Rapid Aging and Pension Reform: The Case of China*

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Abstract

Over the past two decades, China has undergone a dramatic process of rapid aging. Meanwhile, the urban pension system in China has also been fundamentally reformed, 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 urban household saving rate and labor supply. We find that the pension reform is the major driving force behind the drastic increase in labor supply after the late 1990s. The rapid aging and the pension reform together contribute only 9% of the increase in household saving rate from 1995 to 2009. Therefore, both changes seem to *not be* the candidate of main driving force behind dramatic rising urban household saving rate in China after 1995. The general message this paper tries to push is

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that change in pension scheme might be an important determinant of changes in labor supply.

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1 Introduction

This paper studies how demographic change and pension reform would affect individuals' saving and labor supply behavior. And through their impact on individuals' behavior, how would they, *jointly and separately*, change the whole economy. We pick China as a case study or "natural experiment" because China has undergone a rapid aging and a radical pension reform simultaneously over the past two decades. Therefore it provides a natural platform to test our theory.

China has been undergoing a very rapid economic growth over the past three decades. Accompanying with this growth miracle, a well known fact is that the saving rate in China has also been rising very dramatically to make the country rank the highest in terms of saving rate among all countries. Figure 1 shows the urban household saving rate for the time period 1990-2009 that we construct from Chinese Urban Household Survey (UHS).[1] 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 16.6%, the saving rate had increased about 12 percentage points during these fourteen years.

However, a less known fact about China over the past two decades is Chinese also worked much harder 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.[2] Our data again come from a micro-level household survey called Chinese Health and Nutrition Survey (CHNS). UHS also reports the data, but only for a limited time period from 2002 to 2006. For comparison, we also plot the available data from UHS in the same figure. Apparently, it is broadly consistent with the CHNS data. The most striking pattern from Figure 2 is urban workers dramatically increased their

[1] See the data appendix for details.

[2] We start our data 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.

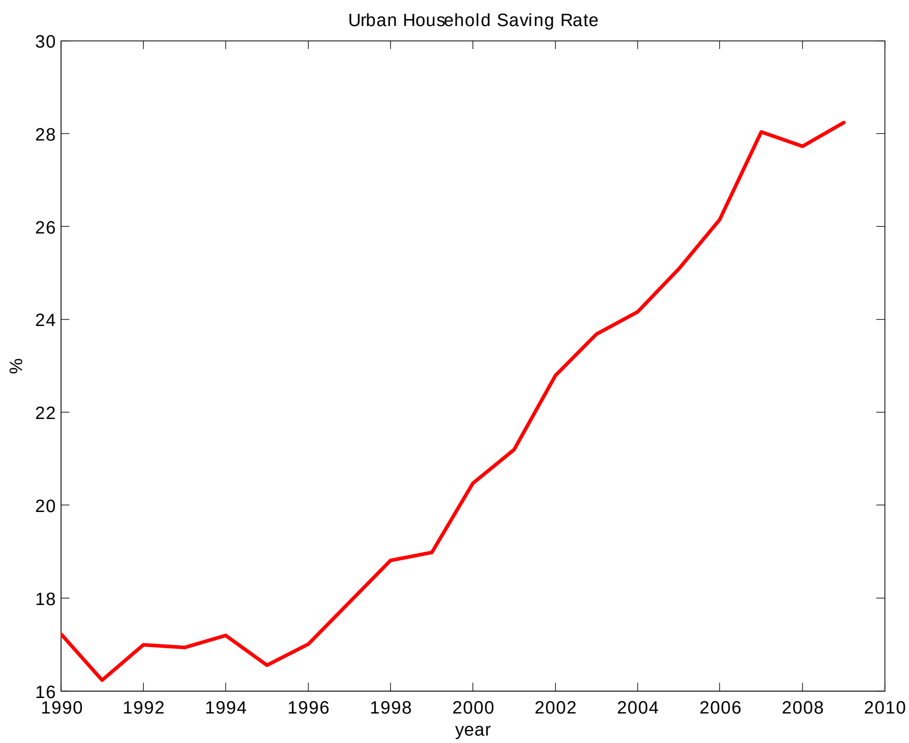

Figure 1: Chinese Urban Household Saving Rate

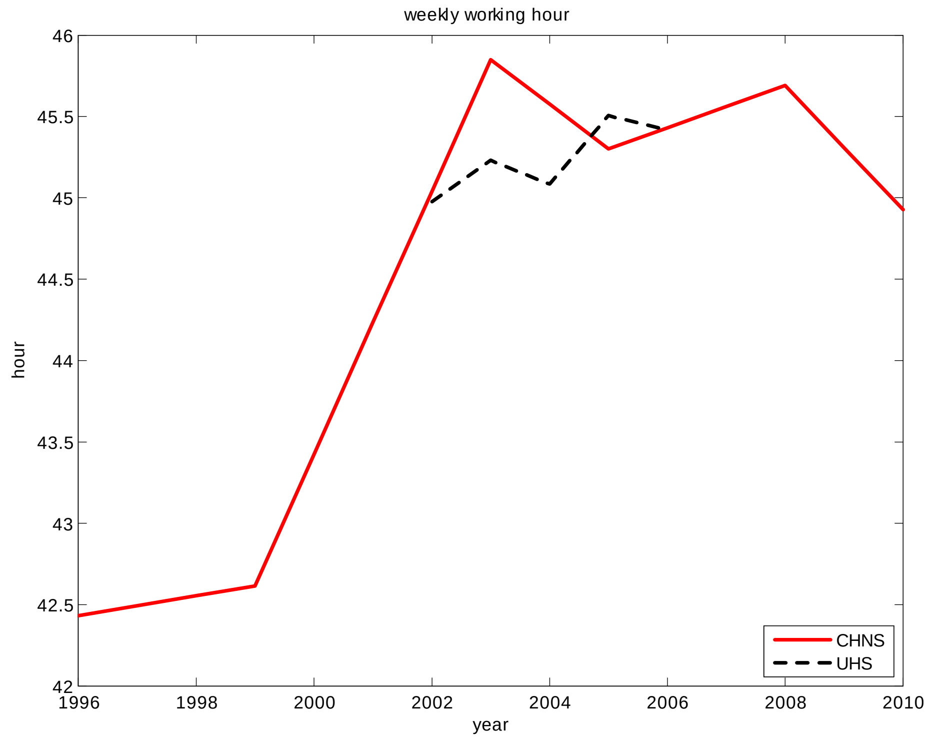

Figure 2: Average Weekly Working Hours in Urban China

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.

So what happened after 1995 in urban China? What could be the driving force behind this dramatic increase in both household saving rate and labor supply among Chinese urban workers? For these workers, probably the most profound change came from the impact of the large-scale state-owned enterprise (SOE) reform that was initiated in 1997. The reform broke the job security–so called "iron rice bowl"–of the state-owned sector. And as an important measure to reduce the fiscal burden and enhance SOE efficiency, the government also launched a radical reform on the pension system. Section 2 will provide a detailed description of the pension reform. The spirit of the pension reform, in summary, is to significantly reduce the generosity of the pension system.

Meanwhile, over the past two decades, China has also been undergoing a dramatic change in demographic structure. As shown in Figure 3 (data source: Chinese Census 1995 and 2010), conditional survival probability is uniformly higher in 2010 than

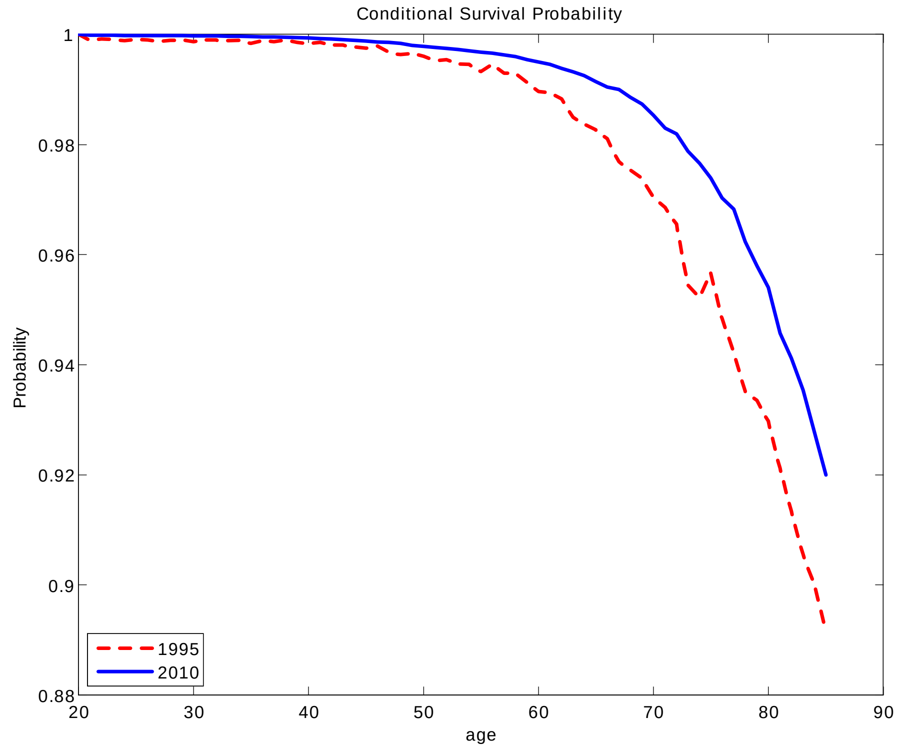

Figure 3: Conditional Survival Probability in Urban China: 1995 vs. 2010

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 then the peer countries. 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 4 (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 had been increasing significantly from 1995 to 2011. And the future does not look like brighter at all. 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.

In this paper, we ask a research 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? And what

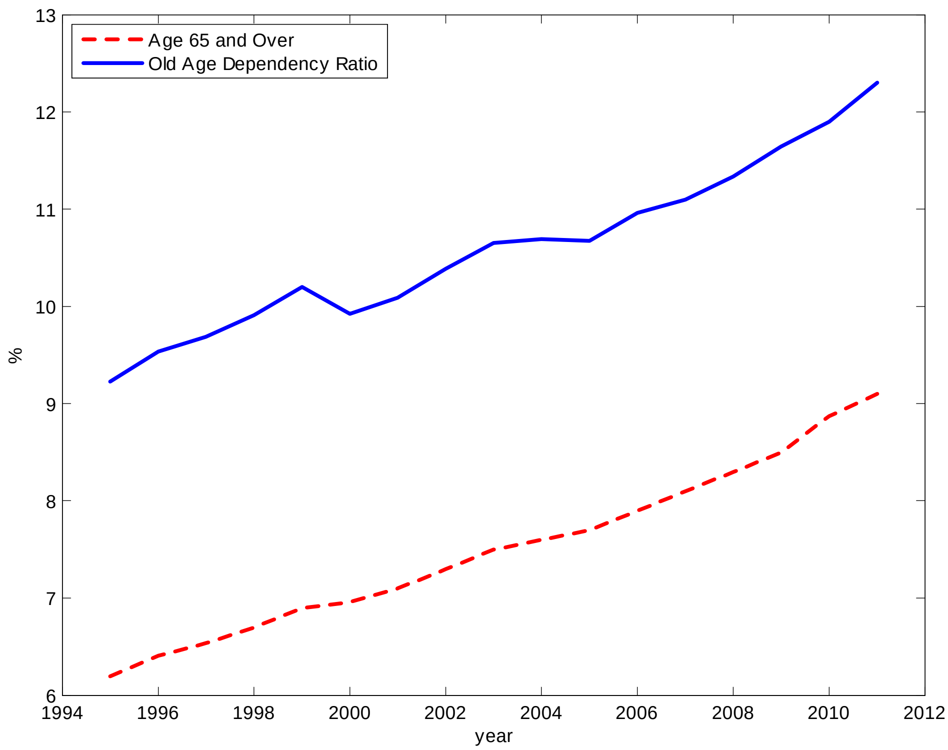

Figure 4: Old Age Dependency Ratio in Urban China

are the impacts of these two changes on Chinese macro economy? We think these two structural changes could have potential impact on saving rate and labor supply for following reasons. First, a change in demographic structure could have important macroeconomic effects on national saving. On one hand, rapid aging will shift 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, facing rapidly increased life expectancy (and given the social security system does not encourage one to delay retirement age), an individual will have a longer time spent on retirement period. Therefore she has an incentive to save more during her working age to support her old-age consumption. *Life expectancy* effect thus tends to raise household saving rate (see Bloom et al. 2007). Probably due to these two contradicting mechanisms, empirical literature finds mixed evidence on the importance of demographic change on aggregate saving behaviors, from only a modest contribution (Deaton and Paxson 2000) to significantly large (Bloom, Canning and Graham 2003 and Bloom et al. 2007).

Second, a change in pension wealth could also affect private saving. 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.

However, literature has put less emphasis on the importance of changes in demographic structure and pension system on aggregate labor supply. Low (2005) emphasizes that an individual could use two ways to hedge against an increase in income uncertainty: work longer hours or save more. Same logic could apply here for changes in demographic structure and pension system. Anticipating the consumption need for a longer period of retirement and a potential reduction in pension wealth, a rational individual would tend to save more and/or work longer hours. In addition, change in demographic structure such as rapid aging could also potentially affect the aggregate labor supply via the composition effect. Older workers usually work less hours than young workers. A shift of the age structure from young towards old would lead to decrease the aggregate labor supply, keeping other things equal. Theoretically speaking, one would expect that the impact of rapid aging on labor supply should be less significant than the impact of pension reforms. The empirical literature, however, is unfortunately absent in studying this potentially important link between the changes in changes in demographic structure and pension system and aggregate labor supply.

Our paper aims to fill this void. To answer the quantitative question raised above, we develop a large-scale (70 period) general equilibrium heterogenous agent overlapping generations 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. and she has to make decisions on consumption, asset holding and labor supply. We calibrate the model to match the Chinese economy before the 1997 pension reform by using intensively micro-level Chinese household surveys. We then input the exogenous demographic change as shown in Figure 3 and the policy changes in pension system as described in details in Section 2 into the model. We compare the model-generated endogenous variables such as saving rates, labor supply, and consumptions before and after the changes to evaluate the long-run impacts of both rapid aging and pension reform. Finally, we conduct several counterfactual experiments to isolate the impact and welfare effect of rapid aging and the pension reforms separately.

We find that the rapid aging and the pension reforms together contribute only 9% of the increase in household saving rate from 1995 to 2009. However, both changes contribute significantly about 72% of the increase in average working hours per worker from 1995 to 2009. Our decomposition exercise shows that the pension reform is the major driving force behind the dramatic increase in labor supply after 1995. It alone contributes 55% of the increase in labor supply. Demographic change alone contributes 29% of the increase in aggregate labor supply, which is significantly lower than the contribution from the pension reform. Therefore our theoretical hypothesis is confirmed here. Both changes, however, contribute about equally, each one for about 5%, to the rising household saving rate from 1995 to 2009.

Our paper 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 (2013) and Curtis, Lagauer and Mark (2014). Both papers emphasize the importance of declining fertility due to "one child policy" on affecting 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 close to Song, Storesletten, Wang and Zilibotti (2014) who 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.

The organization of the rest of the paper is as follows. Section 2 provides a detailed description of Chinese pension reforms. 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.

2 Chinese Pension Reforms

Before 1997, urban pension system is a part of "iron rice bowl" for SOE workers and government employees.[3] It provides a very generous replacement ratio for retirees, which is equal to roughly 80% of the last annual provincial average wage income in the province where a worker retires. In exchange of this generous pension system, workers bear 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 2014). 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 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%.[4] The second pillar is a voluntary

[3] 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.

[4] 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

Table 1: 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).

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." 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 1 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 is carried out by the State Council Document No. 38–"Decision of the State Council on *Improvement* of Unified Basic Old Age Insurance System for Enterprise Staff and Workers"–in 2005. The major change in the 2005 reform is to adjust the formula for social security benefits. Before the 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. 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

social security benefits for retirement ages with a targeted replacement ratio of 59.2%.

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.[5] And it is obvious that as a retiree lives longer, the effective replacement ratio for his benefits gets smaller. By doing so, the government further reduces its social obligation to pension benefits. In Figure 5, 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.[6] It dramatically decreased to 45% in 2011. And the trend still continues.

3 Model

In this section, we describe the model economy. The economy is populated with a continuum of many-period lived overlapping generations individuals. There is a representative firm that uses capital and labor to produce output. The individuals derive utility from consumption and leisure and 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 the retirees. An individual in the economy faces idiosyncratic income risk and lifetime uncertainty. The annuity market is missing.

3.1 Demographic Structure

An individual is born at age $j = 1$ and die 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 a age-dependent conditional survival probability ψ_j. Therefore the unconditional survival probability up to age j is $\prod_{i=1}^{j} \psi_i$. The population in the economy grows exogenously at a rate $n > 0$.

Given the information, the fraction of age-j individuals in the population is cal-

[5] The literature indicates that the weight of the local average wage in the benefit formula was about 40-60% after 2005 reform (see Sin 2005).

[6] 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 men,*" 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.

Figure 5: Average National Replacement Ratio in Urban China

culated by

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

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

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

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

$$q_j = (1-\tau_s) w \varepsilon_j \eta_j \left(1 - l_j\right)$$

where τ_s is the social security payroll tax and w is the wage rate. ε_j is the deterministic age-dependent productivity at age j. η_j represents a stochastic idiosyncratic income shock, which is an AR(1) process with an i.i.d. innovation as described below

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

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 ψ_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 way. 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 that leaves 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, 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 τ_{ss} in exchange of retirement benefits b when she retires. The defined benefit formula for an age-j retiree who retires at time $t-(j-J_R)$ is given by

$$SS_j = \theta\left[\upsilon\overline{E}_j + (1-\upsilon)\,Q\right]$$

where θ represents target replacement ratio and

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

captures the indexed social average wage. On the other hand, the AIME part of the formula is captured by Q which is given by

$$Q = \frac{\sum_{i=1}^{J_R-1}\sum_{\eta} w_i \varepsilon_i \eta_i\,(1-l_i)}{J_R-1}.$$

The weight υ 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 θ and υ. Keeping other things equal, a lower θ can reduce the government's fiscal burden on the social security. So does a lower υ.

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

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

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

$$\begin{aligned} r_t &= \alpha A_t K_t^{\alpha-1} N_t^{1-\alpha} - \delta \\ w_t &= (1-\alpha) A_t K_t^{\alpha} N_t^{-\alpha} \end{aligned} \tag{2}$$

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

$$V(a_j, \eta_j) = \max_{a_{j+1}, c_j, l_j} \left\{ u(c_j, l_j) + \beta \psi_{j+1} E_j V(a_{j+1}, \eta_{j+1}) \right\} \tag{3}$$

subject to

$$\begin{aligned} c_j + a_{j+1} &= (1+r) a_j + (1-\tau_s) w \varepsilon_j \eta_j (1 - l_j) + beq \\ c_j, a_{j+1} &\geq 0, a_0 = 0 \end{aligned} \tag{4}$$

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

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

subject to the same budget constraints as in equation (4).

However, for a retiree, the DP problem changes to

$$V(a_j) = \max_{a_{j+1}, c_j} \left\{ u(c_j, 1) + \beta \psi_{j+1} V(a_{j+1}) \right\} \tag{5}$$

subject to

$$\begin{aligned} c_j + a_{j+1} &= (1+r)\,a_j + SS_j + beq \\ SS_j &= \theta\left[\upsilon \overline{E}_j + (1-\upsilon)\,Q\right] \\ a_{j+1} &\geq 0, a_J = 0 \end{aligned} \tag{6}$$

3.6 Stationary Competitive Equilibrium

Our goal in this paper is to investigate the long-run impact of different social security system and demographic structure. Therefore it involves comparing different steady states of the economy. We thus define the competitive equilibrium for the model economy here.

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' 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 (2).*

3. *Factor markets clear.*

$$K = \sum_j \sum_a \sum_\eta \mu_j \lambda_j(a,\eta) A_j\left(a,\eta\right) \tag{7}$$

$$N = \sum_{j=1}^{J_R-1} \sum_a \sum_\eta \mu_j \lambda_j(a,\eta) \varepsilon_j \eta_j (1 - L_j\left(a,\eta\right)) \tag{8}$$

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.

$$\tau_{ss} = \frac{\sum_{j=J_R}^{J} \mu_j SS_j}{\sum_{j=1}^{J_R-1} \sum_{\eta} \mu_j w_j \varepsilon_j \eta_j (1 - l_j)} \tag{9}$$

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 will 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. 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 3. 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 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 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 (1). Figure 6 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.[7] Figure 7 shows the profile. We estimate the idiosyncratic income shock η 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).[8] 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).

[7] See data appendix for details.

[8] See data appendix for details.

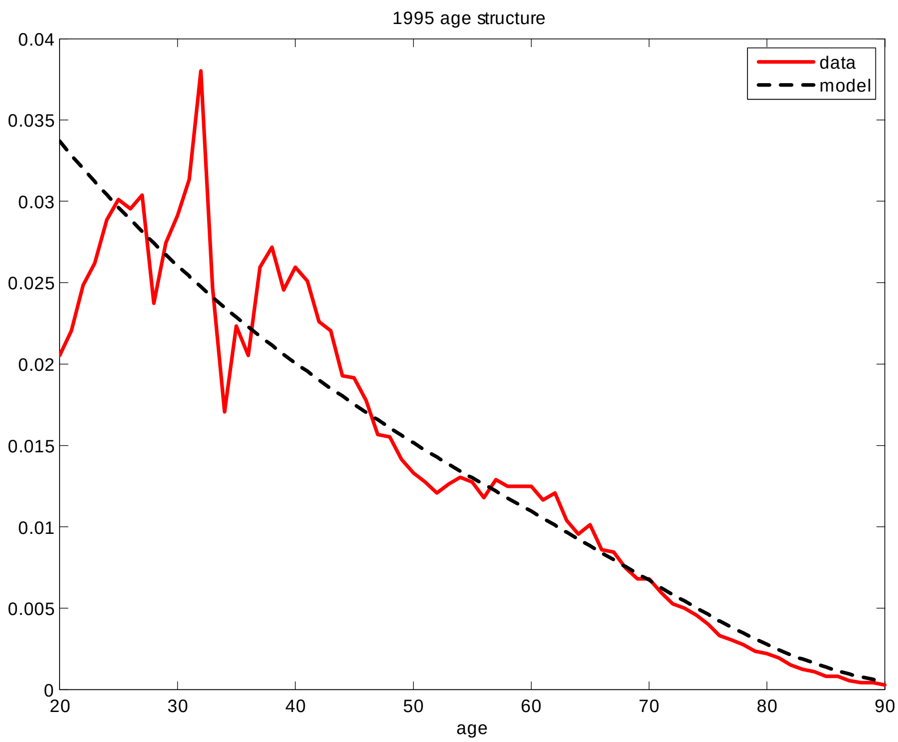

Figure 6: Age structure in urban China in 1995: Data vs. Model

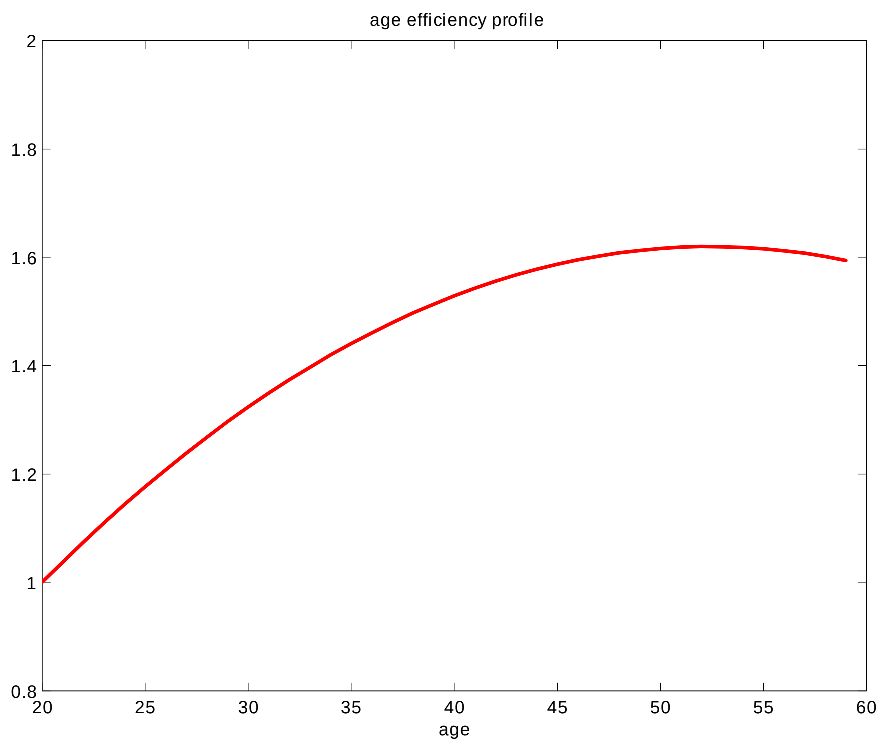

Figure 7: Age-Efficiency Profile

Demographics		
ages	j=1, J_R=41, J=71	age=20, 60, 90
con. survival prob.	$\{\psi_i\}$	Census 1995
pop growth rate	n	0.025
Endowment		
age-efficiency profile	$\{\varepsilon_i\}$	CHNS
Var of innovation to shock	σ_η^2	0.055
Autocorrelation coefficient	ρ	0.84
Technology		
capital share	α	0.5
depreciation rate	δ	0.1
wage growth rate	g	0.058
SS policy		
SS replace. rate	θ	0.8
SS indexation degree	υ	1

Table 2: Model parameters taken from literature or estimated from data

On the technology side, we set capital income share $\alpha = 0.50$ and depreciation rate $\delta = 10\%$ to be consistent with Chinese data.[9] 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.

On the pension system, to be consistent with the system before 1997, we set replacement ratio $\theta = 80\%$ and the degree of indexation in social security benefit formula $\upsilon = 100\%$. The social security payroll tax τ_{ss} is determined in the equilibrium as in equation (9).

Table 2 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 β, γ and σ are calibrated to match three moment conditions simultaneously, i.e., average capital-output ratio 1.85 for period 1990-1997,[10] average working hours ratio (as the share of discretionary time)

[9] 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).

[10] We construct the time series of capital stock using perpetual inventory method. Data of initial

Parameter	**Description**	**Value**	**Target**	**Source**
β	discount rate	1.001	$K/Y = 1.85$	1990-97 data average
σ	CRRA coeff	3.3	IES = 0.5	Commonly used data
γ	Consum. weight	0.47	Av. Hours Ratio = 0.379	1997 CHNS

Table 3: Calibrated model parameters

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.[11] The calibrated parameters are shown in Table 3.

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 3 and also changing replacement rate θ from 80% to 60% and the weight of indexed social average wage υ in defined benefit formula from 100% to 60%. In other words, the pension reform here is a combination of 1997 and 2005 reforms. To make the model to be 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.[12] Our estimation shows that after 1997, the AR(1) coefficient ρ 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 σ_η^2 has increased significantly from 0.055 to 0.075. We think that 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 2 and 3 in the scenario. We call this policy experiment "after reform." In other words, we are comparing the two steady states: benchmark economy vs. an economy with the implementation of both rapid aging and pension reforms. 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

capital stock in 1952 and time series of investment for period 1952-2010 are taken from NBS China Fixed Asset Investment Statistics.

[11]1997 CHNS reports average weekly hours worked per worker is 42.15 hours. We calculate the share of working hours out of weekly discretionary time to be $42.15/(7 \times 16) = 0.379$.

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

	Demographics	SS instrument	
	$\{\psi_i\}$	θ	υ
benchmark	Census 1995	0.8	1
policy I (after reform)	Census 2010	0.6	0.6
policy II (only reform)	Census 1995	0.6	0.6
policy III (only demographic change)	Census 2010	0.8	1

Table 4: The design of quantitative policy experiments

decompose the impact from rapid aging and pension reforms separately. Therefore, we conduct two additional experiments. One is only changing θ and υ to 60% and 60% from the benchmark model, while keep all other parameters unchanged. In other words, we isolate the impact from the pension reform. We call this scenario "only reform." Another one is only changing $\{\psi_i\}$ from 1995 to 2010 level, while keep all other parameters unchanged from the benchmark model. By doing so, we isolate the effect of rapid aging. We call this case "only demographic change." Table 4 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

$$W = \sum_{j=1}^{J} \sum_{a} \sum_{s} \beta^{j-1} \mu_j \lambda_j (a_j, s_j) \left(\prod_{i=1}^{j} \psi_i \right) u \left(C_j \left(a_j, s_j \right), L_j \left(a_j, s_j \right) \right) \tag{10}$$

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 ($p = I, II, III$ as in Table 4). Then CEV is λ 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 5.

We see that with both rapid aging and pension reform, social security tax rate τ_{ss} decreases from around 15% 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 6% and 8.4% respectively. As a result, output increases 14.2% from the benchmark level. Consumption also increases by 8%. Higher capital-output ratio decreases equilibrium interest rate from 17% by 2% to around 15%.

The welfare analysis in Table 5 shows that the welfare for the whole economy improves after rapid aging and pension reforms. The expected life-time utility increases about 7.4%. CEV measure also shows a similar magnitude of increase.

We calculate the household saving rate from the model following the same definition of our empirical work (i.e., saving rate = (household's disposable annual income - household's consumption) / household's disposable annual income). Not by construction, our model matches the average household saving rate very well in 1995. From 1995 to 2009, UHS data show that the household saving rate had increased by 11.5% from 16.88% to 28.24%.[13] Our model is able to generate a 1% increase from 16.47% to 17.45% as shown in Table 6. Therefore the rapid aging and pension reforms that we model jointly contribute about 9% of the increase of household saving

[13] Notice that our UHS data end in 2009.

rate from 1995 to 2009. Although 9% is not negligible, it does indicate that the rapid aging and pension reforms after the late 1990s seem to *not be* the candidate of main driving force behind drastic rising urban household saving rate in China after 1995.

Labor supply, however, is a completely different story. As shown in Table 6, the share of weekly working hours (out of weekly discretionary time) in the CHNS data had increased from 0.379 in 1996 to 0.408 in 2010; while our model predicts it increases from 0.373 to 0.394. Therefore the model is able to capture 72% of the increase in labor supply documented in the data from 1996 to 2010. This shows that the rapid aging and pension reforms are the major driving forces behind the dramatic increase in labor supply among urban Chinese workers after the late 1990s.

5.2 Decomposition Exercise

To isolate the effect from the rapid aging and pension reforms *separately*, we conduct two decomposition exercises, namely "only reform" and "only demographic change." The results are shown in the third and fourth columns of Table 5.

Compared to the benchmark model, we find that pension reforms increase labor supply and capital accumulation more significantly than rapid aging. As shown in "only reform" case, labor supply and capital-output ratio increase about 4.3% and 4.2% respectively compared to the benchmark case; while for "only demo," the changes are 2.4% and 1.4% respectively.

Why pension reforms have a more significant impact on labor supply and capital accumulation than rapid aging? To hedge against the declining replacement rate and glooming future for one's own old-age support, an individual can either save more or work longer. This mechanism is also reinforced by the significant decline in payroll tax rate from 14.7% to 9.5% since it increases the disposable income and also encourages stronger incentive to supply labor. In contrast, rapid aging brings two competing effects: *composition* vs. *life expectancy* effect. As shown in Figure 8, 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 both saving rate and labor supply. 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 the retirement. Therefore she needs to work longer and save more during her working age to prepare for the longer retirement period. Life expectancy effect thus tends to raise both saving rate and labor supply. The two competing effects alleviate the impact on labor supply and saving rate. In addition, rapid aging also puts pressure on pension system. The equilibrium social security tax rate has to increase from 14.7% to 17.4% under the "only demo" scenario, which

	benchmark	after reform	only reform	only demo
SS tax rate	14.74%	10.96%	9.47%	17.37%
Av. hours	0.373	0.394	0.389	0.382
K/Y	1.852	2.008	1.929	1.878
Output	0.969	1.107	1.041	0.976
Consumption	0.639	0.690	0.671	0.632
Wage	0.925	1.004	0.964	0.940
Interest rate	17.02%	14.89%	15.94%	16.61%
Exp. life U	-31.74	-29.38	-28.72	-33.43
CEV	-	7.53%	9.84%	-4.71%

Table 5: Quantitative Results of Three Policy Experiments

reinforces to further reduce labor supply.

To evaluate the relative importance of each force in explaining the rising saving rate and labor supply as observed in the data, we compare the model-generated saving rate and labor supply to the average saving rate and working hours ratio before and after 1997 in the data. We report the comparison in the fourth to seventh column of Table 6. The table shows that pension reforms alone are able to explain 55% of the increase in labor supply and about 5% of the increase in household saving rate, while the rapid aging alone contributes to 29% of the increase in labor supply and about 5% of the increase in household saving rate.

The two changes, however, have a quite different implication on the welfare of the whole economy. As shown in Table 5, pension reforms alone brings a significant welfare gain compared to the benchmark economy. The welfare gain is equivalent to about 10% of CEV. In contrast, rapid aging alone brings a sizable welfare loss equivalent to 4.7% of CEV. The welfare loss mainly comes from a lower consumption compared to the benchmark level, which is caused by a much higher payroll tax rate under "only demo" case and hence significantly lowers an individual's disposable income.

6 Conclusion

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

Table 6: Saving Rate and Labor Supply: Model vs. Data

S/Y	**Data**	**Model**	**Exp.**	**only ref**	**Exp.**	**only demo**	**Exp.**
1995*	16.88%	16.47%		16.47%		16.47%	
2009	28.24%	17.45%	9%	16.95%	4.58%	16.99%	4.93%
n	**Data**	**Model**	**Exp.**	**only ref**	**Exp.**	**only demo**	**Exp.**
1996	0.379	0.373		0.373		0.373	
2010	0.408	0.394	72%	0.389	55%	0.382	29%

* : 1990-1995 average.

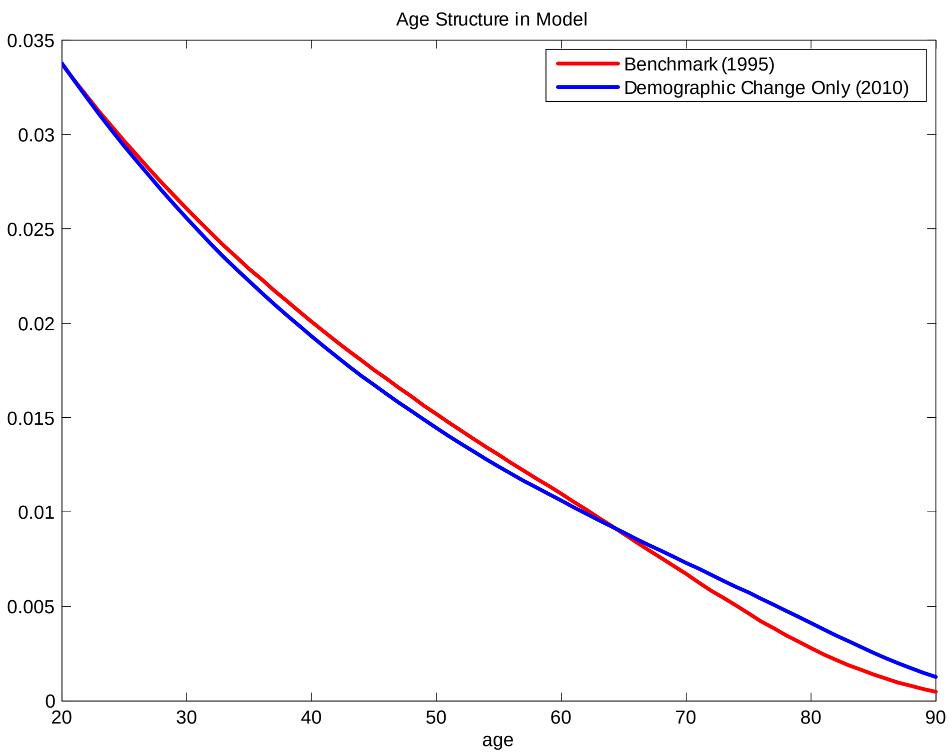

Figure 8: Age Structure in Model: Benchmark (1995) vs. Demographic Change Only (2010)

change and pension reform on Chinese macro economy, especially focusing on their impact on saving rate and labor supply.

We find that the rapid aging and the pension reform together contribute about 9% of the increase in household saving rate from 1995 to 2009. Therefore, both changes seem to *not be* the candidate of main driving force behind drastic rising urban household saving rate in China after 1995. However, two changes together contribute significantly about 72% of the increase in average working hours per worker from 1995 to 2009. Our decomposition exercise shows that the pension reform is the major driving force behind the dramatic increase in labor supply after 1995. It alone contributes 55% of the increase in labor supply. Rapid aging also has a significant impact on labor supply. It alone contributes 29% of the increase in aggregate labor supply.

The general message this paper tries to convey is that an rational individual might use the change in labor supply as a vehicle to hedge against the change in pension system. The impact on labor supply from pension reform and demographic change should not be ignored in theoretical and empirical literature.

7 Appendix: 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 η.

7.1 Urban Household Survey (UHS)

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

7.2 China Health and Nutrition Survey (CHNS)

Our second 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 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 Stochastic Income Process

We estimate the stochastic idiosyncratic income risk η based on CHNS data since it is the only panel data in China that allows us to estimate the income process. We restrict the data to only include aged 25-60 male and aged 25-55 female urban sub-sample. 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 η_{it} is the permanent shock and v_{it} is the transitory shock. We assume v_{it} and ξ_{it} is i.i.d. and the associated variance is σ_v^2 and σ_ξ^2, respectively. Therefore the variance of η_{it} is $\frac{\sigma_\xi^2}{1-\rho^2}$.

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

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

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

Therefore for T waves of data, we have $\frac{T(T+1)}{2}$moments, which include T variances and $\frac{T(T-1)}{2}$covariances. For example, for 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 σ_ξ^2, σ_v^2 and the persistency parameter ρ jointly following Heathcote, Storesletten and Violante (2010).

For simplicity, we ignore σ_v^2 in the calibration.

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