibrium concept used here is the recursive competitive equilibrium as defined in Imrohoroglu et al. (1995).

Definition 1 *A stationary competitive equilibrium consists of individuals' decision rules $\left\{C_j\left(a_j, \eta_j\right), A_j\left(a_j, \eta_j\right), L_j\left(a_j, \eta_j\right)\right\}$, the firm's production plans $\{K, N\}$, factor prices $\{w, r\}$, social security benefit SS, lump-sum transfer beq, and age-dependent (but time-invariant) distributions of individuals $\lambda_j(a, \eta)$ for each age $j = 1, 2, ..., J$, such that*

1. *The decision rules solve the individuals' recursive optimization problems described in Section 3.5.*

2. *The factor prices solve the firm's profit-maxmization problem, as in Equation (9).*

3. *The factor markets clear.*

$$K = \sum_j \sum_a \sum_\eta \mu_j \lambda_j(a, \eta) A_j(a, \eta), \tag{14}$$

$$N = \sum_{j=1}^{J_R-1} \sum_a \sum_\eta \mu_j \lambda_j(a, \eta) \varepsilon_j \eta_j (1 - L_j(a, \eta)). \tag{15}$$

4. *The goods market clears.*

5. *The evolution of the distributions follows*

$$\lambda_{j+1}(a', \eta') = \sum_{a:a'=A_j(a_j, \eta_j)} \sum_\eta \lambda_j(a, \eta).$$

6. *The social security system is self-financing.*

$$\tau_{ss} = \frac{\sum_{j=J_R}^{J} \mu_j SS_j}{\sum_{j=1}^{J_R-1} \sum_\eta \mu_j w_j \varepsilon_j \eta_j (1 - l_j)}. \tag{16}$$

7. *The lump-sum transfer is determined by*

$$beq = \sum_j \sum_a \sum_\eta \mu_j \lambda_j(a, \eta)(1 - \psi_{j+1}) A_j(a, \eta).$$

4 Calibration

We calibrate the model to match the Chinese economy before the 1997 pension reform. Our calibration strategy is to choose common parameters that are widely used in the literature and estimate others using micro-level survey data. We calibrate the remaining "deep" preference parameters to match the long-run ratios in the Chinese economy before 1997.

The model period is one year: $j = 1$ corresponds to age 20 in real life, and $J_R = 41$ corresponds to the mandatory retirement age, which is 60. We set $J = 71$, which corresponds to age 90 in real life. The conditional survival probabilities $\{\psi_j\}_{j=1}^{J}$ are taken from the Chinese Census 1995 as shown in Figure 8. We calibrate the population growth rate $n = 2.5\%$ to match the urban old age dependency ratio in 1995. Since an individual enters into the model at age 20, one way to interpret the
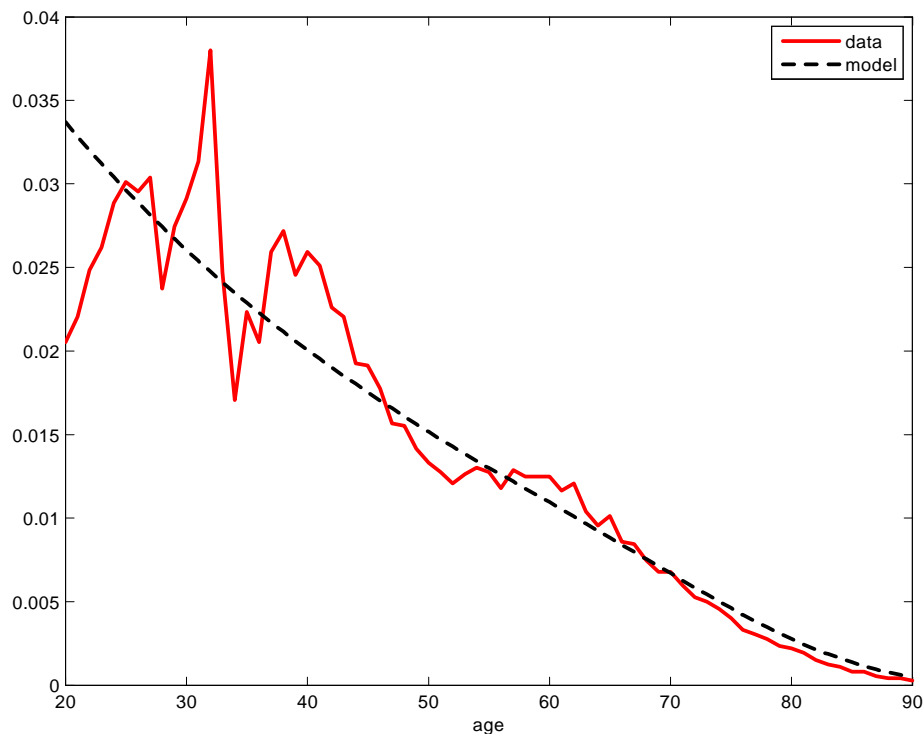
Figure 3: Age Structure in Urban China in 1995: Data vs. Model

population growth rate n here is that it represents the growth rate of the adult urban working age population. It is much higher than China's natural population growth rate because it incorporates the migration to urban areas from rural areas.

The conditional survival probability $\{\psi_j\}_{j=1}^J$ and calibrated population growth rate n jointly determine the age structure in the model as in Equation (5). Figure 3 shows that the benchmark model replicates the data of the age structure in 1995 very well.

On the endowment side, we estimate the age-dependent efficiency profile $\{\varepsilon_j\}_{j=1}^{J_R-1}$ from CHNS data.[12] Figure 4 shows the profile. We estimate the idiosyncratic income shock η from the CHNS data (using four waves of CHNS before 1997, namely, 1989, 1991, 1993 and 1997) following the method outlined in Heathcote, Perri and Violante (2010).[13] The estimation yields $\rho = 0.84$ and $\sigma_\eta^2 = 0.055$. We then discretize the

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[12]See Data Appendix 7.3.3 for details.

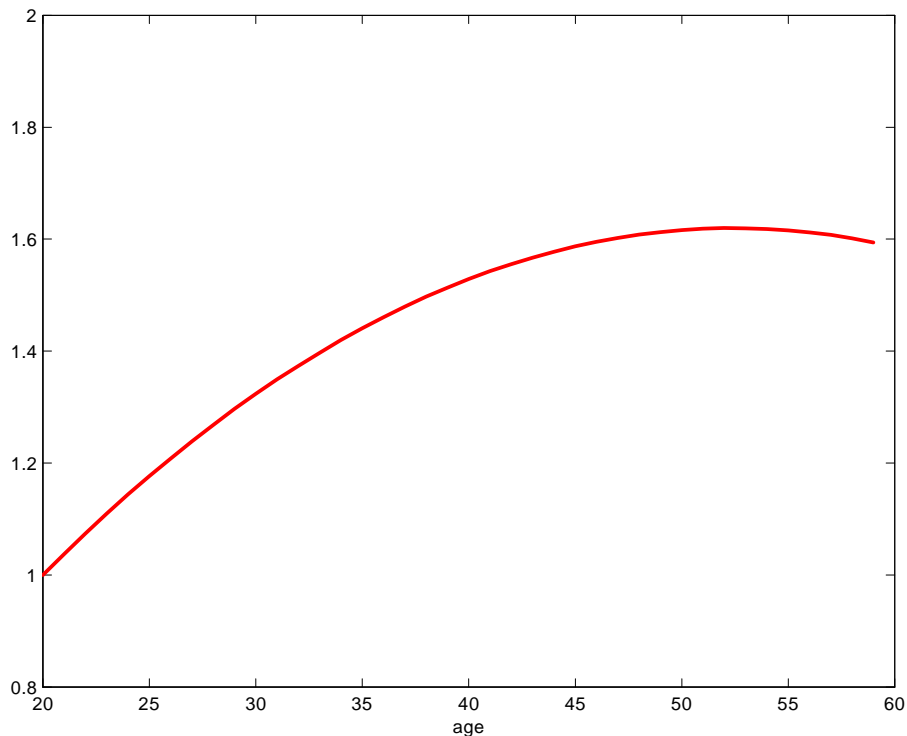[13]See Data Appendix 7.3.3 for details.

Figure 4: Age-Efficiency Profile

AR(1) process into a five-state Markov chain using the method proposed in Tauchen (1986).[14]

On the technology side, we set the capital income share $\alpha = 0.50$ and the depreciation rate $\delta = 10\%$, in order to be consistent with Chinese data.[15] We also set the wage growth rate $g = 5.8\%$, which is taken from Ge and Yang (2014). They use UHS data to estimate that number.

On the pension system, to be consistent with the system before 1997, we set the replacement ratio $\theta = 75\%$, which is about the average replacement ratio before 1997 in Figure 10. We set the degree of indexation in the social security benefit formula $v = 100\%$. The social security payroll tax τ_{ss} is determined in the equilibrium as in

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[14]We ignore the innovation to transitory income shock for simplicity in our quantitative exercises. If we include the estimated innovation to transitory income shock σ_v^2 in the model, our quantitative results in Sections 5.1 and 5.2 are only slightly changed.

[15]The share of capital, in the Chinese data, is in the range from 0.4 to 0.5. And the depreciation rate is in the range from 0.05 to 0.10. See Bai et al. (2006).

Table 3: <u>Model Parameters Taken from the Literature or Estimated from</u> the Data

Description	Parameter	Value
Demographics		
Ages	$j=1, J_R=41, J=71$	age=$20, 60, 90$
Con. survival prob.	$\{\psi_i\}$	Census 1995
Pop. growth rate	n	0.025
Endowment		
Age-efficiency profile	$\{\varepsilon_i\}$	CHNS
Var of innovation to shock	σ_η^2	0.055
Autocorrelation coefficient	ρ	0.84
Technology		
Capital share	α	0.5
Depreciation rate	δ	0.1
Wage growth rate	g	0.058
SS policy		
SS replace. ratio	θ	0.75
SS indexation degree	υ	1

Equation (16).

Table 3 summarizes all parameter values mentioned so far.

The period utility function $u(c, l)$ is taken the CRRA form as follows.

$$u(c, l) = u(c, l) = \frac{[c^\gamma l^{1-\gamma}]^{1-\sigma}}{1-\sigma}.$$

The three "deep" parameters governing preference, namely, β, γ and σ, are calibrated to match three moment conditions simultaneously, i.e., the average household saving rate 15.5% for 1990–1997, the average working hours ratio (as the share of discretionary time) 0.379 in 1996 (data are taken from 1997 CHNS, which asks the weekly working hours in the previous year, i.e., 1996), and the intertemporal elasticity of substitution (IES) 0.5.[16] The calibrated parameters are shown in Table 4.[17]

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[16] 1997 CHNS reports that average weekly hours worked per worker is 42.15 hours. We calculate the share of working hours out of weekly discretionary time to be $42.15/(7 \times 16) = 0.379$.

[17] Notice that given our utility function and calibrated parameter values, the Frisch labor elasticity in the benchmark economy is equal to $\frac{l^*}{n^*} \frac{1-\gamma(1-\sigma)}{\sigma} = 1.02$, which is in the range of plausible values that empirical studies have found.

Table 4: Calibrated Model Parameters

Parameter	Target	Source
Discount rate $\beta = 1.044$	saving rate $= 15.5\%$	1990–97 average
CRRA coeff. $\sigma = 2.8$	IES $= 0.5$	Commonly used
Consum. weight $\gamma = 0.41$	Av. Hours Ratio $= 0.379$	1997 CHNS

5   Quantitative Results

In this section, we show the simulation results of our quantitative exercise.

We do three quantitative experiments here. First, we input the demographic change and pension reforms into the benchmark model. We do so by changing the conditional survival probability $\{\psi_i\}$ from the 1995 level to the 2010 level, as shown in Figure 8, and also changing the replacement rate θ from 75% to 60% and the weight of indexed social average wage υ in the defined benefit formula from 100% to 60%. In other words, the pension reform here is a combination of the 1997 and 2005 reforms.[18] To make the model closer to reality, we also re-estimate the income process for the period after 1997 using the five waves of CHNS data after 1997.[19] Our estimation shows that after 1997, the AR(1) coefficient ρ of the labor income process for urban Chinese workers decreased slightly from 0.84 to 0.83, while the variance of innovation to permanent income shock σ_η^2 increased significantly from 0.055 to 0.075. This reflects the fact that income uncertainty has been increasing after 1997 since the SOE reform broke the "iron rice bowl" for urban workers.[20] Except for implementing these three changes, we keep all other parameters unchanged from Tables 3 and 4 in the scenario. We call this policy experiment the "final steady state." In other words, we are comparing two steady states: the benchmark economy (initial steady state) vs. an economy with the implementation of both rapid aging and a pension reform (the final steady state). We believe that this exercise captures the impact on the benchmark economy of both the rapid aging and the pension reforms from a *long-run* perspective.

However, we also want to decompose the impact from rapid aging and pension reforms separately. Therefore, we conduct two additional experiments. One is only changing θ and υ to 60% and 60% from the benchmark model, while keeping all

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[18]To be more precise, we do not include the "enterprise pension" in the model since its coverage is very limited. Our model does include tiers I and III, which are the two main pillars of the current Chinese urban pension system.

[19]The four waves of CHNS data we used are 2000, 2004, 2006, 2009 and 2011.

[20]Ding and He (2016) also find that the idiosyncratic permanent income shock has increased significantly after the late 1990s, using the UHS data.

Table 5: The Design of Quantitative Policy Experiments

	Demographics	Pension		Income Shock	
	$\{\psi_i\}$	θ	υ	ρ	σ_ξ^2
Initial Steady State	Census 1995	0.75	1	0.84	0.055
I. Pension Reform	Census 1995	0.6	0.6	0.84	0.055
Partial Indexation	Census 1995	0.75	0.6	0.84	0.055
Replacement Ratio Reduction	Census 1995	0.6	1	0.84	0.055
II. Demographic Change	Census 2010	0.75	1	0.84	0.055
III. Final Steady State	Census 2010	0.6	0.6	0.83	0.075

other parameters in Table 3 unchanged. In other words, we isolate the impact of the pension reform. We call this scenario the "pension reform." Another one is only changing $\{\psi_i\}$ from the 1995 level to the 2010 level, while keeping all other parameters unchanged from the benchmark model in Table 3. By doing so, we isolate the effect of the rapid aging. We call this case the "demographic change." Table 5 summarizes the designs of the three experiments.

Before we show the results from these three experiments, we want to emphasize two things. First, the average moment conditions we are using to compare the model performance with the data are all cross-sectional averages (e.g., average working hours ratio). Yet, our model is a life-cycle model. Therefore we need to convert the model-generated life-cycle profiles to cross-sectional ones by appropriately detrending. And we do so. Second, following Imrohoroglu et al. (1995), we adopt two measures of welfare. First, we compute the expected discounted lifetime utility of a newborn by

$$W = \sum_{j=1}^{J} \sum_{a} \sum_{s} \beta^{j-1} \mu_j \lambda_j(a_j, \eta_j) \left(\prod_{i=1}^{j} \psi_i \right) u \left(C_j \left(a_j, \eta_j \right), L_j \left(a_j, \eta_j \right) \right) \qquad (17)$$

under different policy experiments. Second, we use the standard method of consumption equivalence (CEV) to compute what would be the lump-sum compensation in consumption required to make sure a newborn is indifferent between living in the benchmark (initial steady state) economy and living in the economy with the policy change. More specifically, define

$$W^p = \sum_{j=1}^{J} \sum_{a} \sum_{\eta} \beta^{j-1} \mu_j^p \lambda_j^p(a_j, \eta_j) \left(\prod_{i=1}^{j} \psi_i^p \right) u \left(C_j^p \left(a_j, \eta_j \right), L_j^p \left(a_j, \eta_j \right) \right)$$

to be the expected discounted lifetime utility of a newborn under the policy regime

p ($p = I, II, III$ as in Table 5). Then CEV is that Δ such that

$$W^p = \sum_{j=1}^{J} \sum_{a} \sum_{\eta} \beta^{j-1} \mu_j^{bench} \lambda_j^{bench} (a_j, \eta_j) \left(\prod_{i=1}^{j} \psi_i^{bench} \right) u \left((1 + \Delta) C_j^{bench} \left(a_j, \eta_j \right), L_j^{bench} \left(a_j, \eta_j \right) \right)$$

holds. If $\Delta > 0$, policy change p is welfare improving; otherwise, it brings about a welfare loss.[21]

5.1 The Benchmark Scenario

We show the results of the scenario "final steady state," which incorporates the rapid aging and pension reforms *jointly*, in the second column of Table 6.

We see that with both rapid aging and pension reform, in the final steady state, the social security tax rate τ_{ss} decreases from around 14% in the benchmark case to 11% in the "final" scenario due to the dramatically reduced generosity of the pension system. Both the labor supply and the capital-output ratio significantly increase, by 5% and 8.7%, respectively. As a result, output increases 16% from the benchmark level. Consumption also increases by 5.6% in the long run.

Note that by construction, our benchmark model matches the average household saving rate in the initial steady state, which is 15.4% in the model. Table 6 shows that the rapid aging and pension reforms jointly would raise the average saving rate by 4.7% to the level of 20% in the long-run. Comparing the initial and final steady states, the average household saving rate increases about 30.2%.

Finally, the welfare analysis in Table 6 shows that the welfare for the whole economy declines after rapid aging and pension reforms. The expected life-time utility decreases about 7.4%. The CEV measure also shows a similar magnitude of decline.[22]

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[21]Notice that for the policy experiments "final steady state" and "demographic change," the conditional survival probability ψ_j^p and associated age share μ_j^p is different from the ψ_j and μ_j in the benchmark case and the "pension reform" scenario.

[22]Our benchmark model also generates measures of inequality which are reasonably close to the Chinese data. Using the UHS data, Ding and He (2016) report the average Ginis of earnings, disposable income, and total consumption for 1990–1997 to be 0.29, 0.28, and 0.29. Those Ginis in our model are 0.34, 0.32, and 0.21, respectively.

5.2   Decomposition Exercises

5.2.1   Decomposing Rapid Aging and Pension Reforms

To isolate the effects of the rapid aging from those of the pension reforms *separately*, we conduct two decomposition exercises, namely "pension reform" and "demographic change." The results are shown in the third and sixth columns of Table 6.

Compared to the benchmark model, we find that pension reforms increase the labor supply and capital accumulation more significantly than rapid aging does. As shown in Table 7, pension reform alone increases the labor supply and saving rate by about 3% and 29%, respectively, compared to the benchmark case; for demographic change alone, the changes are 3.2% and 3.6%, respectively.

Why do pension reforms have a more significant impact on savings than does rapid aging? To hedge against the declining replacement ratio and gloomy future for one's own old-age support, an individual would like to save more. This mechanism is also reinforced by the significant decline in the payroll tax rate from 13.8% to 9.5% in the scenario, since it increases disposable income. In contrast, rapid aging produces two competing effects: the *composition* vs. the *life expectancy* effects on savings. Rapid aging leads to a shift of age structure in the economy towards the elderly. The elderly work less and save less. Therefore, the composition effect tends to reduce the saving rate. On the other hand, given that the retirement age does not change, which is the case in China, rising life expectancy implies one would have a longer time period living in retirement. Therefore one needs to save more while working to prepare for a longer retirement period. The life expectancy effect thus tends to raise the saving rate. The two competing effects alleviate the impact on the saving rate. In addition, rapid aging also puts pressure on the pension system. The equilibrium social security tax rate has to increase from 13.8% to 16.3% under the "demographic change" scenario, which further reduces the saving rate through the income effect.

The two changes, however, have a quite different implication for the welfare of the whole economy. As shown in Table 6, pension reforms alone bring about a welfare gain compared to the benchmark economy. This welfare gain is equivalent to about 2.3% of the CEV. In contrast, rapid aging alone brings a significant welfare loss, equivalent to 14.3% of the CEV. This welfare loss mainly comes from lower consumption compared to the benchmark level, which is caused by a higher payroll tax rate in the "demographic change" case which significantly lowers an individual's disposable income.[23]

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[23]The welfare loss from the "demographic change" case might also come from the composition effect in the sense that rapid aging shifts the age structure in society towards older people, while

Table 6: Quantitative Results of Three Policy Experiments

| | Initial | Final | Pension Reform | | | Demographic |
			Overall	*Partial Indexation*	*Replace Ratio Reduction*	Change
SS tax rate	13.82%	10.98%	9.47%	11.82%	11.06%	16.28%
Av. hours	0.379	0.398	0.390	0.383	0.385	0.391
K/Y	2.474	2.689	2.585	2.529	2.533	2.532
Saving rate	15.4%	20.0%	19.8%	18.2%	17.3%	15.9%
Output	1.271	1.474	1.372	1.318	1.327	1.303
Consumption	0.691	0.730	0.718	0.704	0.707	0.684
Exp. life U	−63.54	−68.24	−62.50	−62.92	−62.86	−71.09
CEV	−	−9.32%	+2.28%	+1.35%	+1.49%	−14.26%

Table 7: Saving Rate and Labor Supply: Comparing Steady States

	Initial	**Final**	**Difference**	$\triangle\%$
Baseline				
Labor supply	0.379	0.398	0.0192	5.1%
Saving rate	15.4%	20.0%	4.65%	30.2%
Pension reform				
Labor supply	0.379	0.390	0.0112	3.0%
Saving rate	15.4%	19.8%	4.42%	28.7%
Partial indexation				
Labor supply	0.379	0.383	0.0048	1.3%
Saving rate	15.4%	18.2%	2.81%	18.3%
Replacement ratio reduction				
Labor supply	0.379	0.385	0.0068	1.8%
Saving rate	15.4%	17.3%	1.87%	12.2%
Demographic change				
Labor supply	0.379	0.391	0.0121	3.2%
Saving rate	15.4%	15.9%	0.55%	3.6%

5.2.2 Further Decomposing Pension Reforms

In the analysis above, we combined the 1997 and 2005 pension reforms in China into one policy change scenario, by lowering the replacement ratio θ and reducing the degree of indexation ν in the pension benefit formula simultaneously. However, the changes in the two policy instruments might have different impacts on the household saving rate and labor supply. A 100% indexation of pension benefits (i.e., $\nu = 100\%$) and lowering θ from 75% to 60% affects an individual's expectation of future income in retirement. In order to smooth consumption over the life-cycle, that individual has to save more and/or work longer today. This is precisely the consumption smoothing mechanism highlighted in the permanent income hypothesis (PIH) theory. In contrast, given that the replacement ratio is fixed at 75%, reducing the degree of indexation ν from 100% to 60% reduces a retiree's access to risk-sharing from the whole society's redistribution pool.[24] In particular, since China is a fast growing economy, reducing ν limits an individual's ability to share the "growth dividend" since the provincial average wage ($\bar{E}_{j,t}$ in Equation 8) will continuously grow over time while a retiree's life-time average wage (Q_j in Equation 8) remains constant once the individual retires. With limited access to risk-sharing, an individual might tend to save more and/or work longer to hedge against this limitation. In addition, decreasing v from 100% to 60% puts more weight on the individual's *own* life cycle average wage for pension benefits. Therefore it might also strengthen the incentive to work more, since if one works harder during one's working life, the pension benefit will increase. We thus further decompose the impact of these two different aspects of the pension reforms on the household saving rate and labor supply. Table 7 reports the results.

We see that keeping $v = 100\%$, changing the replacement ratio θ from its pre-1997 level of 75% to its post-reform level of 60% ("replacement ratio reduction") alone increases the labor supply slightly in the long run by 1.8%. However, this channel by itself raises the average saving rate by 12.2%, from 15.4% in the initial steady state to 17.3% in the final steady state. On the other hand, keeping $\theta = 75\%$, changing v from its pre-1997 level of 100% to its post-reform level of 60% ("partial indexation") alone increases labor supply in the long-run by 1.3%. However, its impact on the saving rate is significant. The consumption smoothing channel alone raises the average saving rate by 18.3% in the long run.

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their utility is more heavily discounted in calculating social welfare.

[24]We thank Alex Ludwig for pointing out this important difference.

5.2.3 Robustness Check

In this section, we would like to test whether our main results in Sections 5.1 and 5.2 would change significantly or not by further taking out the effect of changes in taxation. In our model, since the pension system is self-financing, the payroll tax rate τ_{ss} has to adjust accordingly in each policy scenario to balance the government's budget constraint. Therefore, as shown in Table 6, the tax rate τ_{ss} varies quite significantly across different cases. One thus might wonder whether the results shown in Tables 6 and 7 might be driven (at least partly) by the endogenous changes in taxation.

To eliminate the possible impact of the changes in taxation, we manually fix the payroll tax rate τ_{ss} to be at the level in the pre-reform benchmark model, i.e., 13.82% for all policy scenarios. To balance the government's budget constraint, we add an additional term, government expenditure G, in the budget constraint to make sure the constraint is adjusted. One way to think about this term is to view it as a lump-sum tax/transfer which would not bring any distortion to the economy via a tax. We then recalibrate the model and redo the exercises in Sections 5.1 and 5.2. To save space, we do not report the results here. But the results show that taking out the distortion from changes in taxation does not significantly change our benchmark results. Demographic change and pension reform together, in the final steady state, increase the household saving rate by 29.7% and the labor supply by 5.04% compared to the initial steady state. Both are very close to the numbers in the baseline model as in Table 7. The decomposition exercises also show similar results compared to the ones in the same table.

5.3 The Importance of Labor Supply

Our quantitative results so far suggest that the pension benefit uncertainty and longevity risk have a much more significant impact on the household saving rate than on the household labor supply. Does this mean the labor supply is not an important instrument to self-insure against those risks? We answer this question by carrying out an additional quantitative experiment. In this experiment, we recalibrate and redo the quantitative exercises in Sections 5.1 and 5.2. However, we fix the labor supply for the working age population (ages 20–59) at its level in the initial steady state, which is 0.379. Therefore, an individual can no longer to use the labor supply to hedge against risks over the life cycle.

Table 8 shows the results of comparing steady states for different scenarios. The first column shows the average saving rate for the initial steady state. The second column shows the ones for the final steady state when both demographic change

Table 8: Saving Rate and the Labor Supply: Comparing Steady States with Fixed Labor Supply

	Initial	Final	Difference	$\triangle\%$	Benchmark
Baseline					
Saving rate	15.5%	22.2%	6.73%	43.25%	30.2%
Pension reform					
Saving rate	15.5%	20.8%	5.28%	33.93%	28.7%
Partial indexation					
Saving rate	15.5%	18.6%	3.14%	20.18%	18.3%
Replacement ratio reduction					
Saving rate	15.5%	17.7%	2.20%	14.14%	12.2%
Demographic change					
Saving rate	15.5%	16.3%	0.84%	5.4%	3.6%

and pension reforms take place and the economy settles down in the long run. The third column is the difference between the two steady states. The fourth column measures the rate of change on the saving rate from the initial to the final steady state. For comparison, we also report the rate of change on the saving rate from the benchmark model (with flexible labor supply) in the fifth column. We see that with a fixed labor supply, an individual has to rely on the adjustment via the saving rate to hedge against longevity risk and changes in pension system. Therefore it is not surprising to see that the model generates much more significant changes in the saving rate than it generates in the benchmark model with flexible labor supply. The average household saving rate increases by 43.3% in the long run compared to 30.2% in the benchmark case. This exercise shows that ignoring the labor supply would lead to a significant over-estimation of the importance of precautionary saving in insuring against uncertainties. Further decomposition exercises also yield a similar message. This is the point made by Low (2005) and Pijoan-Mas (2006). But both papers refer to the self-insurance role of the labor supply's responding to idiosyncratic income shocks, whereas here we find a similar role that the labor supply plays in response to longevity risk and changes to the pension system.

5.4   Changes in the Saving Rate and the Labor Supply Across Ages

Since our model is based on an overlapping generations framework, the exercises in Sections 5.1 and 5.2 can also provide predictions about the changes in the saving

rate and labor supply when responding to rapid aging and pension reforms *across ages*.[25]

Figure 5 show the percentage changes of the model-predicted household saving rate under the three policy change scenarios in Table 5 compared to the saving rate in the pre-reform benchmark economy for working age. Figure 5 shows that for most ages before 35, both the "pension reform" and the "demographic change" cases generate a lower household saving rate compared to the benchmark economy. And the decrease in the saving rate under the "pension reform" scenario is much bigger. This is because the increase in capital accumulation under the "pension reform" is much stronger than that under the "demographic change" case. Therefore the equilibrium interest rate is much lower under the "pension reform" scenario than that for the "demographic change" case. A lower interest rate discourages saving, especially for young ages. However, after age 40, the saving rate starts to increase compared to the saving rate in the benchmark economy, driven by the responses to both longevity risk and pension benefit uncertainty. The changes in savings driven by the pension reform increase dramatically when one is close to retirement age, and they peak at age 59, one year before the mandatory retirement.

Figure 6 reports the changes in the saving rate after age 60 compared to the one in the initial steady state. After retirement at age 60, the increase in the saving rate is mostly driven by the change in household saving behavior responding to rapid aging. Further decomposing the impact from the pension reform shows that the "replacement ratio reduction" has little impact on changes in the saving rate after age 60; while the "partial indexation" drives the increase in the saving rate after age 60, but not as much as the demographic change. The reason is because the "replacement ratio reduction" only affects the magnitude of the pension benefits for retirees. But the pension benefit is not a function of the retiree's age under the scenario (i.e., at time t, no matter what their age is, every retiree receives the same amount of pension benefit). In contrast, "partial indexation" makes the pension benefit to be a decreasing function of the retiree's age. As we analyzed before, "partial indexation" causes retirees to enjoy less the "growth dividend" and hence induces less risk sharing. As a retiree lives longer, the effective replacement ratio for the benefits gets smaller. That is why retirees have to respond by increasing their

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[25]Our pre-reform economy matches the data for the urban household saving rate by ages (e.g., UHS 1995) fairly well and it captures its hump-shape. However, our model fails to capture the "U" shape of the household saving rate by ages after 1997 that is emphasized in Chamon and Prasad (2010) and Yang and Song (2010). A possible reason is that we do not model the dramatic fertility rate change in China due to the "one child policy." Therefore the model cannot capture the so-called dependent children effect for relatively young households that is emphasized in Curtis, Lugauer and Mark (2015).
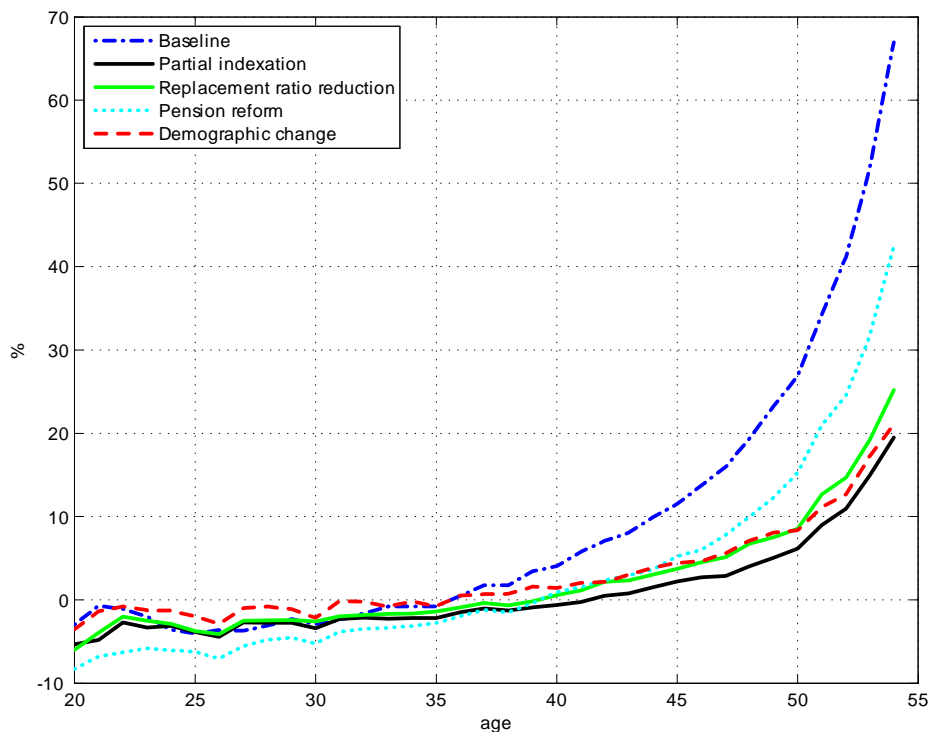
Figure 5: Changes in Savings Rate Compared to Benchmark: Working Age

saving rate with age. In summary, Figures 5 and 6 show that the impact of rapid aging and pension reform on saving rates focuses on relatively old individuals. And the impact increases with age.

Figure 7 shows the percentage change in the labor supply compared to the pre-reform benchmark economy for working age individuals. The labor supply under the "demographic change" case is higher than that in the benchmark economy across the entire working age, which shows that the life expectancy effect dominates the composition effect uniformly across working ages. And the increase is bigger as the age increases. The labor supply under the "pension reform" scenario is lower than that in the benchmark economy until the early 30s. It then starts to exceed the pre-reform level and increases significantly. After age 40, the increase in the labor supply due to the pension reforms even exceeds that due to longevity risk, which confirms the main point made in Erosa, Fuster and Kambourov (2012). They link government programs such as pensions to the labor supply and find that social security rules account for the bulk of cross-country differences in labor supply *late*
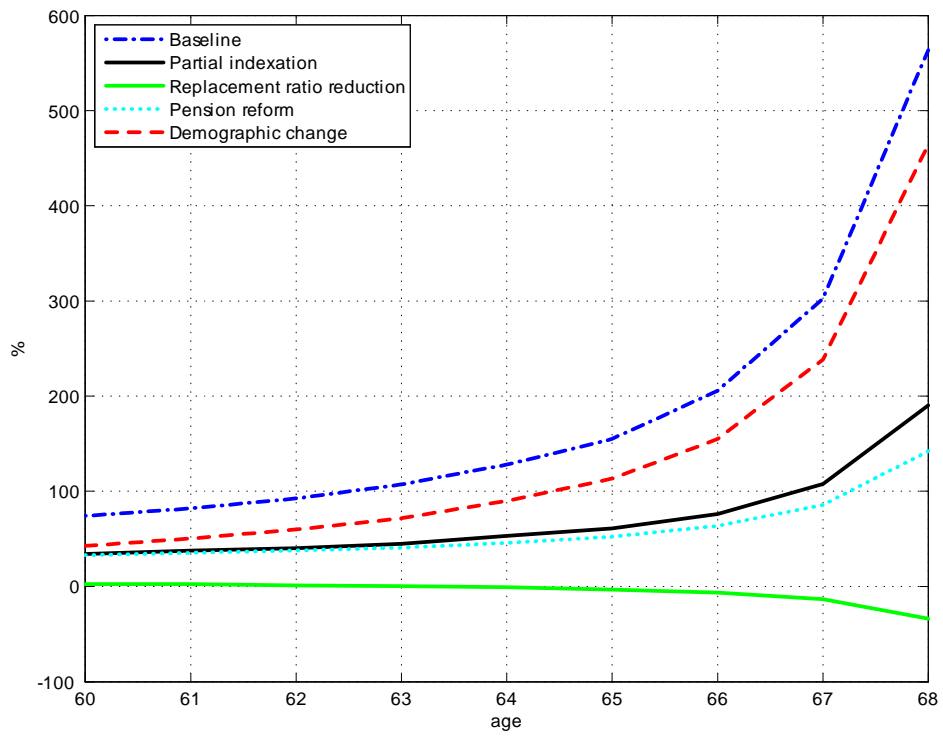
Figure 6: Changes in Savings Rate Compared to Benchmark: Retirement
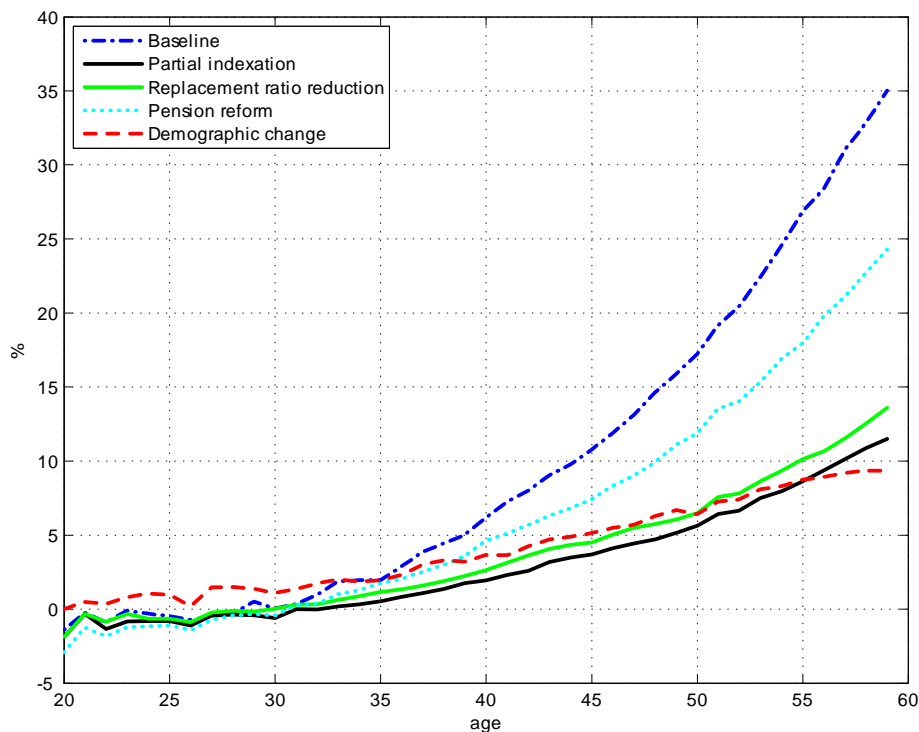
Figure 7: Changes in Labor Supply Compared to Benchmark

in the life cycle.

In conclusion, during the working life, the impact of rapid aging and pension reform on the saving rate and labor supply increases with age. On the other hand, the increase in the saving rate after retirement is dominated by the rapid aging. The changes in the labor supply are limited to the working years, whereas the changes in the saving rate are over the whole life cycle. Furthermore, the increase in the saving rate gets bigger with age. At age 65, the average household saving rate in the baseline case is already 1.5 times higher than its pre-reform level. This is the reason why the pension benefit uncertainty and longevity risk have a much more significant impact on the household saving rate than on the household labor supply.

5.5 The Transition Path

By comparing the initial and final steady states, the quantitative exercises we have done so far answer the first research question raised in the Introduction: how would

changes in longevity risk and pension benefits affect quantitatively households' savings and labor supply on the aggregate level and over the life cycle in the long run? However, in order to answer the second question, to what extent do the rapid demographic changes and pension reforms contribute to the increasing household saving rate and labor supply in urban China after 1997, we cannot take any recent year, e.g., 2010 as a final steady state since it is obviously not a steady state for a fast growing transition economy like China. To more accurately address the question, we are going to assume that the final steady state for the Chinese economy will be reached in the far future. The timing of the final steady state should be far enough so that even the youngest cohort born after the implementation of the pension reform would surely die. We do so to guarantee that the direct impact of the pension reform over time would not be interrupted by the ad hoc choice of timing of the final steady state. We thus pick the transition length to be $T = 90$, so that cohorts born before the 1997 pension reform and 20 cohorts after 1997 would surely die before the final steady state arrives. Therefore the timing of the final steady state would never intervene in the decisions made by all living cohorts for the time period in which we are interested.

We again assume that the Chinese economy was in an initial steady state before the 1997 pension reform, and calibrate the model economy to match the Chinese economy in 1995, as we did in Section 4. We then assume that the pension reform (reducing θ from 75% to 60% and ν from 100% to 60%) is implemented in 1997. Therefore the pension reform is a "once for all" policy change. For the demographic change, we extrapolate the survival probabilities $\{\psi_j\}_{j=1}^J$ on an annual basis from 1995 to 2010 using the Chinese census data. We assume that $\{\psi_j\}_{j=1}^J$ stays constant after 2010 until the final steady state. We put the resulting time-varying survival probabilities $\{\psi_{jt}\}_{j=1}^J\big|_{t=1997}^{1997+T}$ into the model and solve for the transition path from the initial steady state to the final steady state.

Based on the input time-varying survival probabilities $\{\psi_{jt}\}_{j=1}^J\big|_{t=1997}^{1997+T}$, we compute the transition path and truncate the model-generated variables to 1995–2010 and compare them with the data. We also do the decomposition exercises in Section 5.2 over the transition path. Table 9 summarizes the results.

Table 9 shows that the rapid aging and the pension reform together contribute about 55.4% of the increase to 2009 in the aggregate household saving rate from its average level before 1995, as observed in the data. However, their impact on the labor supply is even bigger. Together, they capture about 64% of the increase in the labor supply for the time period 1996–2010 as observed in the data. The decomposition exercises show that the rapid aging alone accounts for about 11.2% of the increase in the household saving rate; while the explanatory power of the pension reform with

Table 9: The Savings Rate and Labor Supply: Transition Path

	Data			Model			Explain
	1995	2009	change	1995	2009	change	
Baseline							
Labor Supply	0.379	0.408	0.029	0.379	0.397	0.019	64.0%
Saving rate	15.5%	28.17%	12.67%	15.4%	22.4%	7.0%	55.4%
Pension reform							
Labor Supply	0.379	0.408	0.029	0.379	0.390	0.012	40.9%
Saving rate	15.5%	28.17%	12.67%	15.4%	20.6%	5.2%	40.6%
Partial indexation							
Labor Supply	0.379	0.408	0.029	0.379	0.384	0.006	19.3%
Saving rate	15.5%	28.17%	12.67%	15.4%	18.4%	3.0%	23.4%
Replacement ratio reduction							
Labor Supply	0.379	0.408	0.029	0.379	0.385	0.007	24.1%
Saving rate	15.5%	28.17%	12.67%	15.4%	17.6%	2.2%	17.2%
Demographic change							
Labor Supply	0.379	0.408	0.029	0.379	0.389	0.011	36.1%
Saving rate	15.5%	28.17%	12.67%	15.4%	16.8%	1.4%	11.2%

regard to the saving rate is much bigger. It alone accounts for about 40.6% of the increase in the household saving rate over 1995–2009. The pension reform alone also accounts for about 41% of the increase in the labor supply from 1996 to 2010; while the demographic change contributes about 36%.

Our empirical analysis in Section 2.2 shows that by reducing the degree of indexation of pension benefits from 100% to 60%, the 2005 pension reform increases the labor supply by 0.794 hour and raises the household saving rate by 6.18%. The "partial indexation" exercise in Table 9, which captures the essential spirit of the 2005 reform, predicts that the labor supply increases by 0.006, which converts to 0.672 hour. On the other hand, the household saving rate increases by 3.0 percentage points in the "partial indexation" scenario. Since our empirical analysis might not perfectly identify the impact of the 2005 reform, and hence those numbers might be the upper bound of the actual impact of the 2005 pension reform on the labor supply and saving rate, our model prediction is reasonably close to the ones obtained in the empirical analysis. We view this as an alternative validation of our theoretical model.

6   Conclusion

This paper studies, both empirically and quantitatively, the roles played by savings and the labor supply as self-insurance channels over one's *life cycle* when one faces not only idiosyncratic income risks, but also changes in longevity risk and pension benefits. We pick China as a case study because over the past two decades, China has undergone a dramatic rapid aging. Meanwhile, the pension system in China was also fundamentally reformed in the late 1990s, becoming significantly less generous and with a tremendous change in the social security benefits formula. We find that both savings and the labor supply are quantitatively important self-insurance channels in responding to changes in longevity risk and pension benefits. The magnitude of the responses increases with age, and the responses via adjustment to savings and labor supply have significant macroeconomic implications.

Applying the model to China, we find that the rapid aging and the pension reforms together contribute 55% of the increase in the household saving rate from 1995 to 2009, and they jointly capture about 64% of the drastic increase in the labor supply for the same period. The exercise shows that the impact of the demographic change and the pension reform on the aggregate household saving rate and labor supply in urban China has an importance of the *first order*. Further decomposition exercises show that the associated changes in pension benefits due to the pension reform alone contributed about 41% of the increase in the household saving rate and 41% of the increase in the labor supply over this time period. At the same time, the rapid aging contributed more to the increase of the labor supply than to that of the saving rate. It alone contributed about 36% of the increase in the labor supply but only 11% of the increase in the household saving rate over that time period.

7   Appendix

7.1   Rapid Aging in China

China has been undergoing a dramatic change in demographic structure over the past two decades. As shown in Figure 8 (data source: Chinese Census 1995 and 2010), the conditional survival probability is uniformly higher in 2010 than in 1995 in urban China. As a consequence, the average life expectancy of the Chinese people increased from 68.55 years in 1990 to 74.83 years in 2010, about 6.3 years over twenty years, which is far more significant than that experienced by other major
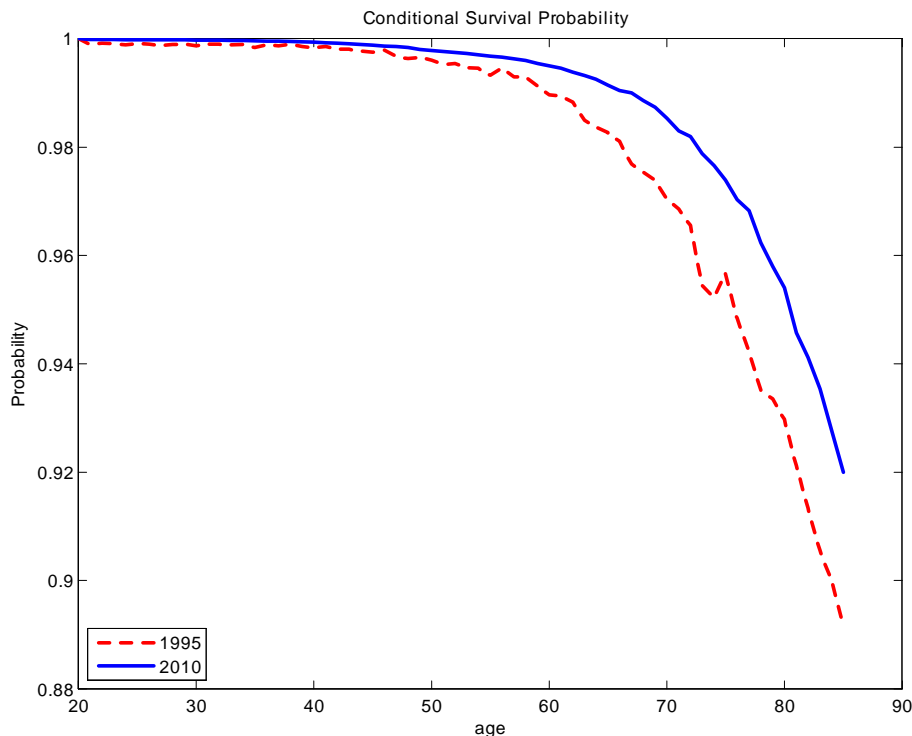
Figure 8: Conditional Survival Probability in Urban China: 1995 vs. 2010

countries.[26] In a fast growing yet still developing country, this rapid aging phenomenon creates a severely increasing burden on old-age support. As shown in Figure 9 (data source: China Statistical Yearbooks), both measures, the population share aged 65 and above, and the old-age dependency ratio, i.e., the ratio of those aged 65 and above to those of working age (16–64), in urban China increased significantly from 1995 to 2011. This trend is expected to continue in the future. According to the UN population database, the share of those aged 60 and above in the population will increase dramatically from 13.9% in 2013 to 32.8% in 2050.

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[26]According to data from the World Health Organization (WHO) and the World Bank, the US, Japan, and Germany experienced an increase in life expectancy of 3.9 years, 4.3 years, and 3.1 years, respectively, for 1960–80 (roughly a similar development stage as China for the 1990–2010 period).
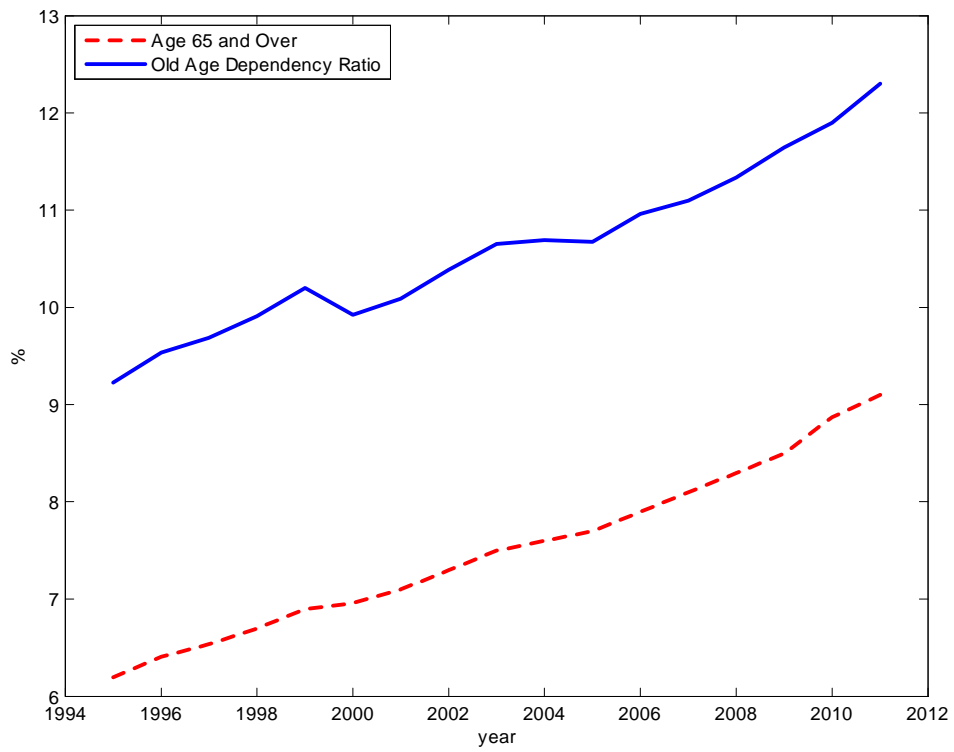
Figure 9: Old Age Dependency Ratio in Urban China

7.2   The Chinese Pension Reforms

Before 1997, the urban pension system was a part of the "iron rice bowl" for SOE workers and government employees.[27] It provided a very generous replacement ratio for retirees, which was equal to roughly 80% of the pre-retirement year annual provincial average wage income in the province where a worker retires (Sin 2005). In exchange for this generous pension system, workers endured low wages. In this sense, the pension system before 1997 can be viewed as a huge pay-as-you-go (PAYG) framework in that the government taxed workers heavily (see Song, Storesletten, Wang and Zilibotti 2015). The State Council Document No. 26—"Decision of the State Council on Establishment of Unified Basic Old Age Insurance System for Enterprise Staff and Workers"—was enacted in 1997. It aimed to radically reform the old pension system and establish a unified national pension system. At the heart of the new system is the so-called "three-pillar" system. The first pillar consists of two parts: a mandatory pay-as-you-go part, which is called the "social pool,", and a mandatory fully funded part, which is called the "individual account." The "social pool" imposes a contribution of 20% of the employee's wages. It ensures that all the employees who had worked and paid the contribution for more than 15 years would receive the basic pension benefit, aiming at a fixed replacement rate at retirement and afterward of 35% of the local average wage. The "individual account" imposes a contribution of 8% of the employee's wage. The target replacement rate from this tier is 24.2%, based on the assumption of 15 years of continuing contribution and a monthly payment formula of dividing the accumulated amount plus investments by 120 after retirement. Therefore the total target replacement ratio for the first pillar is around 60%.[28] The second pillar is a voluntary contribution-based on old-age insurance, that is financed either by the employers or by a mix of employer and employee payments, which is called the "enterprise pension."[29] The third pillar consists of a voluntary complementary private savings account, which has no tax favorable treatment. In this system, pillar I is the basic pillar and pillars II and III are both supplementary (see Salditt, Whiteford, and Adema 2007). Table 10 summarizes the

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[27]The rural population was not covered by the pension system until 1991. Since then, policies have been conducted to extend the coverage to rural areas, but the effort is still limited.

[28]The "individual account" in China remains only nominal in the sense that the government uses the funds in the individual accounts to pay for current retirees' social security benefits. Therefore the current practice of the first pillar in the Chinese pension system can be viewed as an integrated PAYG system in which workers have to contribute 28% of their income, in exchange for receiving social security benefits for retirement with a targeted replacement ratio of 59.2%.

[29]Since the second tier is voluntary and is subject to several regulatory restrictions, the coverage rate of the "enterprise pension" in urban China remains low. See Sladitt et al. (2007).

Table 10: The Three Pillars of the Chinese Pension System

		Contributions	Benefits
Pillar I	Part I (PAYG)	20% of employee's wage	target to 35% average monthly wages in province (if work >15 years)
	Part II (Funded)	8% of employee's wage	Individual account, balance/120 at retirement target to 24.2% average monthly wage in province
Pillar II	(Funded)	Enterprise Pension	Individual account
Pillar III	(Funded)	Employee's voluntary contributions	Individual account
TOTAL		28% employee's wage + voluntary contribution	59.2% of average monthly wages in province + voluntary pensions

Source: Salditt et al. (2007).

"three-pillar" system.

Several other pension reforms followed the initial step in 1997, aiming at improving the three-pillar system and dealing with the emerging pressure from the rapid aging. Among them, perhaps the most important one was carried out by the State Council Document No. 38—"Decision of the State Council on Improvement of Unified Basic Old Age Insurance System for Enterprise Staff and Workers"—in 2005. The major change in the 2005 reform was to adjust the formula for social security benefits. Before the 2005 reform, the benefits were calculated by a multiplication of the target replacement ratio by the local average wage at retirement. The 2005 reform states that the benefits are to be calculated based on a *weighted* average of the local average wage and the retiree's life-cycle average monthly wage, which is similar to the average indexed monthly earnings (AIME) in the US pension system. The weight for the indexed local average wage in the benefit formula varies across provinces, and it is in the range from 40% to 60% (Sin 2005). Since the Chinese economy is a fast growing economy with an average annual growth rate of about 9% over the past two decades, the local average wage follows the trend of economic growth and hence that part of the social security benefits is indexed. However, a retiree's life-cycle average monthly wage is fixed at retirement and hence is not indexed. The change in the benefit formula therefore shifts a retiree's social security benefits from 100% indexation to a *partial indexation*. It is obvious that as a retiree
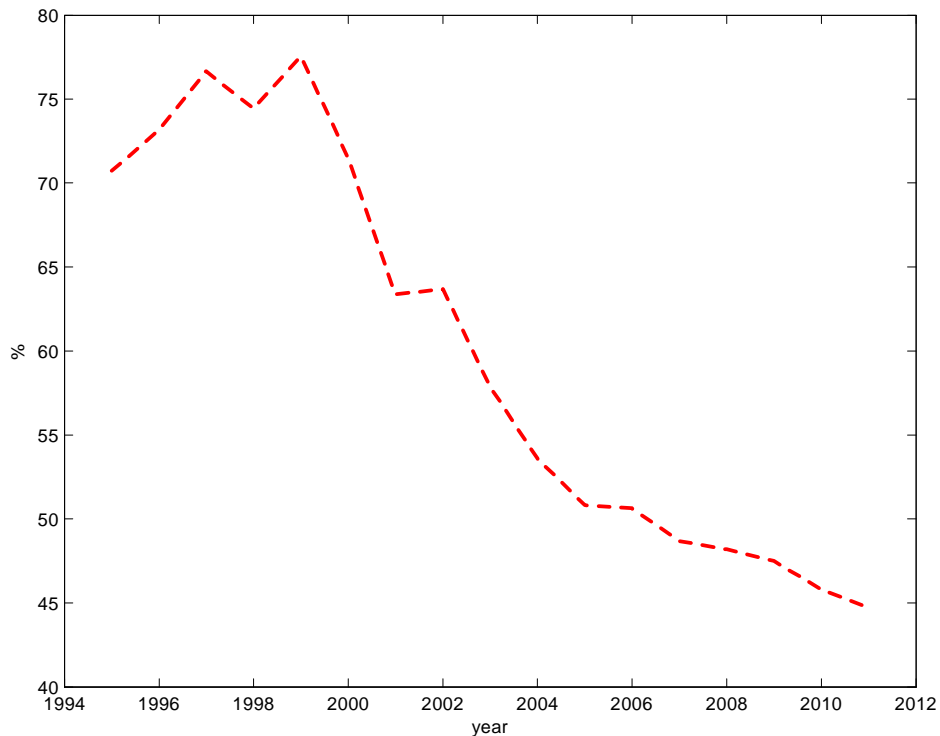
Figure 10: Average National Replacement Ratio in Urban China

lives longer, the effective replacement ratio for benefits gets smaller. By doing so, the government further reduced its social obligation to pension benefits. In Figure 10, we calculate the average national replacement ratio over time by dividing the current year's aggregate social security benefits to all retirees by the current year's aggregate wage income. As shown in the figure, this ratio was close to 80% before 1999.[30] It dramatically decreased to 45% in 2011. And the trend still continues.

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[30]The reason why the effective replacement ratio did not decrease immediately after the 1997 reform is partially due to the time lag of the implementation of the reform, and partially due to the fact that most retirees from 1997 to 1999 are so-called *"old people,"* and they continued to receive their pension entitlements in accordance with the old defined benefit formula, see Sin (2005) for details on the transition of the Chinese pension reform.

7.3 Data

In this appendix, we describe our main data source. We also provide a detailed explanation of the estimation of the age-dependent efficiency profile $\{\varepsilon_j\}_{j=1}^{J_R-1}$ and the idiosyncratic income shock η.

7.3.1 The Urban Household Survey (UHS)

We use three main datasets in the paper. The first one is the annual Urban Household Survey (UHS) conducted by the National Bureau of Statistics (NBS) of China. The UHS is based on a probabilistic sample and stratified design, similar to that used in the Current Population Surveys (CPS) in the US. It provides detailed information about income, consumption expenditures, as well as the demographic characteristics of household members at the household level.

Our access to the UHS data covers the time period from 1986 to 2009. The number of provinces and households covered varies with time. For example, for 2003–2009, we have access to 16 provinces (Beijing, Shanxi, Liaoning, Heilongjiang, Shanghai, Jiangsu, Anhui, Jiangxi, Shandong, Henan, Hubei, Guangdong, Chongqing, Sichuan, Yunnan, Gansu) covering more than 30,000 households.

Following the literature (e.g., Chamon and Prasad 2010), we define the savings of a household as the difference between disposable income and the consumption expenditures of the household.

7.3.2 The Chinese Household Income Project Survey (CHIPS)

Our second household-level dataset is the Chinese Household Income Project (CHIP) surveys. The surveys are conducted by the Chinese Academy of Social Science (CASS) and the NBS through a series of questionnaire-based interviews done in rural and urban areas in China in six different years: 1988, 1995, 2002, 2007, 2008 and 2013. The households in each survey are randomly selected following a strict sampling process so that they are nationally representative. The surveys cover a sample of about 15,000 to 20,000 households in about 10 provinces in China. The surveys contain detailed data on the household's economic status, employment, levels of education, sources of income, compositions, expenditures, and wealth. The CHIP data have been frequently used in the empirical literature.

In the empirical analysis in Section 2, we used the answers to question P147a ("How many working days per month on average? (Excluding weekends)") and P147b ("How many hours per working day on average?") in CHIPS 2002 and question C16 ("How many hours on average do you work at your current primary job per

week?") in CHIPS 2007 to construct the weekly working hours. And we use the answers to question A181 ("Contribution to pension fund") in CHIPS 2002 and question C03 ("Do you have pension insurance?") to construct the pension dummy used in the empirical analysis.

7.3.3 The China Health and Nutrition Survey (CHNS)

Our third dataset is the China Health and Nutrition Survey (CHNS). It is conducted jointly by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. The survey is constructed with a multistage, random cluster design, and it covers nine provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong). By now, the data set has had nine waves: 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. The data cover approximately 4,400 households and 19,400 individuals that are tracked over time. In the 2011 survey, the number of households increased to about 5,700.

We use CHNS to obtain the data of average weekly working hours per worker used in Figure 2. The number of weekly working hours is calculated based on the answers to two questions: "C5: For how many days in a week, on average, did you work?" "C6: For how many hours in a day, on average, did you work?" The average weekly working hour is obtained by $C5 \times C6$. We only focus on males aged 18 to 60 and females aged 18 to 55 in the urban sub-sample.

7.3.4 The Stochastic Income Process

We estimate the stochastic idiosyncratic income risk η based on CHNS data since it is the only panel data in China that allows us to estimate the income process. We restrict the data to only include males aged 25–60 and females aged 25-55 in the urban sub-sample, to be consistent with our empirical analysis in Section 2.2. We provide a detailed procedure for the estimation as follows:

Step 1: Take the logarithm of household labor income. We now observe $Y_{it} = \log(W_{it})$, where W_{it} is the labor income of household i at time t.

Step 2: Run a Mincerian income regression $Y_{it} = f(X_{it}) + y_{it}$, where X_{it} is a set of demographic variables associated with the deterministic component of income, which includes age, age^2, sex dummies, wave dummies, province dummies, and a series of dummies for the household head such as education, occupation, sectors of employment, etc...... Notice that now the age-efficiency profile $\{\varepsilon_j\}_{j=1}^{J_R-1}$ can be easily estimated based on the coefficients of age and age^2.

Step 3: Obtain the residuals y_{it} from the Mincerian regression. Treat the residuals as the sum of permanent and transitory shocks

$$
\begin{aligned}
y_{it} &= \eta_{it} + v_{it}, \\
\eta_{it} &= \rho \eta_{it-1} + \xi_{it},
\end{aligned}
$$

where η_{it} is the permanent shock and v_{it} is the transitory shock. We assume v_{it} and ξ_{it} are i.i.d. and the associated variance is σ_v^2 and σ_ξ^2, respectively. Therefore the variance of η_{it} is $\frac{\sigma_\xi^2}{1-\rho^2}$.

We use the variance and covariance of y_{it} to generate the moments for estimation

$$
\begin{aligned}
var(y_{it}) &= var(\eta_{it}) + var(v_{it}) \\
&= \frac{\sigma_\xi^2}{1-\rho^2} + \sigma_\nu^2,
\end{aligned}
$$

$$
\begin{aligned}
cov(y_{it}, y_{it-s}) &= cov(\eta_{it} + v_{it}, \eta_{it-s} + v_{it-s}) \\
&= cov(\eta_{it}, \eta_{it-s}) \\
&= \rho^s \frac{\sigma_\xi^2}{1-\rho^2}.
\end{aligned}
$$

Therefore, for T waves of data, we have $\frac{T(T+1)}{2}$ moments, which include T variances and $\frac{T(T-1)}{2}$ covariances. For example, for four waves (1989, 1991, 1993, 1997) of the CHNS data, we have four variances: $var(y_{1989})$, $var(y_{1991})$, $var(y_{1993})$, and $var(y_{1997})$ and six covariances: $cov(y_{1989}, y_{1991})$, $cov(y_{1989}, y_{1993})$, $cov(y_{1989}, y_{1997})$, $cov(y_{1991}, y_{1993})$, $cov(y_{1991}, y_{1997})$, and $cov(y_{1993}, y_{1997})$.

Step 4: We apply the equally-weighted minimum distance estimator to estimate the permanent and transitory variances σ_ξ^2, σ_v^2 and the persistency parameter ρ jointly following Heathcote, Storesletten and Violante (2010).

To be consistent with our model specification of the income shock in Equation (7), we ignore σ_v^2 and only use ρ and σ_ξ^2 in the calibration.

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