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

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## Abstract

We study, both empirically and quantitatively, the role of savings and labor supply play as self-insurance channels over the life cycle when one faces not only idiosyncratic income risk, 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 the social security benefits. We find that savings and labor supply both are quantitatively important self-insurance channels in responding to changes in longevity risk and pension benefits. And the responses via adjustment to savings and labor supply have a significant macroeconomic implication.

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Applying the model to China, we find that the rapid aging and the pension reform together contribute 55% of the increase in household saving rate from 1995 to 2009 and they jointly capture about 64% of the drastic increase in labor supply for the same period.

*JEL classifications:* E21, E65, H55

*Keywords:* Demographic Change, Pension System, Saving, Labor Supply, Life Cycle, Heterogeneity Agent Model

# 1 Introduction

Since Aiyagari's path-breaking work (Aiyagari 1994), saving has been recongnized as an important instrument to self insure against idiosyncratic income shock. Labor supply, as another instrument to self insure against idiosyncratic income shock, 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 data. Flexibility of working hours allows individuals to react to income shocks by changing hours of work, and thus reducing the cost of uncertainty. Pijoan-Mas (2006) also highlights the self-insurance channel of labor supply and shows that labor supply is at least as important as savings when it comes to the instruments to insure against income risk.

This paper studies, both empirically and quantitatively, the role of savings and labor supply play as self-insurance channels over the *life cycle* when one faces not only idiosyncratic income risk, 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 pension benefit is linked to an individual's average (life-cycle) wage (e.g., 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 link of one's working age income to her retirement benefit extends the idiosyncratic income shocks that she faces during working age to retirement period.To hedge against the increase in income shocks during the retirement period, one could start to save more and/or increases labor supply during her working age. On the other hand, changes in pension benefits via reducing generosity of pension system (i.e., replacement ratio) could also affect household's savings and labor supply due to consumption smoothing motive. A lower replacement ratio would reduce the available pension wealth after the retirement and hence would encourage an individual increases savings during her working age.

Empirical literature such as 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 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 labor supply and savings. An increase in longevity would allow an individual live a longer time during retirement period. In order to prepare for that, one could increase savings and/or labor supply during her working age to effectively insure against the change in longevity risk. We call this channel *life expectancy* effect (see Bloom et al. 2007).

By putting idiosyncratic income risk, longevity risk and uncentainties about pension system together, and allow both savings and labor supply to insure against those risks, this paper provides a comprehensive view on how an individual responses to those risks and uncertainties over her life cycle and investigates the aggregate implications of those responses. This is the main contribution of the 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 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 it provides an ideal "natural experiment" to test the impacts of rapid aging and pension reform on savings and labor supply, both on household and aggregate levels. The first research question we ask is: how would changes in longevity risk and pension benefits, such as the ones that Chinese has experienced, affect qutitatively households' saving and labor supply behavior on aggregate level and over life cycle in the long run? In addition, as shown in more details in Section 2, both average household saving rate and weekly working hours per worker has been increasing significantly in urban China since 1997. We therefore ask a further and specific question: to what extent do the rapid demographic change and the pension reforms mentioned above contribute to the increasing household saving rate and labor supply in urban China after 1997?

To answer the quantitative questions raised above, we first provide an empirical analysis showing that the Chinese pension reform indeed had an impact on saving rate and labor supply on household level using data from Chinese Household Income Project Survey (CHIPS). We use 2005 Chinese pension reform (see details in 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. And households respond to 2005 pension reform by increasing their savings and labor supply in response to the reduction of generosity of pension system. In addition, our empirical analysis shows that the impact of pension reform is more significant on saving rate than on labor supply.

Motivated by our empirical evidence, we then develop a large-scale (70 period) heterogenous 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 risk up to retirement and a non-borrowing constraint. She has to make decisions on consumption, asset holding and labor supply. We calibrate the model to match the Chinese economy before the rapid aging and pension reform 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 how an individual responses to those exogenous changes in longevity risk and pension benefits and investigate the aggregate implications of those individual responses in the long-run. In addition, we also input demographic change in China on the annual base, together with a carefully modeled "once-for-all" pension reform into the model and solve it as a transition path, to investigate the *short-run* impact of rapid aging and pension reform on our interested variables.

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

To highlight the importance of labor supply as a self-insurance channel in response to longevity risk and pension benefit uncertainties, 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 52% in the long-run compared to 30.2% in the benchmark case. This exercise shows that ignoring labor supply would lead to a significant overestimation of the importance of precuationary savings in insuring against uncertainities over life cycle, not only for idiosyncratic income shocks as emphasized by Low (2005) and Pijoan-Mas (2006), but also for longevity risk and pension benefit uncertainties.

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

To what extent that these two self-insurance channels can help to explain the rising household saving rate and labor supply in urban China after 1997? Data show that aggregate household saving rate increased 12.7 percentage from 15.5% which is the average for 1990-1997 to 28.2% in 2009. And 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 contributes about 41% of the increase in 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 labor supply than 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 percentage of the increase in household saving rate from 1995 to 1999 and 64 percentage of the increase in labor supply from 1996 to 2010. The exercise shows that the impact of demographic change and pension reform on aggregate household saving rate and labor supply in urban China

is on the *first order* importance.

This paper is related to several strands of literature. First of all, empirical literature on the impact of demographic change on aggregate saving behaviors finds mixed evidence on the importance of demographic change on aggregate saving rate, from only a modest contribution (Deaton and Paxson 2000) to significantly large (Bloom, Canning and Graham 2003 and Bloom et al. 2007). We also quantify the importance of the rapid aging on household saving rate in the current paper and find that the contribution indeed is modest. This might reflect the fact there are two opposite driving forces are in action in our general equilibrium framework. On 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 demographic change would reduce household saving rate. On the other hand, *life expectancy* effect as mentioned above tends to raise household saving rate. Probably these two contradicting mechanisms offset each other to generate the modest quantitative results.

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

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

Although our paper does not aim to solve the "Chinese saving rate puzzle," it does contribute to understanding why Chinese household saving rate had been rising.[1] Our quantitative exercise shows that the pension reform, which significantly

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[1] For papers specifically target to explain dramatically rising saving rate in China, please see

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 literature on quantifying the effects of China's demographic transition on its household saving rate such as Choukhmane, Coeurdacier and Jin (2014) and Curtis, Lagauer and Mark (2015). Both papers emphasize the importance of declining fertility due to "one child policy" on affecting Chinese households' saving behavior. We complement to their research by focusing on another end of the demographic change spectrum, namely rising life expectancy due to rapid aging. Both papers also abstract the impact of demographic change on aggregate labor supply from the model, which is an important focus of our paper.

This paper is also related to 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 cohort aged 25-29 and by about 2-3 percentage points for cohort aged 50-59. We emphasize the importance of labor supply as another instrument to self-insure against the 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 Chinese economy facing *future* pension reform and demographic transitions. Our focus here is the *current* impacts of the demographic change and pension reforms on household saving rate and labor supply. Put in this way, their paper is a normative one while ours is a positive analysis with a different focus. In addition, in their paper they abstract away idiosyncratic risks, while how an individual uses savings and labor supply to insure against idiosyncratic risks over life cycle is our main focus.

The organization of the rest of the paper is as follows. Section 2 provides stylized facts on the changes in household saving rate and labor supply in urban China and it describes the empirical analysis of the impact of the pension reform on labor supply and household saving rate based on Chinese household survey data. Section 3 describes the model. Section 4 illustrates the calibration of the model economy. Section 5 demonstrates the simulation results after we input rapid aging and the pension reform into the benchmark model. It also conducts several counterfactual experiments. Finally, Section 6 concludes.

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Song and Yang (2010), Chamon and Prasad (2010) and Wei and Zhang (2011).

# 2   Empirical Evidence

In this section, we first provide data describing the evoluation of 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 pension reforms on households' saving behavior and labor supply.

## 2.1   Trend of Household Saving Rate and Labor Supply

What happened to 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 saving rate among all countries. Figure 1 shows the average urban household saving rate for the time period 1990-2009 that we construct from Chinese Urban Household Survey (UHS).[2] As shown in this figure, Chinese urban household saving rate had been fairly stable since 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 about 12.7 percentage points during these fourteen years.

However, a less known fact about China over the past two decades is that 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 the time period 1996-2010 from a micro-level household survey called Chinese Health and Nutrition Survey (CHNS).[3] The panel data structure of CHNS also makes tracking changes of working hours over time more credible. We therefore use the data from CHNS as our main data source for labor supply. The most striking pattern from Figure 2 is that urban workers dramatically increased their labor supply after the late 1990s. 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 CHNS data, we also plot the weekly working hours per worker from Chinese Household Income Project Survey (CHIPS) in the same graph.[4] We see a significant increase in weekly working hours from 1995 to 2007. Finally, 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

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[2]The average household saving rate in the figure is defined as 1 - 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-day per week to five-working-day per week, which was conducted in 1995.

[4]Data are from CHIPS 1995, 2002, 2007 and 2008.
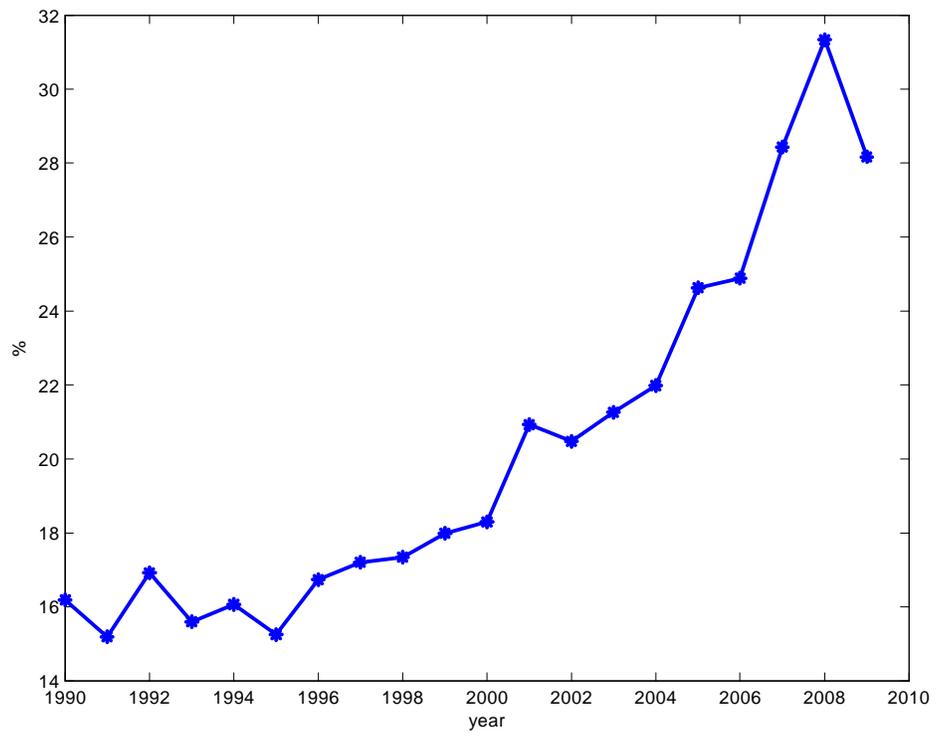
Figure 1: Chinese Urban Household Saving Rate
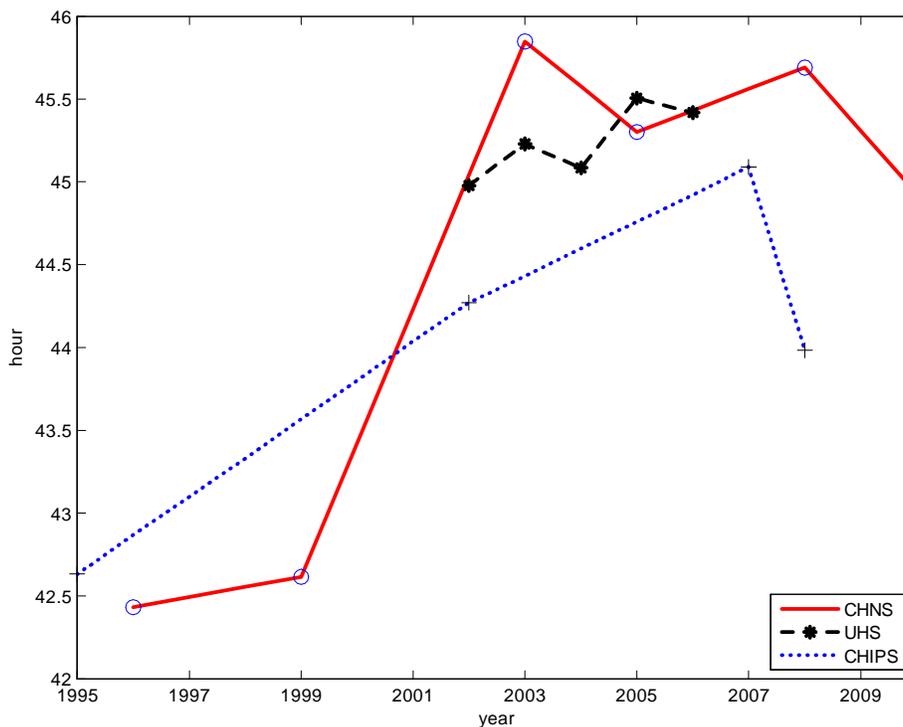
Figure 2: Average Weekly Working Hours in Urban China

plot the available data from UHS in the same figure. The data from UHS is 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 for the effect of changes in pension benefits on labor supply and household saving rate using CHIPS data.

### 2.2.1   Impact of Pension Reform on Labor Supply

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

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

where pension is a dummy variable that indicates whether household $i$ is enrolled in 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 that household head is employed, labor contract tenure, industry and provincial dummies.

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

We restrict our sample to those non-government urban workers aged 25-55 for female and 25-60 for male.[8] The reason why we restrict our sample to only include 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, keep other things equal. In other words, our hypothesis 1 is that for given year $t$, $\beta_1 < 0$. In addition, as we described in details in the appendix, pension system in China had undergone a significant change in 2005. The generosity of pension system has been 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 pension (they thus tend to supply more labor), workers with pension will work significant less hours in 2002. This should be capture in the coefficient $\beta_1^{2002} < 0$. However, in 2007, workers with pension=1, facing much less generous pension benefits in future, would increase their labor supply to hedge against the change in pension benefits. This implies

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

[6]In 2002, there's no direct question about weather a worker has pension or not. We therefore use A181 ("Contribution to pension fund") to construct the dummy. If A181>0, i.e., answer is "yes" to A181, 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. Pension=0 if choose "none."

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

[8]The mandatory retirement age for urban workers is 55 for female and 60 for male.

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

the difference in labor supply between workers with and without pension 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 $\beta_1$ might also decrease from 2002 to 2007. This is our hypothesis 2.

We also conduct an alternative empirical specification to equation (1):

$$working\ hour_i = \alpha_0 + \alpha_1 year + \alpha_2 pension_i + \alpha_3 year \times pension_i + \alpha_4 year \times X_i + \varepsilon_i \quad (2)$$

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

To further clean up our identification, we also consider two possible alternative explanations for dramatically rising working hours after 1997 (shown in Figure 2). The first one could be remaining SOE workers had to take more workload after a large-scale layoff among SOE workers due to SOE reform occurred from 1997 to 2001.[10] In addition, another possible alternative explanation could be that large-scale layoff provides a very strong incentive for remaining SOE workers to work harder for signalling purpose. We also evaluate the validation of these hypotheses based on our CHIPS data in the regression.

If the first alternative hypothesis ("workload channel") explains a large fraction of 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 labor supply. We thus control the "ownership change" dummy variable (=1 if firms changed ownership recently, zero otherwise, the question 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 labor supply after 1997, we should be able to see that the workers who had laid-off experience would tend to work longer to signal to managers to avoid being laid off. In CHIPS 2002, there is a question asking "have you ever had laid-off experience?" We thus control this "lay-off" dummy variable in our regression for 2002. By controlling those two possible alternative channels in regressions, we should be able to obtain a much "cleaner" identification of the impact of pension reforms via $\beta_1$ and $\alpha_3$.

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[10]See He et al. (2014) for details of the large-scale layoff in SOE sector and the impact of this layoff on Chinese household saving behavior.

Table 1 shows the estimation results for our most interested coefficients, namely $\beta_1$, $\alpha_2$ and $\alpha_3$. In this table, first two columns show the results for equation (1) using 2002 and 2007 sample seperately. $\beta_1^{2002} = -0.982$, meaning having pension would reduce an individual's working time by about one hour. And $\beta_1^{2007} = -0.238$. We do have $\beta_1^{2002} < \beta_1^{2007} < 0$. And the statistical significance of $\beta_1$ does decrease from 1% level in 2002 to not statistically significant in 2007. Thus hypotheses 1 and 2 are confirmed. In addition, "lay-off experience" turns out to be significantly positive. Individuals who had lay-off experience tend to supply more labor, possibly due to a stronger precautionary motive. However, 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 1% level. More importantly, the coefficient of the interaction term $\alpha_3 = 0.794$ and it is significant at 10% level. This shows that individuals do response to the 2005 pension reform, which further reduces generosity and strengthens the link of the pension benefits to one's own past labor income, by significantly reducing their working time by 0.8 hour.

### 2.2.2 Impact of Pension Reform on Saving Rate

Next, we would like to empirically identify the impact of pension reform on 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 saving rate, which is 1 - household consumption/household disposable income. Following Curtis, Lugauer and Mark (2015), we control gender, age, age-squared, number of children, household income and education in $X$. Besides those, we also control marital status, share of elderly in the household, firm ownership, working status, province and hukou dummies.

Similar to the argument above for labor supply, our theory implies that workers with pension will tend to save less, keeping other things equal, i.e., $\beta_1 < 0$. In addition, our DiD approach by comparing 2002 and 2007 also implies the gap of saving rate between workers with and without pension should be smaller (also might be less statistically significant) in 2007 compared to 2002, i.e., $\beta_1^{2002} < \beta_1^{2007} < 0$.

Similar to equation (2), we also run an alternative empirical specification to equation (3):

$$saving\ rate_i = \alpha_0 + \alpha_1 year + \alpha_2 pension_i + \alpha_3 year \times pension_i + \alpha_4 year \times X_i + \varepsilon_i \tag{4}$$

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

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) |
| lay-off experience | 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 and province dummies, and hukou

Table 2: The Effect of Pension Reform on Saving 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, province
and hukou dummies.

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

In conclusion, our empirical analysis shows that households do response to the

pension reform by significantly reducing both labor supply and saving rate in China. With the strong support from the empirical evidence, we feel confident to move to the theoretical framework trying to model an individual's optimal response to changes in longevity risk and pension benefits.

# 3    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.

## 3.1    Demographic Structure

An individual is born at age $j = 1$ and dies for sure after age $J$. She starts to work at age 1 and has to retire at $J_R$. From age $j - 1$ to $j$, she faces an age-dependent conditional survival probability $\psi_j$. 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 the information, the fraction of age-$j$ individuals in the population $\mu_j$ is calculated by

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

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

## 3.2    Preference

An individual maximizes her 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 $j$.

In any age $j$, an individual faces the following budget constraint

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

where $a_{j+1}$ is the saving for the next period and $r$ is the interest rate. labor income at age $j$ $q_j$ is determined as follows

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

where $\tau_{ss}$ is the social security payroll tax and $w$ is the wage rate. $\varepsilon_j$ is the deterministic age-dependent productivity at age $j$. $\eta_j$ represents a stochastic idiosyncratic income shock, which is an AR(1) process with an i.i.d. innovation as described below

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

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 consumption, asset holding and labor supply decisions. 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 redistribute back to all alive 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

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

And there is no private insurance market. Therefore each individual has to self-insure the risks she faces 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 Chinese pension system (see details in 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 payroll tax $\tau_{ss}$ in exchange of retirement benefits $b$ when she retires. The defined benefit formula for an age-$j$ retiree who retires at time $t - (j - J_R)$ (and the current calendar time is year $t$) is given by

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

where $\theta$ 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 her social security benefits is *fixed* and not indexed at all. The weight $\upsilon$ measures the importance of indexed social average wage in the determination of social security benefits. Different from the government in the US as described in Imrohoroglu et al. (1995), now in this model economy the government can manipulate two policy instruments $\theta$ and $\upsilon$. Keeping other things equal, a lower $\theta$ can reduce the government's fiscal burden on the social security. So does a lower $\upsilon$. Therefore the formula in equation (8) captures the spirit of radical pension reforms summarized in Appendix 7.2.

## 3.4   Production

In each time $t$, the representative firm produces output $Y$ using aggregate capital $K$ and labor $L$ as inputs according to a constant-return-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 net real return to capital and real wage

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

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

## 3.5   Individual Dynamic Programming Problems

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

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

subject to

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

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

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

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

However, for a retiree, the DP problem changes to

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

subject to

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

## 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 $\left\{ C_j \left( a_j, \eta_j \right), A_j \left( a_j, \eta_j \right), L_j \left( a_j, \eta_j \right) \right\}$, 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 HH's recursive optimization problems described in Section 3.5.*

2. *Factor prices solve firm's profit-maxmization problem as in equation (9).*

3. *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. *Good Market clears.*

5. *The evolution of the distributions follows*

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

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

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

7. *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 Chinese economy before 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. And we calibrate remaining "deep" preference parameters to match the long-run ratios in Chinese economy before 1997.

The model period is one year. $j = 1$ corresponds to age 20 in the real life. $J_R = 41$ corresponds to the mandatory retirement age 60.[11] We set $J = 71$ which corresponds to age 90 in the real life. Conditional survival probability $\{\psi_j\}_{j=1}^{J}$ are taken from 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 population growth rate $n$ here is that it represents the growth rate of adult urban working age population. It is much higher than China's natural population growth rate because it incorporates the migration inflow to urban from rural area.

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 age structure in 1995 very well.

On the endowment side, we estimate 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 $\eta$ from the CHNS data (using four waves of CHNS before 1997, which are 1989, 1991, 1993 and 1997) following the method outlined in Heathcote, Perri and Violante (2010).[13] The estimation obtains $\rho = 0.84$ and $\sigma_\eta^2 = 0.055$. We then discretize the AR(1) process into a five-state Markov chain using the method proposed in Tauchen (1986).[14]

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

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[11] The retirement age is 60 years for men and 50–60 years for women in China, with the general rule that professional and higher rank government officials retire later.

[12] See data appendix 7.3.3 for details.

[13] See data appendix 7.3.3 for details.

[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 $\sigma_v^2$ into the model, our quantitative results in Sections 5.1 and 5.2 are only slightly changed.

[15] Capital share in 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).
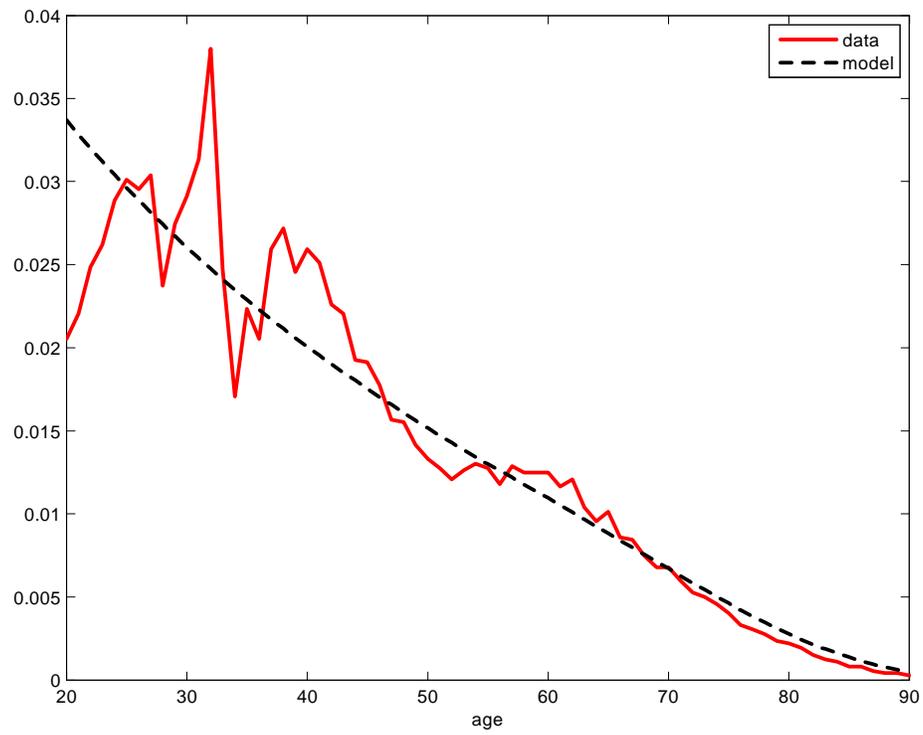
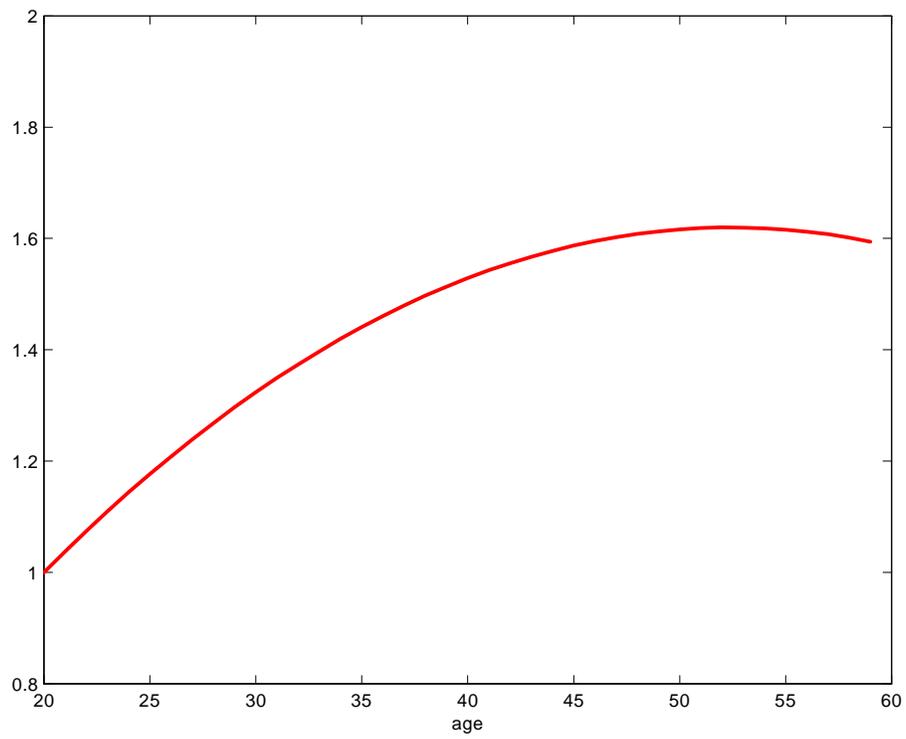Figure 3: Age Structure in Urban China in 1995: Data vs. Model

Figure 4: Age-Efficiency Profile

Table 3: Model Parameters Taken from Literature or Estimated from 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 | $\sigma_\eta^2$ | 0.055 |
| Autocorrelation coefficient | $\rho$ | 0.84 |
| **Technology** | | |
| Capital share | $\alpha$ | 0.5 |
| Depreciation rate | $\delta$ | 0.1 |
| Wage growth rate | $g$ | 0.058 |
| **SS policy** | | |
| SS replace. rate | $\theta$ | 0.75 |
| SS indexation degree | $\upsilon$ | 1 |

On the pension system, to be consistent with the system before 1997, we set replacement ratio $\theta = 75\%$, which is about the average replacement ratio before 1997 in Figure 10. We set the degree of indexation in social security benefit formula $\upsilon = 100\%$. The social security payroll tax $\tau_{ss}$ is determined in the equilibrium as in equation (16).

Table 3 summarizes all the parameter values mentioned so far.

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

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

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

---

[16] 1997 CHNS reports that average weekly hours worked per worker is 42.15 hours. We calculate

| 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 |

Table 4: Calibrated Model Parameters

# 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 conditional survival probability $\{\psi_i\}$ from 1995 level to 2010 level as shown in Figure 8 and also changing replacement rate $\theta$ from 75% to 60% and the weight of indexed social average wage $\upsilon$ in defined benefit formula from 100% to 60%. In other words, the pension reform here is a combination of 1997 and 2005 reforms.[18] To make the model closer to the 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 $\rho$ of labor income process for urban Chinese workers has decreased slightly from 0.84 to 0.83, while the variance of innovation to permanent income shock $\sigma_\eta^2$ has 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. Except these three changes that are implemented, we keep all other parameters unchanged as in Tables 3 and 4 in the scenario. We call this policy experiment "after reform." In other words, we are comparing the two steady states: benchmark economy (initial steady state) vs. an economy with the implementation of both rapid aging and pension reforms (final steady state). We believe that this exercise captures the impact of both rapid aging and pension reforms to the benchmark economy 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

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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, 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 found.

[18]To be more precise, we do not include "enterprise pension" in the model since its coverage is very limited. Our model does include tier I and III which consist 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.

Table 5: The Design of Quantitative Policy Experiments

|  | Demographics | Pension | | Income Shock | |
|---|---|---|---|---|---|
|  | $\{\psi_i\}$ | $\theta$ | $\upsilon$ | $\rho$ | $\sigma_\xi^2$ |
| Initial Steady State | Census 1995 | 0.75 | 1 | 0.84 | 0.055 |
| 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 |
| Demographic Change | Census 2010 | 0.75 | 1 | 0.84 | 0.055 |
| Finial Steady State | Census 2010 | 0.6 | 0.6 | 0.83 | 0.075 |

$\theta$ and $\upsilon$ to 60% and 60% from the benchmark model, while keep all other parameters in Table 3 unchanged. In other words, we isolate the impact from the pension reform. We call this scenario "pension reform." Another one is only changing $\{\psi_i\}$ from 1995 to 2010 level, while keep all other parameters unchanged from the benchmark model in Table 3. By doing so, we isolate the effect of rapid aging. We call this case "demographic change." Table 5 summarizes the design of 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 average (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 new born 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 on consumption required to make sure a new born is indifferent between living in the benchmark economy and living in the economy with the policy change. More specifically, let's define

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

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

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

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

holds. If $\lambda > 0$, policy change $p$ is welfare improving; otherwise, it brings welfare loss.

## 5.1   Benchmark Scenario

We show the results of the scenario "after reform," 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, social security tax rate $\tau_{ss}$ decreases from around 14% in the benchmark case to 11% in the "after reform" scenario due to the dramatic reducing generosity of pension system. Both labor supply and 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 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 state, 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%. CEV measure also shows a similar magnitude of decline.

## 5.2   Decomposition Exercises

### 5.2.1   Decompose Rapid Aging and Pension Reforms

To isolate the effect from the rapid aging and 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 labor supply and capital accumulation more significantly than rapid aging does. As shown in Table 7, pension reform alone increases labor supply and saving rate by about 3% and 29% respectively compared to the benchmark case; while for demographic change lone, the changes are 3.2% and 3.6% respectively.

Why pension reforms have a more significant impact on savings than rapid aging? To hedge against the declining replacement ratio and glooming 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 payroll tax rate from 13.8% to 9.5% since it increases the disposable income. In contrast, rapid aging brings two competing effects: *composition* vs. *life expectancy* effect on savings. Rapid aging leads to a shift of age structure in the economy towards elderly. Elderly work less and save less. Therefore, composition effect tends to reduce 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 she needs to save more during her working age to prepare for a longer retirement period. Life expectancy effect thus tends to raise saving rate. The two competing effects alleviate the impact on saving rate. In addition, rapid aging also puts pressure on pension system. The equilibrium social security tax rate has to increase from 13.8% to 16.3% under the "demographic change" scenario, which reinforces to further reduce saving rate through income effect.

The two changes, however, have a quite different implication on the welfare of the whole economy. As shown in Table 6, pension reforms alone bring a welfare gain compared to the benchmark economy. The welfare gain is equivalent to about 2.3% of CEV. In contrast, rapid aging alone brings a significant welfare loss equivalent to 14.3% of CEV. The welfare loss mainly comes from a lower consumption compared to the benchmark level, which is caused by a higher payroll tax rate under "demographic change" case and hence significantly lowers an individual's disposable income.[20]

### 5.2.2 Further Decompose Pension Reforms

In the analysis above, we combine the 1997 and 2005 pension reforms in China together into one policy change scenario by lowering replacement ratio $\theta$ and reducing the degree of indexation $\nu$ in pension benefit formula simultaneously. However, the changes in two policy instruments might have different impacts on household saving rate and labor supply behavior. Giving 100% indexation of pension benefits (i.e., $\nu = 100\%$), lowering $\theta$ from 75% to 60% affects an individual's expectation about her future income in retirement period. In order to smooth consumption over the life-cycle, she has to save more and/or work longer today. This is precisely a consumption smoothing mechanism highlighted in permanent income hypothesis (PIH) theory. In

---

[20]The welfare loss from "demographic change" case might also come from the composition effect in the sense that rapid aging shifts age structure in the society towards older people, while their utility is more heavily discounted in calculating social welfare.

Table 6: Quantitative Results of Three Policy Experiments

| | Initial | Final | Pension Reform | | | Demographic |
| --- | --- | --- | --- | --- | --- | --- |
| | | | Overall | *Partial Indexation* | *Replcement 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% |
| *Replcement 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% |

contrast, given replacement ratio is fixed at 75%, reducing the degree of indexation $\nu$ from 100% to 60% reduces a retiree's access to risk-sharing from the whole society's redistribution pool. In particular, since China is a fast growing economy, reducing $\nu$ limits an individual's ability to share the "growth dividend" since the provincial average wage will continuously grow over time while a retiree's life-time average wage 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.[21] In addition, decreasing $v$ from 100% to 60% puts more weights on the individual's *own* life cycle average wage for pension benefits. Therefore it might also strengthen the incentive of labor supply since if one works harder in working age, the pension benefit would increase consequently. We thus further decompose the impact of these two different aspects of the pension reforms on household saving rate and labor supply respectively. Table 7 reports the results.

We see that keeping $v = 100\%$, changing replacement ratio $\theta$ from its pre-1997 level of 75% to its post-reform level of 60% ("replacement ratio reduction") alone increases labor supply slightly in the long-run by 1.8%. However, this channel alone raises 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 saving rate is significant. The consumption smoothing channel alone raises average saving rate by 18.3% in the long run.

### 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 from changes in taxation. In our model, since the pension system is self-financing, the payroll tax rate $\tau_{ss}$ has to adjust accordingly in each policy scenario to balance the government's budget constraint. Therefore, as shown in Table 6, tax rate $\tau_{ss}$ varies quite significantly across different cases. One thus might wonder 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 from the changes in taxation, we manually fix the payroll tax rate $\tau_{ss}$ to be at the level in the pre-reform benchmark model, i.e., 13.82% for all policy scenarios summarized in Table 5. 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 $G$

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

term is to view it as a lump-sum tax/transfer which would not bring any distortion to the economy via tax. We then recalibrate the model and redo the exercises in Sections 5.1 and 5.2. To save the space, we would 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 household saving rate by 29.7% and 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 household saving rate than on household labor supply. Does this mean 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 Section 5.1 and 5.2. However, we fix labor supply for 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 labor supply to hedge against risks over her life cycle.

Table 8 shows the results of comparing steady states for different scenarios. The first column shows the results for the initial steady state. The second column shows the results for the final steady state when both demographic change 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 change rate from the initial to final steady state. For comparison, we also report the change rates from the benchmark model (with flexible labor supply) in the fifth column. We see that with fixed labor supply, an individual has to rely on the adjustment via saving rate to hedge against longevity risk and changes in pension system. Therefore it is not surprising to see the model generates much more significant change on saving rate than it generates in the benchmark model. The average household saving rate increases around 52% in the long-run compared to 30.2% in the benchmark case. This exercise shows that ignoring labor supply would lead to a significant overestimation of the importance of precautionary savings in insuring against uncertainities. Further decompostion exercises also show the similar message. This is the point made by Low (2005) and Pijoan-Mas (2006). But both papers refer to the self-insurance role of labor supply responding to idiosyncratic income shocks. While here we find the

Table 8: Saving Rate and 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% |
| *Replcement 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% |

similar role that labor supply plays in response to longevity risk and changes to pension system.

## 5.4  Changes in Saving Rate and 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 prediction on the changes in saving rate and labor supply responding to rapid aging and pension reforms *across ages*.[22]

Figure 5 show the percentage changes of model-predicted household saving rate under three policy change scenarios in Table 5 compared to the saving rate in pre-reform benchmark economy for working age. Figure 5 shows that for most of ages before 35, both "pension reform" and "demographic change" cases generate lower household saving rate compared to the benchmark economy. And the decrease in saving rate under "pension reform" scenario is much bigger. This is because the increase in capital accumulation under "pension reform" is much stronger than that under "demographic change" case. Therefore the equilibrium interest rate is much lower under "pension reform" scenario than that for "demographic change" case.

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[22]Our pre-reform economy matches the data of 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 household saving rate by ages after 1997 as emphasized in Chamon and Prasad (2010) and Yang and Song (2010). A possible reason is that we do not model dramatic fertility rate change in China due to "one child policy." Therefore the model cannot capture the so-called dependent children effect for relatively young households as emphasized in Curtis, Lugauer and Mark (2015).

Lower interest rate discourages saving especially for young ages. However, after age 40, saving rate starts to increase compared to the saving rate in 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 of saving rate afer age 60 compared to the one in the initial steady state. After retirement at age 60, the increase in 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 "replacement ratio reduction" has no impact on changes in saving rate after age 60; while "partial indexation" drives the increase of saving rate after age 60, but not as much as the demographic change. The reson is because "replacement ratio reduction" only affects the magnitude of the pension benefits for retirees. But the pension benefit is not a function of retirees' age (i.e., under "replacement ratio reduction", at time $t$, no matter what age she is, every retiree receives the same amount of pension benefit). In contrast, "partial indexation" makes the pension benefits as a decreasing function of retirees' age. As we analyzed before, "partial indexation" causes retirees enjoy less the "growth dividend" and hence induces less risk-sharing. As a retiree lives longer, the effective replacement ratio for her benefits gets smaller. That's why retirees have to response by increasing their 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 as the age goes up.

Figure 7 shows the percentage change in labor supply compared to the pre-reform benchmark economy for working age individuals. The labor supply under "demographic change" case is higher than that in benchmark economy across the entire working age, which shows that life expectancy effect dominates composition effect uniformly across working age. And the increase is bigger as the age increases. The labor supply under "pension reform" scenario is lower than that in benchmark economy until early 30s. It then starts to exceed the pre-reform level and increases significantly. After age 40, the increase in labor supply due to 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 labor supply and find that social security rules account for the bulk of cross-country differences in labor supply late in the life cycle.

In conclusion, for working age, the impact of rapid aging and pension reform on saving rate and labor supply increases as age increases. On the other hand, the increase in saving rate after retirement is dominated by rapid aging. The changes
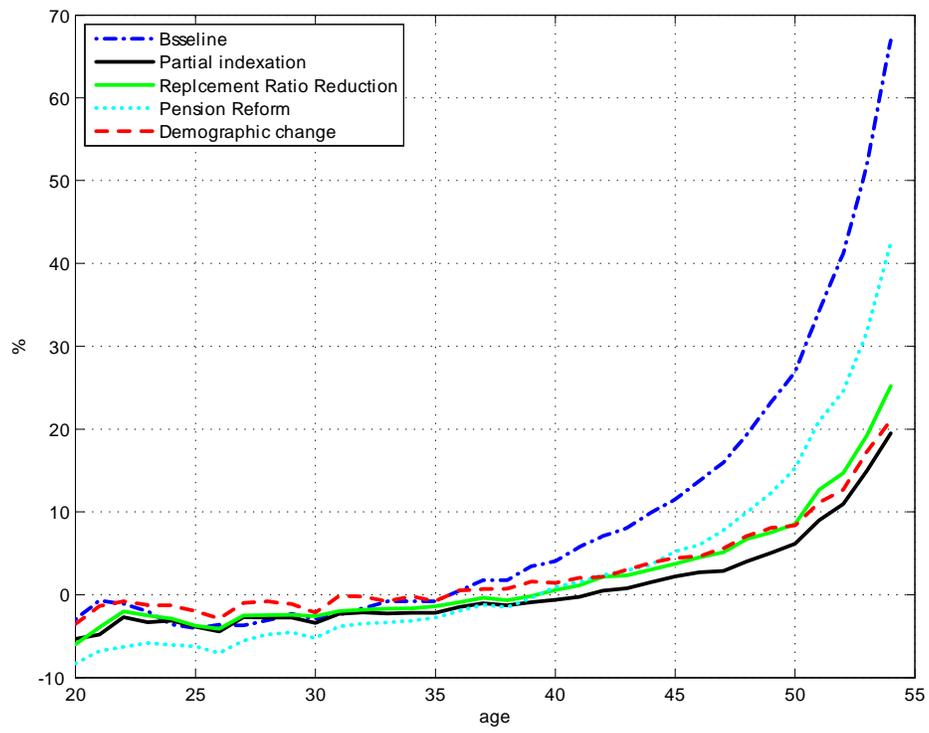
Figure 5: Changes in Saving Rate Compared to Benchmark: Working Age
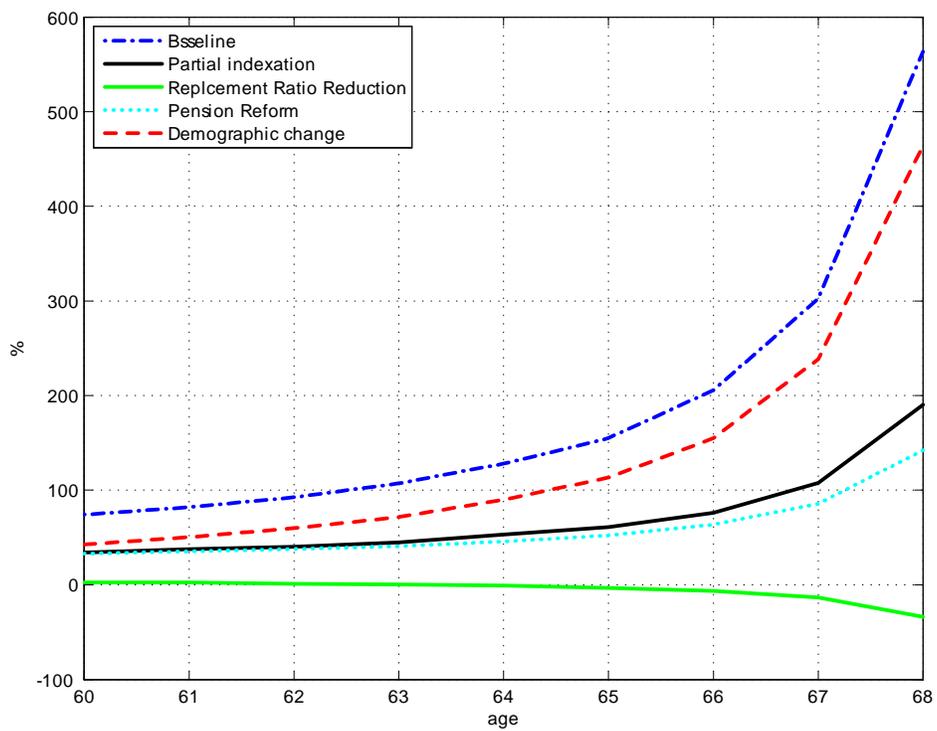
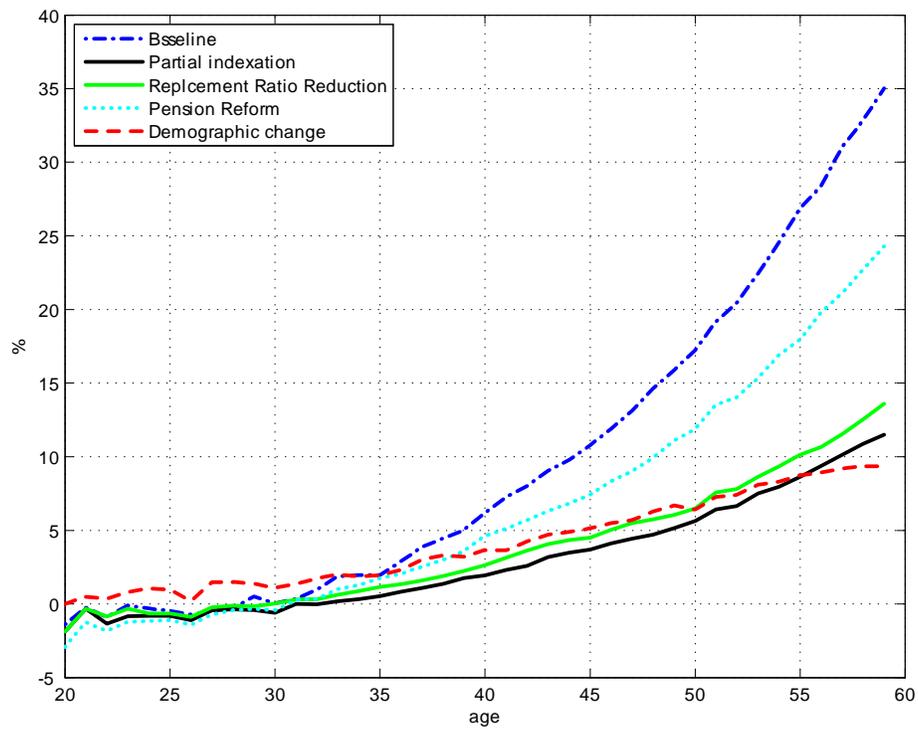Figure 6: Changes in Saving Rate Compared to Benchmark: Retirement

Figure 7: Changes in Labor Supply Compared to Benchmark

in labor supply are limited to working age; while the changes in saving rate are over the whole life cycle. Furthermore, the increase in saving rate gets bigger as the age goes up. At age 65, the average household saving rate in the "after reform" baseline case is already 2.5 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 household saving rate than on household labor supply.

## 5.5  Transition Path

By comparing 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 qutitatively households' saving and labor supply behavior on aggregate level and over life cycle in the long run? However, in order to answer the second question: to what extent do the rapid demographic change and the 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 reach in a 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 reform would die surely. We do so to guarantee 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 $T = 90$ so that for cohorts born after the 1997 pension reform would surely die before the final steady state arrives. Therfore the final steady state would not be affected by the pension reform.

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

Based on inputted time-variant 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 period and compare them with data. We also do the decomposition exercises in Section 5.2

over the transition path. Table 9 summarizes the results.

Table 9 shows that rapid aging and pension reform together contribute about 55.4% of the increase in aggregate household saving rate from its average level before 1995 to 2009 as observed in the data. However, their impact on labor supply is much bigger. Together they capture about 64% of the increase in labor supply for the time period 1996-2010 as observed in the data. Decomposition exercises show that rapid aging alone accounts for about 11.2% of the increase in household saving rate; while the pension reform's explanation power on saving rate is much bigger. It alone accounts for about 40.6% of the increase in household saving rate for 1995-2009. Pension reform alone also accounts for about 41% of the increase in labor supply from 1996 to 2010; while demographic change contributes to about 36%.

Our empirical analysis in Section 2 shows that by reducing the degree of indexation of pension benefits from 100% to 60%, the 2005 pension reform increases labor supply by 0.794 hour and raises 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, household saving rate increases by 3.0% in "partial indexation" scenario. Given 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 pension reform on 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 role of savings and labor supply plays as self-insurance channels over the *life cycle* when one faces not only idiosyncratic income risk, 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 has also been fundamentally reformed in late 1990s, featuring significantly reduced generosity and a tremendous change in the social security benefit formula. This paper quantitatively studies the effects of both demographic change and pension reform on Chinese macro economy, especially focusing on their impact on saving rate and labor supply. We find that savings and labor supply both are quantitatively important self-insurance channels in responding to changes in longevity risk and pension benefits. The magnitude of the responses also changes across ages. And the responses via adjustment to savings and labor supply have a significant macroeconomic implication.

Table 9: Saving Rate and Labor Supply: Transition Path

| | Data | | | Model | | | Explain |
|---|---|---|---|---|---|---|---|
| | 1995 | 2009 | change | 1995 | 2009 | change | |
| Baseline | | | | | | | |
| working hour | 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 | | | | | | | |
| working hour | 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* | | | | | | | |
| working hour | 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% |
| *Replcement Ratio Reduction* | | | | | | | |
| working hour | 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% |
| Demography Change | | | | | | | |
| working hour | 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% |

Applying the model to China, we find that the rapid aging and the pension reform together contribute 55% of the increase in household saving rate from 1995 to 2009 and they jointly capture about 64% of the drastic increase in labor supply for the same period. The exercise shows that the impact of demographic change and pension reform on aggregate household saving rate and labor supply in urban China is on the *first order* importance. Further decomposition exercise shows that the associated changes in pension benefits due to the pension reform alone contribute about 41% of the increase in 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 labor supply than 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.

# 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),

conditional survival probability is uniformly higher in 2010 than 1995 in urban China. As a consequence, the average life expectancy of Chinese people had increased from 68.55 years in 1990 to 74.83 years in 2010, about 6.3 years during twenty years, which is far more significant than the peer countries had experienced.[23] 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 of the population share of aged 65 and above and old-age dependency ratio (the ratio of aged 65 and above to working age (16-64) population) in urban China had been increasing significantly from 1995 to 2011. And the trend is expected to continue in the future. According to UN population database, the share of aged 60 and above in the population will increase dramatically from 13.9% in 2013 to 32.8% in 2050.

## 7.2   Chinese Pension Reforms

Before 1997, urban pension system was a part of "iron rice bowl" for SOE workers and government employees.[24] 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 of this generous pension system, workers bore a low wage. In this sense, the pension system before 1997 can be viewed as a huge pay-as-you-go (PAYG) framework that the government taxes 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, which aimed to radically reform the old pension system and establish a unified national pension system. At the heart of the new system is so-called "three-pillar" system. The first pillar consists of two parts: a mandatory pay-as-you-go pillar which is called "social pool," and a mandatory fully funded pillar which is called "individual account." "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, targeting to a fixed replacement rate at retirement and afterward of 35% of the local average wage. "Individual account" imposes a contribution of 8% of the employee's

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[23]According to data from World Health Organization (WHO) and World Bank, US, Japan and Germany had experienced an increase in life expectancy of 3.9 years, 4.3 years and 3.1 years, respectively, for period 1960-80 (roughly similar development stage as China for 1990-2010 period).

[24]Rural population was not covered by the pension system until 1991. Since then, policies have been conducted to extend the coverage to rural area, but the effort is still limited.
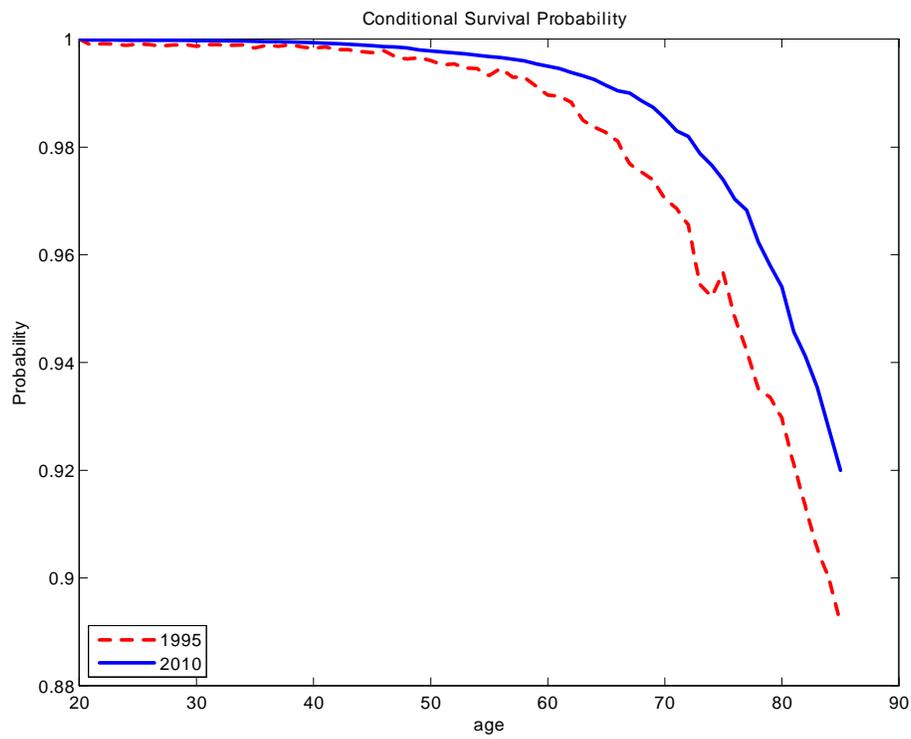
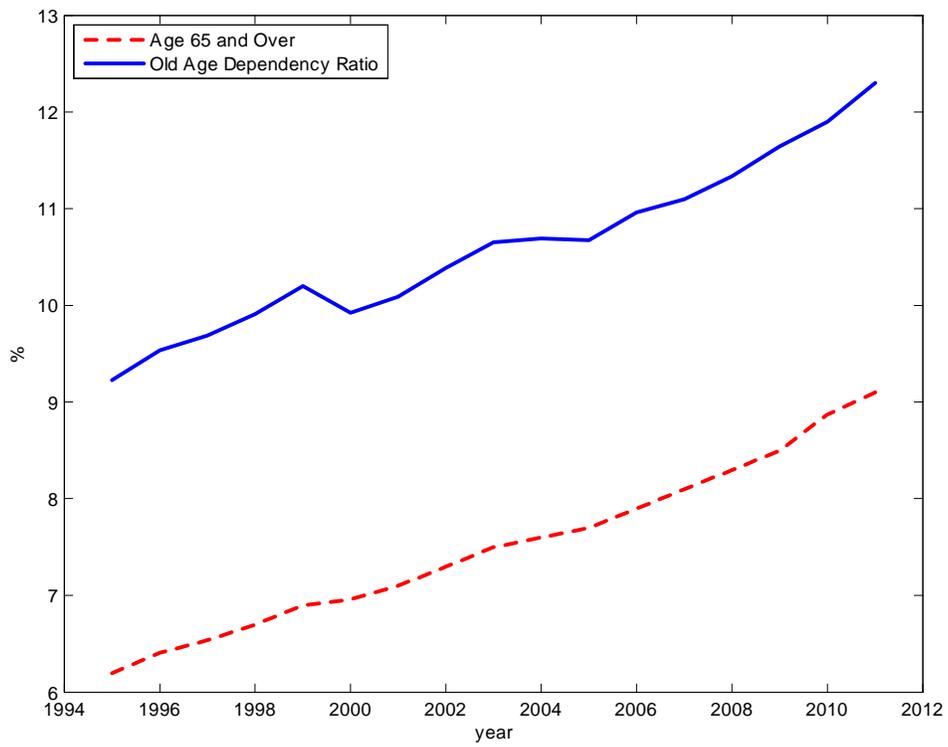Figure 8: Conditional Survival Probability in Urban China: 1995 vs. 2010

Figure 9: Old Age Dependency Ratio in Urban China

Table 10: The Three Pillars of Chinese Pension System

|  |  | Contributions | Benefits |
|---|---|---|---|
| Pillar I | Tier I (PAYG) | 20% of employee's wage | target to 35% average monthly wages in province (if work >15 years) |
|  | Tier 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).

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 the retirement. Therefore the total target replacement ratio for the first pillar is around 60%.[25] The second pillar is a voluntary contribution-based old-age insurance that is financed either by the employers or by a mix of employer and employee payments, which is called "enterprise pension."[26] Finally, 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 tier and pillars II and III are both supplementary (see Salditt, Whiteford, and Adema 2007). Table 10 summarizes the "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

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[25]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 and in exchange of receiving social security benefits for retirement ages with a targeted replacement ratio of 59.2%.

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

Old Age Insurance System for Enterprise Staff and Workers"–in 2005. The major change in the 2005 reform is to adjust the formula for social security benefits. Before the 2005 reform benefits are calculated by the multiplication between the target replacement ratio and the local average wage at the retirement. 2005 reform states that the benefits are calculated based on a *weighted* average of local average wage and the retiree's life-cycle average monthly wage, which is similar to AIME (average indexed monthly earnings) in the US pension system. The weight for indexed local average wage in the benefit formula varies across provinces and it is in the range from 40% to 60% (Sin 2005). Since Chinese economy is a fast growing economy with average annual growth rate at about 9% over the past two decades, the local average wage follows the trend of economic growth and hence that part of social security benefits are indexed. However, a retiree's life-cycle average monthly wage is fixed at the retirement and hence is not indexed. The change of the benefit formula therefore shifts a retiree's social security benefits from 100% indexation to a partial indexation. And it is obvious that as a retiree lives longer, the effective replacement ratio for her benefits gets smaller. By doing so, the government further reduces its social obligation to pension benefits. In Figure 10, we calculate the average national replacement ratio over time by dividing the current year aggregate social security benefits to all retirees to the current year aggregate wage income. As shown in the figure, this ratio was close to 80% before 1999.[27] It dramatically decreased to 45% in 2011. And the trend still continues.

## 7.3   Data

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

### 7.3.1   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

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[27]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 facts 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 Chinese pension reform. Section 5.5 also provides a detailed description of this "grandfathering" of pension reform.
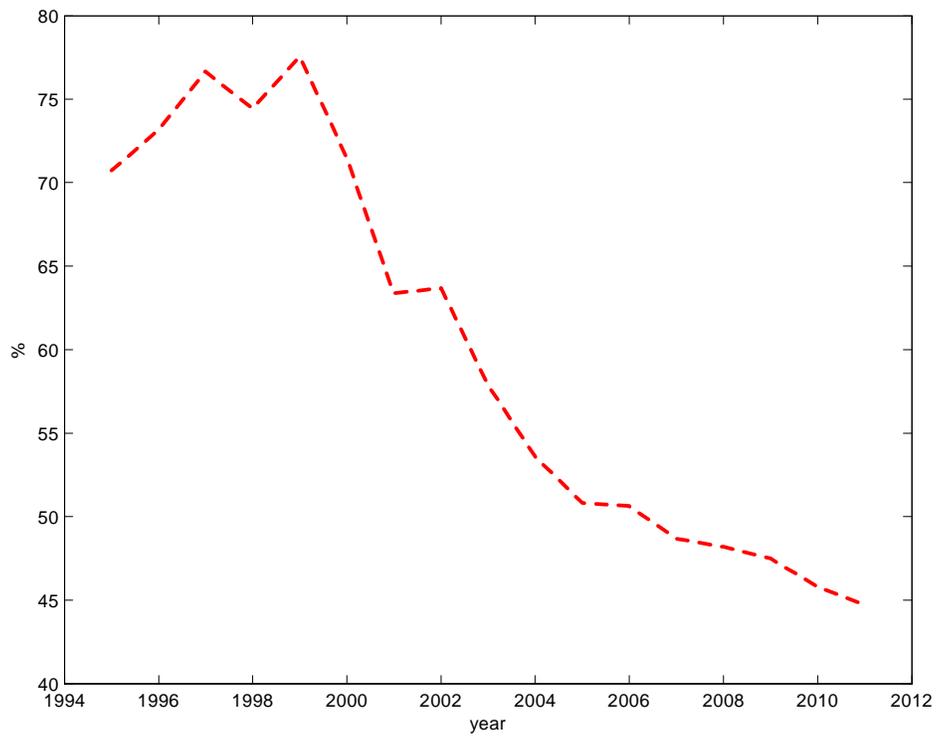
Figure 10: Average National Replacement Ratio in Urban China

the Current Population Surveys (CPS) in the US. It provides detailed information about income, consumption expenditure as well as the demographic characteristics of household members at household level.

Our access to the UHS data covers the time period from 1986 to 2009. The number of provinces and households covered varies over time. For example, for time period 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 30000 households.

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

### 7.3.2 Chinese Household Income Project Survey (CHIPS)

Our second household-level dataset is Chinese Household Income Project (CHIP) surveys. The surveys are conducted by the Chinese Academy of Social Science (CASS) and 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 households' economic status, employment, levels of education, sources of income, household compositions, household expenditures and wealth. The CHIP data have been frequently used in the empirical literature.

In the empirical analysis in Section 2, we use answers to P147a ("How many working days per month on average? (Excluding weekend)") 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 hour. And we use answers to question A181 ("Contribution to pension fund") in CHIPS 2002 and question C03 ("Do you have pension insurance?") to construct pension dummy used in the empirical analysis.

### 7.3.3 China Health and Nutrition Survey (CHNS)

Our third dataset is 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 9 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 2011 survey, the number of households increases to about 5,700.

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

### 7.3.4 Stochastic Income Process

We estimate the stochastic idiosyncratic income risk $\eta$ 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 aged 25-60 male and aged 25-55 female 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 logarithm of household labor income, we now observe $Y_{it} = \log(W_{it})$, where $W_{it}$ is labor income of the 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 include 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 age-efficiency profile $\{\varepsilon_j\}_{j=1}^{J_R-1}$ can be easily estimated based on coefficients of age and age$^2$.

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

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

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

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

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

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

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 4 waves (1989, 1991, 1993, 1997) CHNS data, we have four variances: $var(y_{1989})$, $var(y_{1991})$, $var(y_{1993})$, $var(y_{1997})$ and six covariances: $cov(y_{1989}, y_{1991})$, $cov(y_{1989}, y_{1993})$, $cov(y_{1989}, y_{1997})$, $cov(y_{1991}, y_{1993})$, $cov(y_{1991}, y_{1997})$, $cov(y_{1993}, y_{1997})$.

Step 4: Finally we apply the equally-weighted minimum distance estimator to estimate the permanent and transitory variances $\sigma_\xi^2$, $\sigma_v^2$ and the persistency parameter $\rho$ jointly following Heathcote, Storesletten and Violante (2010).

To be consistent with our model specification of income shock in equation (7), we ignore $\sigma_v^2$ and only use $\rho$ and $\sigma_\xi^2$ in the calibration.

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