PENSION SYSTEM REFORM FACING RAPID AGING: LESSONS FROM CHINA

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ABSTRACT

Pension reform is certainly the most complex of all structural reforms because it upsets existing political-economy equilibria, affects public finances, intervenes in the functioning of labor and capital markets, distributes income both across and within generations, and changes an economy’s saving, investment, and growth paths from the short to the very long term (Schmidt-Hebbel 1999). Therefore, the impact of a pension reform on capital accumulation, saving, output, labor participation, income distribution, and individual welfare have long been of critical concerns to both academic economists and policy-makers.

Since the early 1990s, China’s national pension system, one of the largest pension systems in the world\(^1\), has undergone quite a few major fundamental reforms and been shifting from a traditional Pay-As-You-Go (PAYG) system to a Partially Funded (PF) multi-pillar system under an era featuring rapid economic growth and drastic demographic change. Given its complexity, scale, and importance, the practice of China’s pension reform provides a good research case to study the macroeconomic and welfare effects of the type of pension reform from PAYG to partial funding. This dissertation presented in three essays aims to investigate the macroeconomic and welfare effects of China’s pension reform, to review the progress and challenges facing China’s pension systems, and to study some options for further parametric pension reform. It is worthy to note though our model targets China’s pension reform, it is also suited to studying the type of pension reform from PAYG to partial funding in other countries.

Essay one is the first of kind to use Auerbach–Kotlikoff framework to assess the macroeconomic and welfare effects of China’s pension reform when population aging and transition costs are considered. We first build a two-period Overlapping Generation (OLG) Simulation Model in a general equilibrium framework with homogeneous agent under the context

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\(^1\) China’s national pension system discussed in this paper, actually the national urban pension system that only covers 219 million urban adults (including 166 million contributors and 53 million pensioners as of the end of 2008, China’s Statistical Yearbook 2009) is one of the largest pension systems in the world. However, about 653 million rural adults remain outside the national urban pension system and depend mainly on familial transfers and personal savings for old-age support.
of population aging and endogenous labor force participation of the elderly to simulate quantitatively the two economies under PAYG system and PF system respectively. Then we analyze and compare the two economies at steady state to observe the effects of China’s pension reform on capital accumulation, saving, output, wage, interest rate, lifetime utility, and income distribution.

Our analysis shows China’s pension reform from PAYG to partial funding has notable and positive effects on China’s macro economy and intergenerational equality. Simulation results show impact of China’s pension reform can be substantial. For example, under the cases of endogenous labor force participation of the elderly, the capital stock rises by 14%, output by 5.5%, national saving rate by 17%, real wage by 5.5%, lifetime income by 9.9%, and pension replacement ratio by 70%. Moreover, the reform significantly improves intergenerational fairness by reducing upward intergenerational transfers by 24%. Additionally, although the Reform brings up certain transition costs, the government can make appropriate policy measures such as imposing special consumption tax on consumer to deal with the challenge of financing the transition costs. Finally, the economy reaches its new steady state five periods after the Reform, yet the future generations gain at the cost of the transition generation’s welfare loss, which may cause a challenge to the implementation of the pension reform.

In order to make our model more suited to China’s reality, the second essay extends the two-period OLG General Equilibrium Model with heterogeneous agents to study the effects of China’s pension reform on macro economy and intergenerational and intragenerational income distribution. We assume two types of agents differ in their human capital endowments and in their access to the financial system. We first build the two-period OLG general equilibrium model and quantitatively simulate the economic effects of China’s pension reform on macro economy, individual welfare, income distribution, and transition costs, then we discuss the sensitivity level of the simulated results to some important parameters, finally we analyze the specific transitional path of the Reform.
Our analysis shows that China’s pension reform not only has significant and favorable effects on macro economy, individual welfare, but also improves income inequality substantially. Compared with the rich agent, the poor agent gains 70% higher from the Reform in the long run. Additionally, the economy reaches its new steady state nine periods after the Reform. However, a majority of the changes happen before the end of the fourth period (period 4). During the first period after the Reform (period 1), agent 1(rich agent)’s welfare decreases by -4.2%, while the welfare of the rich agent and the poor agent increase by 32% and 40% at the steady state respectively. Also, China’s pension reform improves both intragenerational and intergenerational income distribution, a result different from James (1997)’ claim that privatization of PAYG system may deteriorate income equality. Furthermore, the larger are $\eta$ or $\gamma$, the smaller the favorable economic effects of the Reform become. In terms of sensitivity level, the effects of the Reform on macroeconomic economy, individual welfare, and income distribution are sensitive to the change in values of $\eta$ or $\gamma$ while the transitional cost variables are little sensitive. Finally, the results show partial funding is better than full funding for China’s pension reform, which compliments the current literature.

The third essay seeks to review the evolution of China’s urban and rural pension systems, to investigate the progress and challenges facing the pension systems, and then to simulate the quantitative impact of further parametric pension reforms as China’s population is rapidly aging.

Our paper shows despite notable institutional improvement and other progress, China’s pension systems are still facing many challenges such as high implicit pension debt (IPD) and empty individual account, the fragmented and decentralized system, low coverage rate, low pension fund investment returns and inefficient fund management, high contribution rate and low retirement age.

We make two kinds of simulation analysis to evaluate the effects of possible parametric reform options. One is to apply Generational Accounting method to assess the intergenerational
fiscal effects of four pension reforms. The results show under the current pension policy, the fiscal burden facing future generations is at least 35% higher than that facing the newborns in 2000. Higher contribution rate and retirement age, lower pension benefits, and subsidy from state-owned asset interest can decrease the fiscal burden on future generations significantly at the certain cost of current generations, among which, raising retirement age and lowering pension benefits are more appropriate to improve intergenerational fiscal burden distribution.

The other is to use an extended simulation model adapted to China’s partially funded pension system to simulate the impact of five reform options on the pension replacement ratio. The simulation results indicate under the current pension policy, the pension replacement ratio is 45.6%, much lower than the promised 59% by China’s government. The results also show the low return of pension investment is the main reason for the low replacement ratio and the robust impact of the five reform options in increasing pension benefits, among which, diversifying pension investment is the most effective and viable one.

For building a unified, efficient, and financially sustainable pension system to accommodate 330 million old-age population by 2050, possible pension reform alternatives are proposed including raising the retirement age, expanding the pension system coverage, unifying the fragmented and varied pension system across the nation, and diversifying the pension fund investment.
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Chapter 1: Macroeconomic and Welfare Effects of China’s Pension Reform Facing Rapid Aging

1.1 Introduction

Since the early 1980s, China has been witnessing unprecedented economic and social achievements and drastic demographic changes featuring increasing life expectancy, falling fertility, and population aging. Against the background of fast economic development and rapid population aging, China’s pension system, one of the largest in the world, has undergone quite a few major fundamental reforms, especially the crucial 1997 pension reform, which transformed a traditional unfunded Pay-As-You Go (PAYG) system to a Partially Funded (PF) multi-pillar system. Given its complexity, scale, and importance, the practice of China’s pension reform provides a good case to study the macroeconomic and welfare effects of the type of pension reform from PAYG to partial funding.

How the type of pension reform¹ from PAYG to funding affects various aspects of the economy such as economic growth, capital accumulation, saving, and labor markets has been receiving great attention from academia, policy-makers, and international organizations² across the world.

The basics in theoretical literature are the lifecycle theory (Modigliani and Brunberg 1954) and overlapping generation model (Samuelson 1958; Diamond 1965) that provide economic rationale of pension system. Later, “Aaron condition”³ outlined by Aaron (1966) is widely used to compare unfunded pension systems such as PAYG with funded ones. World Bank

¹ There are two kinds of pension reform: parametric reform and fundamental reform. The latter includes three types: from PAYG to funding, from non-actuarial to actuarial, or the combination of both such as China’s pension reform (Lindbeck and Persson 2003). Please see more details in Section 1.3 regarding the pension reform around the world and in China.

² For example, World Bank proposed the influential 1994 Three-Pillar Partially Funded Model. China’s 1997 pension reform just followed this Model.

³ It is $1+r\leq (1+n)(1+g)$. If $g$ and $n$ are only slightly greater than zero, then the condition is reduced to $r\leq n+g$, that is, if the market interest rate $r$ is less than the economic growth rate $n+g$, then PAYG system is better than funded system, and vice versa.
(1994) claims economic growth is higher in countries with funded pension system than those with unfunded system due to less labor distortion, higher saving, and more efficient capital market.

Empirically, Holzmann (1996) finds a significant positive relationship between pension reform and Chilean economic growth. Many researchers (Coronado 2002; Schmidt-Hebbel 1999; Samwick 2000) find mixed results on how pension reform affects private saving and national saving in OECD countries and Chile. Regarding pension reform’s effect on labor markets, there is also hot debate with mixed findings (Disney 2003; Packard 2001).

Auerbach and Kotlikoff (1987) build a large-scale Overlapping Generation (OLG) Simulation Model that contains 55 generations with certain lifetime, perfect foresight, exogenous technical change, and endogenous labor force participation. Later, the original Auerbach-Kotlikoff model is extended to uncertain lifetime, heterogeneous agents, and credit restrictions. Many studies use Auerbach-Kotlikoff framework to simulate the macroeconomic and welfare effects of pension reform in quite a few countries such as Chile, U.S., Mexico, and some European countries (Auerbach et al. 1989; Kotlikoff 1998; Hviding and Merette 1998; Serrano 1998).

Most of existing research mainly focuses on the pension reform from PAYG to full funding in OECD countries or Chile, yet there is little research on the pension reform from PAYG to partial funding in developing countries such as China in current literature. This paper intends to fill the gap. The purpose of the paper is to use an extended two-period Overlapping Generation (OLG) Simulation Model to analyze the macroeconomic and welfare effects of China’s pension reform under the context of population aging. That is, the paper attempts to answer how a shift from a PAYG system to a partially funded (PF) system affects capital accumulation, economic growth, saving, labor force participation, individual welfare, and economic fairness when population aging and transition costs are taken into account. It is worthy to note though our model targets China’s pension reform, it is also suited to studying the type of pension reform from PAYG to partial funding in other countries.
We first build a two-period OLG Model with homogeneous agent under the context of population aging and endogenous labor force participation of the elderly to simulate the two economies under PAYG system and PF system respectively, and then analyze and compare the two economies at steady state to observe the economic and welfare effects of China’s pension reform.

Our simulation results show China’s pension reform has positive and favorable effects on China’s economy by increasing capital level, output, wage rate, and capital-output ratio, decreasing interest rate, raising lifetime utility and pension replacement ratio, improving economic fairness. Although there are certain transition costs caused by the reform, the government can make appropriate measures to deal with the challenge of financing the transition costs. In addition, in order to make our model more suited to China’s reality, we also extend our model by considering heterogeneous agents with different income levels due to the differences in human capital endowments and in access to financial market. We will present these results in the next chapter.

The structure of this paper is organized as follows. Section 1.2 reviews current literature on economic effects of pension reform. Section 1.3 overviews of pension system reform in the world and in China. Section 1.4 details the calibration method— two-period OLG Simulation Model and then presents the simulation and comparison results. Section 1.5 concludes the paper.

1.2 Literature Review

During the last several decades, given high importance and complexity of pension reform, there is a large literature of theoretical and empirical work on this field. Many economists like Samuelson, Feldstein, Diamond, James, Holzmann, Auerbach, Kotlikoff, and Mason have made important contributions to the current literature.

This section mainly reviews two topics from both theoretical and empirical perspectives. One is the basic economics of unfunded and funded pension systems. The other is on the issue of
pension reform from PAYG to funding. Firstly, we review arguments and critics of PAYG system. Secondly, we discuss the macroeconomic and welfare effects of pension reform including the impact on saving, labor markets, capital formation, economic growth, and income distribution respectively. Finally, we review some relevant issues such as the saving effect of demographic change and transfer system.

1.2.1 Basic Economic Rationale of Unfunded and Funded Pension Systems

The starting point in theoretical literature is the lifecycle theory. Modigliani and Brunberg (1954) develop the basic lifecycle model, the central theory to explain individual’s economic behavior, in which people’s primary motive for saving/dissaving is smoothing their lifetime’s consumption, and they determine their optimal consumption path by maximizing lifetime utility subject to the lifetime budget constraints during periods of the lifecycle.

Based on lifecycle theory, Samuelson (1958) and Diamond (1965) develop the original overlapping generation (OLG) model used to explain the economics of PAYG system though Samuelson assumes no capital accumulation in the economy while Diamond does. A basic two-period overlapping generation (OLG) model is:

\[
\begin{aligned}
\text{Maximizes} & \quad U = U(c_{1,t}, c_{2,t+1}) \\
\text{s.t.} & \quad c_{1,t} + s_{1,t} = (1 - \tau) w_{1,t} \\
& \quad c_{2,t+1} = (1 + \tau)s_{1,t} + b
\end{aligned}
\]

In period 1 (working-age period), people work, save, and pay the PAYG contributions with constant tax rate \( \tau \) of wage income \( w \). In period 2 (old-age period), they retire and live on the savings and the PAYG pension benefits \( b \) that are equal to \( \tau w_{1,t}(1 + n)(1 + g) \). Labor and wage increase at a constant rate \( n \) and \( g \) respectively. People solve their lifetime utility maximization problem to determine the optimal consumption \( c_{1,t}, c_{2,t+1} \) subject to the lifetime budget constraint.
In addition, Samuelson and Diamond suggest the implicit rate of return under PAYG pension system is equal to \((1+n)(1+g)\). Following Samuelson and Diamond, Aaron (1966) outlines “Aaron condition” that is widely used to compare unfunded system with funded system. He notes the rate of return under a funded system is the market return rate \(1+r\) while the rate of return under PAYG system is \((1+n)(1+g)\). Thus, Aaron condition is:

\[
1 + r \leq or \geq (1 + n)(1 + g) \quad \text{or} \quad r \leq or \geq n + g
\]

The economic meaning is if \(r < n + g\), the market interest rate \(r\) is less than the economic growth rate \((n + g)\), then PAYG system is better than funded system. If \(r > n + g\), funded system is more advantageous than PAYG system.

### 1.2.2 Pension Reform Issues

**1) Economic Arguments for and against PAYG Pension System.**

At least four favorable functions of PAYG system have been identified including paternalism, correcting market failures, redistributing income, and lower administration costs to account for the popular existence of PAYG pension system in most countries (Diamond 1977; Lindbeck and Persson 2003). Regarding paternalism, many people do not save or save little for retirement life as they are myopic, thus, governments should help them by providing public mandatory pension. Private annuity markets subject to market failure caused by adverse selection resulting from information asymmetry. Public pension system such as PAYG can help overcome the market failure by making participation compulsory and providing basic pension benefits. PAYG system has strong income redistributive effect from the young to the old or from the rich to the poor, which improves intergenerational and intragenerational fairness. PAYG system has low transaction costs partly due to its feature of greatest economies of scale as a public pension system.

\[
b = \frac{\tau w_{s,j}(1+n)(1+g)}{\tau w_{s,j} = (1+n)(1+g)}
\]

\[2\] If \(g\) and \(n\) are only slightly greater than zero, then \((1+r) \leq or \geq (1+n)(1+g)\) becomes \(r \leq or \geq n + g\)
However, many studies show PAYG system has negative economic effects on saving, capital accumulation, and labor markets. Feldstein (1974, 1980, 1996) find under the lifecycle theory, unfunded PAYG system reduces private saving and national saving significantly. Using general equilibrium simulation analysis based on an OLG model, Auerbach and Kotlikoff (1987) estimates the introduction of PAYG system in U.S. decreases capital stock by about 20% after twenty years. Others (Feldstein 1974; Disney 2003; James 1996) argue that PAYG pension system may cause the labor market distortions such as early retirement, escaping from formal sector to informal sector due to “actuarial unfairness”. Partly due to these economic disadvantages, many countries such as Chile, Mexico, Italy, Sweden, and China have reformed their pension system.

(2) Macroeconomic and Welfare Effects of Pension Reform

**Effect of Pension Reform on Labor Market.** Lindbeck and Persson (2003) claim one main reason for the labor market distortions is “actuarial unfairness”, and show pension reform from PAYG to funding can achieve the efficiency gains in the labor markets like increasing labor supply by tightening the link between pension contributions and future benefits.

Empirically, Packard (2001) estimates the impact of pension reform on the share of the workforce working in formal sectors using the panel data of 18 Latin American countries from 1980 to 1999. His results show in the long run, a shift from PAYG to funding has a incentive effect to encourage people to work in the formal industries while there is a disincentive effect in the short run as employer and employee may need time to adjust this change.

**Effect of Pension Reform on Private Saving.** Kohl and O’Brien (1998) cite three saving motives to explain individual saving behavior: pension motive, bequest motive, and precautionary motive. Pension motive assumes people’s primary motive for saving/dissaving is smoothing their lifetime’s consumption. They normally accumulate assets during working life and deplete assets

---

1 The lack of direct link between pension contributions and future benefits at the individual level, please see Lindbeck and Persson (2003).

2 Please see 3.1 for the detailed information on pension reform in the World.
after retirement. Bequest motive assumes individuals not only maximize their own utility but also their children’s utilities when making saving decision. Precautionary motive assumes people may save to protect themselves against uncertain and unfavorable events such as unemployment and serious illness. They argue that depending on different saving motives, pension reform could affect private saving in different directions and to different magnitudes. These theoretical ambiguities therefore highlight the need for empirical research.

Engen and Gale (1997) and Samwick (2000) list four channels through which pension reform from PAYG to funding may increase private saving. First, private saving might increase if the increase in pension assets cannot be one-to-one offset by reduction in other savings due to credit constraints, pension assets’ illiquidity, or precautionary saving motive. Second, tax incentive of pension assets that income and capital gain tax is deferred until asset decumulation raises the rate of return on saving and then encourages more saving. Third, the recognition effect that people raise awareness of the importance of saving for retirement via pension reform may drive people to save more. Fourth, the improvements in access to and the functioning of capital markets driven by pension reform may contribute to higher saving. The recognition effect and financial effect are larger in developing countries as compared to developed countries.

Empirically, Coronado (2002) employs a difference in difference approach to analyze the impact of Chile pension reform on household saving rate. He finds that the 1981 reform stimulates savings among higher income households strongly, increasing their saving rates by about 7.8 percent points and the aggregate private saving rate by 2.8% of GDP. The increase in household saving can translate into an increase in national saving of more than 2% of GDP. Yet, Kovrova (2007) finds the impact of 2002 Russian Pension reform that introduces a funded pillar on household’s savings is negative. He argues the 2002 pension reform in Russia decreases the household’s saving rate by 1%.
A cross-country study by Bailliu and Reisen (1997) finds statistically significant evidence that mandatory funded pensions do contribute to higher aggregate private saving in a panel of 11 OECD and developing countries after controlling for country heterogeneity. However, another international study by Bosworth and Burtless (2003) shows growth in pension assets reduces private saving by crowding out other forms of private savings across 11 advanced OECD countries. Yet, their econometric model specification is relatively simply, with only five independent variables.

**Effect of Pension Reform on National Saving.** By definition, national saving is the sum of private saving and public saving. Cesaratto (2003) shows the means by which government finances the transition costs is crucial to the effect of a pension reform on national saving. Governments can finance the existing pension liabilities by issuing public bonds and increasing taxes. If government issues public bonds, public saving would decrease, thus the national saving might be unchanged or even decrease although the pension reform has increased private saving.

Many empirical studies analyze the 1981 Chilean pension reform, the first and most radical pension reform from PAYG to full funding in the world. Holzmann (1996) uses regression analysis to investigate the effect of pension reform in Chile on national saving. The econometric evidence shows the direct saving effect is negative from 1981 to 1988, peaks 4 percent in 1990, and decreases to between 2 and 3 percent from 1991 to 1995. These estimates may overstate the impact on national saving because they neglect the possible reduction in other savings induced by reform. Schmidt-Hebbel (1999) also finds pension reform in Chile spurs the national saving rate. They estimate pension reform could account for the rise in national saving by from 9.8% to 45%, with the remaining being explained by other structural reforms.

However, some studies find pension reform has no effect on national saving. Bosworth and Burtless (2003) gives empirical evidence that pension saving reduces non-retirement public saving in some European countries. Therefore, national saving does not necessarily increase as
public saving might decrease correspondingly. Samwick (2000) considers the effects of specific pension reforms in a panel of countries on national saving. He finds only Chilean pension reform has a positive effect while none of the European reforms such as in UK (1986) has a significant effect.

**Effects on Capital Formation and Economic Growth.** The report “Averting the Old Age Crisis” (1994) by World Bank claims economic growth is higher in countries with funded pension system than those with unfunded system due to less labor distortion, higher saving, and more efficient capital market. Yet, Barr (2000) argues there is no direct link between funding and growth. He claims three channels through which funding could induce economic growth. First, pension reform leads to a higher saving rate. Second, the higher saving results in more investment. Third, that investment causes an increase in output. However, he argues all of the three links do not necessarily hold.

Empirically, Holzmann (1996) finds a positive relationship between pension reform and economic growth in Chile. He shows improved financial markets following the pension reform significantly increase the total factor productivity (TFP) and the investment rate, thus increasing output by from 1.0% to 2.9%. Yet, Schmidt-Hebbel (1999) finds a much less positive effect with the contribution of pension reform to economic growth ranging from 0.4% to 1.4%.

**Simulation Studies using Auerbach-Kotlikoff Model.** Auerbach and Kotlikoff (1987) develop the large-scale numerical model--Auerbach-Kotlikoff Dynamic Lifecycle Simulation Model. The model is an extended overlapping generation (OLG) model where model parameters are assigned realistic values and simulations are made to observe the effects of different fiscal policies. Their original model contains 55 generations with certain lifetime, perfect foresight, exogenous technological change, and endogenous labor force participation. Later, the original model is extended by adding uncertain lifetime, heterogeneous agents, and credit constraints.
Auerbach et al. (1989) use the model to analyze the effects of aging for four OECD countries: the U.S., Japan, Germany, and Sweden. In their baseline scenario, they simulate the “pure effect” of aging and find aging may decrease national saving rate by 4 percentage points in the United States, and by more than 18 percentage points in Japan between 1990 and 2030. They also simulate the effects of three different policy options: freezing non-pension government expenditures in per capita terms; 2-year increase in the retirement age; and 20% cut in pension benefits. They find all options have a positive effect on the national saving rate compared with the baseline scenario.

A study by European Commission (2001) investigates a transition to a fully funded system in the European Union. If a shift to fully funded system were funded by double-taxing, initially, the total contribution rate would be as high as 28%, yet it would gradually fall to 20% in 2050 and to 17% in 2100. In the long run, this shift would increase GDP by 5%.

A simulation study on seven OECD countries by Hviding and Merette (1998) investigates the macroeconomic impact of possible pension reform options combined with population aging. Reform options include a reduction in pension benefits, phased abolition of PAYG schemes, and general fiscal consolidation. They find fundamental pension reform (gradual removal of public old-age pensions) has a greater effect than parametric reform (20% reduction in the replacement ratio). Although the reform can raise the national saving rate and future GDP levels, the positive effect is not enough to offset the effects of aging in most cases. Thus, to prevent dramatic increases in future taxes, more reduction in benefits or a combination of the simulated measures are necessary.

(3) Other Important Relevant Issues. First, many researchers (Fry and Mason 1982; Mason 1988; Tomoko and Mason 2007) study how demographic transition such as age structure change and increased life expectancy could affect aggregate saving.

Fry and Mason (1982; 1988) develop the “Variable Rate of Growth Effect (VRG) Model” to assess the saving effect of change in dependency ratio. Their basic model is: S/Y = B₀ +
(A_c-A_y) Y_{gr}, where $A_c$ is the mean age of consumption, $A_y$ is the mean age of income, and $Y_{gr}$ is the rate of growth in real GDP. The VRG model shows the rate of growth effect is variable and depends on $(A_c-A_y)$. The change in dependency ratio can affect the timing of consumption over the lifecycle, and thus alters the rate of growth effect on aggregate savings. Tomoko and Mason (2007) analyze steady state and out-of-steady state effects of the increased adult longevity on the national saving rate using an extended two-period OLG simulation model incorporating lifetime uncertainty. They find the increased adult life expectancy has a positive and significant effect on national saving rate if the economy is growing.

Second, some studies discuss the effect of transfer system on saving. Transfers for old-age support can be through family, the familial transfer, or through government, the public transfer in the form of PAYG pension. Barro (1974) argues if the households are altruistic, the introduction of social security may lead to offsetting changes in familial transfer so that social security has no effect of on private saving. Barro’s model suggests public transfer and familial transfer are perfect substitute.

Lee, Mason, and Miller (2003) make a first step to examine the combined effect of transition from public transfer to individual responsibility and aging on saving and wealth in U.S. and Taiwan. They show familial transfer has been replaced by PAYG public pension system in many developing countries and privatization of PAYG pension system in developed countries, which leads to erosion of transfer system. Their simulation results find the waning transfer system may increase wealth accumulation substantially as population is aging rapidly.

In sum, pension reform has received much research attention. Many economists claim pension reform has positive effects on labor markets, saving, and economic growth, yet predicting the magnitude of these effects is very difficult, which depends not only on the features of the reform plan, but also on the reaction and behavior of the households, firms, and government. Additionally, most of existing research mainly focuses on the pension reform from PAYG to full
funding in OECD countries or Chile, yet there is little research on the pension reform from PAYG to partial funding in developing countries such as China in current literature.

1.3 Overview of Pension System Reform in the World and in China

1.3.1 Pension Reform around the World

Current PAYG social security system is facing two challenges: one is financial shortfall of PAYG systems in many countries as their population is aging; the other is its potential negative effects on labor markets, saving, and economic growth. To deal with the two challenges, many countries reformed or are reforming their pension systems from PAYG to funding since the 1981 Chilean pension reform, the first and most radical pension reform (Schmidt-Hebbel 1999) and the influential three-pillar model proposed by the World Bank (1994). These countries range from Latin America (Chile 1981, Mexico 1991, Argentina 1994) to OECD countries (Switzerland 1985, Australia 1992, Italy 1995), from East Europe (Czech 1994, Hungary 1997) to Asia (China 1997, Hong Kong 2000).

In general, there are two types of pension reform in the world: parametric and fundamental pension reform (Lindbeck and Persson 2003). Parametric reform is the one only to improve the long-term solvency of the PAYG pension system by raising contribution rate, reducing pension benefits, etc. France, US, and Ireland have undertaken this kind of reform. Fundamental reform is the one that radically changes the PAYG system by shifting from PAYG to funding, from non-actuarial to actuarial, or the combination of both. In detail, there are four types of fundamental pension reform in practice. First, some Latin America countries such as Chile, Mexico, and Argentina undertook pension reform from PAYG system to privately-managed fully funded system. Second, some economies like Singapore, Hong Kong, and Malaysia implemented Provident Pension Fund system, which is a public-managed fully funded system. Third, many countries like China, Hungary, and Czech Republic have followed the 1994 World Bank Model, which is a partially funded three-pillar system combining a PAYG pillar with
a mandatory fully funded pillar and a voluntary pension pillar. Fourth, some countries like Italy, Poland, and Sweden have moved from non-actuarial PAYG system to notional defined contribution (NDC) system, which in fact is a quasi-actuarial system with closer link between pension contribution and benefit, yet still PAYG-based.

1.3.2 China’s Partially Funded (PF) Three-Pillar Urban Pension System

Since the early 1990s, quite a few major fundamental pension reforms, especially the crucial 1997 reform have transformed an unfunded PAYG system to a Partially Funded multi-pillar system. Table 1.1 lists the basics of China’s new partially funded three-pillar system.

<table>
<thead>
<tr>
<th>Three Pillars</th>
<th>Quality</th>
<th>Contributions</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillar I: Basic Pension Plan</td>
<td>IA: Social Pooling Account</td>
<td>Basic, PAYG, Public-Managed, and Mandatory</td>
<td>From Employer: 20% of employee's wage, at least 15-year contribution</td>
</tr>
<tr>
<td>IB: Individual Account</td>
<td>From Employee: 8% of employee's wage, at least 15-year contribution</td>
<td>Individual Account Assets Divided by Distributing Months¹ (expected 24% replacement ratio)</td>
<td></td>
</tr>
<tr>
<td>Pillar II: Supplementary Pension Plan</td>
<td>Enterprise Annuity Plan</td>
<td>Funded, Complementary, and Voluntary</td>
<td>Contributions from Employer and Employee</td>
</tr>
<tr>
<td>Pillar III: Supplementary Pension Plan</td>
<td>Individual Saving Plan</td>
<td>Funded, Complementary, and Voluntary</td>
<td>Contributions from Employee</td>
</tr>
</tbody>
</table>

¹ Distributing months depend on the life expectancy, retirement age, and interest rate, currently is 139 months.
First, the basic pension (pillar I) consists of a PAYG-based social pooling account and a fully funded individual account, thus the new system is a partially funded pension system in essence. Second, the new system is funded by contributions from both employer and individual, and the government covers the pension deficits. Third, pillar IA, the social pooling account promises the retirees a flat replacement ratio of 35% of previous year’s local average wage. That is, the new system has a partial function of intragenerational income redistribution. Fourth, the total contribution rate is 28% and the expected replacement ratio of the basic pension plan is about 59%, relatively low compared with pre-reform pension benefits, which forces people to save more through voluntary pillar II enterprise annuity plan and pillar III individual saving plan.

1.4 An OLG Model with Homogeneous Representative Agent

In this section, we discuss the macroeconomic and welfare effects of China’s pension reform if the agents are homogeneous and their labor force participation at old-age period is endogenous.\(^1\)

In theory, if the labor force participation is endogenous, agents will maximize their lifetime utility function from both consumption and leisure to determine the optimal amounts of consumption and labor force participation.

Feldstein (1974) shows that there are two opposite effects on saving by introducing social security tax: negative wealth substitution effect and positive earlier retirement effect. The net effect of social security tax on saving is dependent on the relative strength of the two offsetting effects, which resorts to empirical analysis. Hu (1979) and Matsuyama (2000) develop OLG models to consider the case of endogenous labor force participation of old-age people, and find an increase in social security tax induces earlier retirement. Here following Hu (1979) and Matsuyama (2000), we develop a two-period OLG model where the working-age people work

---

\(^1\) For the purpose of comparative analysis, we also consider the case of exogenous labor force participation. Please see the detailed calculation results in Appendix 1.F and Appendix 1.G.
full time and the elderly choose how much they work before retirement by maximizing their lifetime utility.

In the economy, there are two generations of adults coexist at each period: working-age and old-age adults. Each person lives up to two periods, each of which lasts 30 years\(^1\). We assume all individuals lives during working-age period (period 1), yet survives to old-age period (period 2) with the survival rate \(q_t\).\(^2\) At the end of period 2, all survivors will die. Annuity market is perfect so that individuals can purchase an annuity to protect against longevity risk.

There are three sectors in the economy. In this homogenous agent case, all individuals in the same generation are identical, represented by a representative agent. The representative agent seeks to maximize lifetime utility. Here we assume the agent’s retirement decision is endogenous and the saving motive is only for old-age security. Perfectly competitive firms seeking to maximize their profits produce the output of economy. The government is only concerned with the pension system with the responsibilities of establishing, managing, and if necessary, reforming the pension system.

1.4.1 The Economy under PAYG Pension System

Under PAYG pension system, current workers pay contributions to the system in the form of a payroll tax while the current retirees receive pension benefits from the system. In the same period, all contributions are paid out and no reserves are accumulated.

1.4.1.1 Model Set-Up

(1) Representative Firm

Perfectly competitive firm aims to maximize its profits. Output function is a Cobb-Douglas production function:

\[
Y_t = K_t^\alpha (L_t)^{1-\alpha}
\]  

\(^1\) We assume working-age period is from 25 to 55 years old and old-age period is from 55 to 85 years old.

\(^2\) \(q_t\) is the survival rate for working-age adult at the end of working period \(t\).
Where $Y_t$ is output, $K_t$ is the stock of physical capital, $L_t$ is effective labor supply.

$$L_t = H_t(N_{y,t} + N_{a,t}lp_t) \quad (1.2)$$

Where $H_t$ is the stock of human capital owned by a representative agent, an exogenous variable determined by the technology and growing at a constant rate $g$. $N_{y,t}$ is the population of working-age adults, also an exogenous variable growing at a constant rate $n$. $N_{a,t}$ is the population of old-age adults and $lp_t$ is the labor force participation of the old-age adults.

Dividing (1.1) by $L_t$, we get $y_t = H_t k_t^\alpha$, where $y_t$ and $k_t$ represent output per unit of labor and capital per unit of effective labor respectively.\(^1\)

The firm’s profit function is:

$$\pi_t = Y_t - r_t K_t - w_t L_t \quad (1.3)$$

Where $\pi_t$, $w_t$, $r_t$ represent firm profit, real wage, real interest rate at period $t$ respectively.

The representative firm maximizes its profit. Solving the maximization problem (1.3), we get:

$$r_t = \frac{\partial Y_t}{\partial K_t} = \alpha k_t^{\alpha-1} \quad (1.4)$$

$$w_t = \frac{\partial Y_t}{\partial L_t} = (1-\alpha)k_t^\alpha \quad (1.5)$$

(2) Homogeneous Representative Agent

The representative agent lives two periods and two generations coexist at the same period. The agent lives during working-age period (period 1), yet survives to old-age period (period 2) with the survival rate $q_t$. At working-age period, the agent works, saves, and pays PAYG payroll tax. He also uses savings to purchase an annuity from a perfect annuity market with a rate of

\(^1\) Later, lower case letters represent quantities per unit of labor.
return of the annuity \( \frac{1 + r_{t+1}}{q_t} \). During old-age period, instead of immediate retirement, he determines the amount to work before retirement. We assume the agent only provide one unit of labor at each period. After retirement, he lives on pension benefits and the savings.

The agent decides the optimal amount of working-age consumption, old-age consumption, and labor force participation by maximizing the following lifetime utility function\(^1\).

\[
U = U(c_{y,t}, c_{o,t+1}, \ell_p) = \ln c_{y,t} + \frac{q_t}{1 + \rho \beta} \left[ \ln c_{o,t+1} + \beta \ln (1 - \ell_p) \right] 
\]

(1.6)

The working-age budget constraint is:

\[
c_{y,t} + s_{y,t} = (1 - \tau_{pg}) H_t w_t
\]

(1.7)

where subscript \( y \) means working-age, \( o \) means old-age, \( pg \) means PAYG system; \( c_{y,t}, s_{y,t}, \) and \( c_{o,t+1} \) represent consumption per capita, saving per capita during working-age, and consumption per capita during old-age respectively; \( \tau_{pg} \) is the PAYG social security contribution rate and \( \rho \) is the pure rate of time preference. \( \ell_p \) is the labor force participation of the elderly and \( 1 - \ell_p \) is the leisure enjoyed by the elderly, \( 0 \leq \ell_p \leq 1. \beta \) is the agent’s preference for leisure.

During old-age period, the agent provides \( \ell_p \) unit of labor before retirement. After retirement, he gets pension benefits. The old-age budget constraint is:

\[
c_{o,t+1} = \left( \frac{1 + r_{t+1}}{q_t} \right) s_{y,t} + (1 - \tau_{pg}) H_{t+1} w_{t+1} \ell_p + B_{t+1}
\]

(1.8)

Where \( B_{t+1} \) is the pension benefits. Under PAYG system, the pension benefits are equal to pension contributions at the same period, so \( B_{t+1} \) is:

\[
B_{t+1} = \frac{\tau_{pg} H_{t+1} w_{t+1} N_{o,t+1}}{N_{o,t+1}} + H_{t+1} w_{t+1} \tau_{pg} \ell_p \rightarrow N_{o,t+1} = \tau_{pg} H_{t+1} w_{t+1} \left[ \frac{(1 + n)}{q_t} + \ell_p \right]
\]

(1.9)

\(^1\) Here we follow Tomoko and Mason (2007)’s utility function incorporating adult survival rate \( q_t \), yet for simplicity, we assume the utility function is a two-period separable logarithmic-linear utility function.
From (1.7), (1.8), and (1.9), we can get the following agent’s lifetime budget constraint:

$$c_{y,t} + \frac{c_{o,t+1}}{(1+r_{t+1})/q_t} = (1-\tau_{pg})H_t w^t + \frac{lp_{t+1}H_{t+1}w_{t+1}}{(1+r_{t+1})/q_t} + \frac{\tau_{pg}H_{t+1}w_{t+1}(1+n)}{(1+r_{t+1})}$$  \hspace{1cm} (1.10)

(3) Government

Government is responsible for levying the payroll tax from working population and distributing pensions to the retired population. We assume all pension contributions are paid out for benefits and thus no reserves are accumulated in the same period. Therefore, government budget is balanced under PAYG system.  

1.4.1.2 Solving the Model

The agent’s utility maximization problem is:

Maximizes \( U = \ln c_{y,t} + \frac{q_t}{1+\rho} \left[ \ln c_{o,t+1} + \beta \ln (1-lp_{t+1}) \right] \)

s.t. \( c_{y,t} + \frac{c_{o,t+1}}{(1+r_{t+1})/q_t} = (1-\tau_{pg})H_t w^t + \frac{lp_{t+1}H_{t+1}w_{t+1}}{(1+r_{t+1})/q_t} + \frac{H_{t+1}w_{t+1}(1+n)}{(1+r_{t+1})} \)

Solving the Agent’s Utility Maximization Problem (1.11) ², we can get the agent’s optimal consumption during working age \( c_{y,t} \), consumption during old-age \( c_{o,t+1} \), saving of working-age \( s_{y,t} \) and labor force participation of the elderly \( lp_{t+1} \):

\[
\begin{align*}
c_{y,t} & = \frac{1}{\lambda} \times \frac{(1+r_{t+1})(1-\tau_{pg})H_t w^t + H_{t+1}w_{t+1} [\tau_{pg}(1+n) + q_t]}{(1+r_{t+1})(1+q_t \beta \delta + q_t \delta)} \quad (1.12) \\
c_{o,t+1} & = \frac{1+r_{t+1}}{1+\rho} \times \frac{1}{\lambda} \times \frac{(1+r_{t+1})(1-\tau_{pg})H_t w^t + H_{t+1}w_{t+1} [\tau_{pg}(1+n) + q_t]}{(1+q_t \beta \delta + q_t \delta)/\delta} \quad (1.13) \\
lp_{t+1} & = \frac{H_{t+1}w_{t+1}(1+q_t \delta) - H_t w^t \beta \delta (1+r_{t+1})(1-\tau_{pg}) - \beta \delta H_{t+1}w_{t+1} \tau_{pg}(1+n)}{H_{t+1}w_{t+1}(1+q_t \beta \delta + q_t \delta)} \quad (1.14)
\end{align*}
\]

¹ We also assume except for the pension-related contributions and payments, other government incomes and expenses are balanced automatically.

² Here we do not consider the optimal corner solution. In fact, if there exists corner solution, that is \( lp_{t+1}=0 \) or 1, it is just the case of exogenous labor force participation. Please see Appendix 1.A for the detailed calculations of solving the problem.
The total savings in the economy $S_t$ are the sum of the working people saving $S_{y,t}$ and retired people saving $S_{o,t}$. During the working period, the agent saves and accumulates assets. After retirement, he uses the accumulated assets to smooth his consumption. Because there is no bequest motive, he will deplete all his assets at the end of the old-age period. The saving of old-age $s_{o,t}$ is:

$$s_{o,t} = \left(1 + \frac{r}{q_{t+1}}\right) s_{y,t} - c_{o,t} = \left(1 + \frac{r}{q_{t+1}}\right) s_{y,t} - \frac{1 + r}{q_{t+1}} s_{y,t} - 1 = -s_{y,t}$$

$$S_t = s_{y,t} + s_{o,t} = s_{y,t} N_{y,t} - s_{y,t} N_{o,t}$$

The national saving rate $\frac{S_t}{Y_t}$ is:

$$\frac{S_t}{Y_t} = \frac{s_{y,t} N_{y,t} - s_{y,t} N_{o,t}}{L_k k_t^{\alpha}} = \phi \omega H - \phi \omega \left(\frac{k}{k_{t+1}}\right)^\alpha \frac{H_{t+1} k_t^{\alpha}}{1 + \frac{q_{t+1}}{1 + n}} = \frac{(1 - \alpha) \left[ \phi - \phi_{t+1} \left(\frac{k}{k_{t+1}}\right)^\alpha \right]}{(1 + \frac{q_{t+1}}{1 + n} l p) (1 + n)(1 + g)}$$

(1.16)

Where $\phi$ is the share of saving of wage income for working-age adults:

$$\phi = s_{y,t} = \frac{(1 + r_{t+1})(q_{y,t} - q_{y,t}) - (1 - \tau_{pg})(1 + g)}{(1 + r_{t+1})(1 + q_{y,t} + q_{y,t})}$$

(1.15)

The capital condition for the PAYG economy is:

$$K_{t+1} = s_{y,t} N_{y,t}$$

(1.17)

That is, only the working-age people’s savings channeled through the financial system are accumulated as capital and take part in the economy’s production process. The contributions
to the PAYG system do not become capital because they are directly paid to current old-age adults as intergenerational transfers.

\[ k_{t+1} = s_{y,t} \frac{N_{y,t}}{L_{y,t}} = \frac{\phi_{t}w_{t}N_{y,t}}{L_{y,t}} = \frac{\phi_{t}(1-\alpha)k^{*}}{(1 + n + q_{t}lp_{t})(1 + g)} \]  

(1.18) is an equation describing the evolution of capital per unit of effective labor from period t to period t+1 under PAYG economy.

At steady state, the capital per unit of effective labor at PAYG system \( k^{*}_{pg} \) is:

\[ k^{*}_{pg} = \frac{\phi^{*}(1-\alpha)}{(1 + n + q^{*}lp^{*})(1 + g)} \]  

(1.19)

Where, \( \phi^{*} \) is the steady state share of saving of wage income for working-age adults and \( lp^{*} \) is the steady state labor force participation of the elderly.

\[ \phi^{*} = \frac{(1 + r^{*})(q^{*} \beta \delta + q^{*} \delta)(1-\tau_{pg})-(1+g)[\tau_{pg}(1+n)+q^{*}]}{(1 + r^{*})(1 + q^{*} \beta \delta + q^{*} \delta)} \]  

(1.20)

\[ lp^{*} = \frac{(1 + q^{*} \delta) - \beta \delta(1 + r^{*})(1-\tau_{pg})/(1 + g) - \beta \delta \tau_{pg}(1+n)}{(1 + q^{*} \beta \delta + q^{*} \delta)} \]  

(1.21)

(1.19) - (1.21) are an implicit equation group, from which, we can know \( k^{*}_{pg} \) is dependent on seven parameters including \( q^{*} \), \( \alpha \), \( \tau_{pg} \), \( \rho \), \( n \), \( g \), \( \beta \). If we assign the specific values to the six parameters resembling one country’s specific scenario, we can get the real value for \( k^{*}_{pg} \).

Now we can further calculate a series of economic variables to resemble the steady state economy under PAYG pension system\(^1\). These variables can be organized into two groups: macroeconomic variables group and individual welfare variables group.

1) Macroeconomic Variables: \( k^{*}_{pg} \), \( y^{*}_{pg} \), \( (\frac{S}{Y})^{*}_{pg} \), \( (\frac{K}{Y})^{*}_{pg} \), \( r^{*}_{pg} \), and \( w^{*}_{pg} \)

---

\(^1\) Please see Appendix 1.B for the detailed calculations of the steady state economic variables.
The steady state output per worker $y^*$ is:

$$y^* = H k^* \alpha$$  \hspace{1cm} (1.22)$$

The steady state national saving rate $\left( \frac{S}{Y} \right)^*$ is:

$$\left( \frac{S}{Y} \right)^* = \frac{(1 - \alpha) \phi * \left[ \frac{n g + n + g}{(1 + n)(1 + g)} \right]}{1 + \frac{q^*}{1 + n} l p^*}$$  \hspace{1cm} (1.23)$$

The steady state interest rate $r^*$ and wage $w^*$ are:

$$r^* = \alpha k^* \alpha^{-1}$$  \hspace{1cm} (1.24)$$

$$w^* = (1 - \alpha) k^* \alpha$$  \hspace{1cm} (1.25)$$

In addition, $r^*$ is the interest rate for a period, which lasts 30 years, so the annual interest rate $\overline{r} = \sqrt[30]{1 + r} - 1$.  \hspace{1cm} (1.26)$$


The steady state young-age consumption per unit of labor $c^*_{y,pg}$ is:

$$c^*_{y,pg} = \frac{(1 + r^*_p)(1 - \tau_p)H^* w^*_{pg} + H^* w^*_{pg} (1 + g)\left[ \tau_p (1 + n) + q^* \right]}{(1 + r^*_p)(1 + q^* \beta \delta + q^* \delta)}$$  \hspace{1cm} (1.27)$$

The steady state old-age consumption per unit of labor $c^*_{o,pg}$ is:

$$c^*_{o,pg} = \frac{(1 + r^*_p)(1 - \tau_p)H^* w^*_{pg} + H^* w^*_{pg} (1 + g)\left[ \tau_p (1 + n) + q^* \right]}{(1 + q^* \beta \delta + q^* \delta) / \delta}$$  \hspace{1cm} (1.28)$$

The steady state agent’s lifetime utility $U^*_p$ is:

$$U^*_p = \ln c^*_{y,pg} + \frac{q^*}{1 + \rho} \left[ \ln c^*_{o,pg} + \beta \ln (1 - lp^*) \right]$$  \hspace{1cm} (1.29)$$
The pension replacement ratio $\text{REP}_{pg}$ is the ratio of the pension received after retirement to the wage income before retirement, considered as the index of pension benefits level.

$$\text{REP}_{pg} = \frac{\tau_{pg} (1+g)w_{t+1}}{w_t} \left(\frac{1+n}{q_t} + lp_{t+1}\right),$$

so the steady state pension replacement ratio $\text{REP}_{pg}^*$ is

$$\text{REP}_{pg}^* = \tau_{pg} (1+g)\left(\frac{1+n}{q^*} + lp^*\right) \quad (1.30)$$

The agent’s lifetime income $I_{pg}$ is the present value of the total income throughout his whole life. $I_{pg} = (1-\tau_{pg})H_w + \frac{lp_{t+1}H_{w_{t+1}}}{(1+r_{pg})} + \frac{\tau_{pg}H_{w_{t+1}}}{(1+r_{pg})}$, so the steady state lifetime income $I_{pg}^*$ is:

$$I_{pg}^* = (1-\tau_{pg})H^* w^* + H^* w^* \left[\frac{\tau_{pg} (1+n)(1+g)}{q^*(1+r_w^*)} + lp^*\left(1+g\right)\right] \quad (1.31)$$

The present value of income redistribution $R_{pg}$ is defined as the ratio of the present value of agent’s net pension income during the lifetime to the wage income during working-age, a variable measuring the intergenerational or intragenerational income redistribution effect of PAYG system. Here under the case of homogeneous agent, $R_{pg}$ only measures intergenerational income redistribution effect. $R_{pg} = \frac{\tau_{pg}H_{w_{t+1}}}{(1+r_{pg})}$, so the steady state present value of income redistribution $R_{pg}^*$ is:

$$R_{pg}^* = \frac{\tau_{pg} (1+g)}{1+r_w^*} \left(\frac{1+n}{q^*} + lp^*\right) - \tau_{pg} = \frac{\tau_{pg} (1+g)}{1+r_w^*}[\left(\frac{1+n}{q^*} + lp^*\right) - (1+r_w^*)] \quad (1.32)$$

From (1.32), if $(1+g)\left(\frac{1+n}{q^*} + lp^*\right) < (1+r_w^*)$, then $R_{pg}^* < 0$, similar to Aaron condition (1966), which means if the rate of economic growth is greater than the steady state interest rate, it
is intergenerationally unfair for the current generation as he makes upward intergeneration transfer to other generations.

1.4.2 The Economy under Partially Funded System

Under the Partially Funded (PF) pension system, current workers pay contributions to the system in the form of the payroll tax. The contributions are used for two aims. On one hand, like the PAYG system, part of the contributions is used as social pension payments for the retired people. On the other hand, the rest of the contributions are accumulated as pension savings at their individual accounts. After retirement, correspondingly, the retirees can get two kinds of pensions. One is the social pensions from social account; the other is the accumulated pension savings at their individual accounts.

We assume at the reform period t, the PAYG economy reaches steady state and a pension reform from PAYG to partial funding occurs.

One issue challenging the kind of pension reform from PAYG to funding is the implicit pension debts become explicit. Under the PAYG system, the current working population pays contributions in the form of the payroll tax to the system while the current retired population receives benefits in the form of pension from the system. All contributions and benefits are balanced and no reserves are accumulated at the same period. Now once the pension reform from PAYG to funding occurs, all or part of contributions of current working population are accumulated at their individual account and no longer used to pay the pension benefits for the retired population, so there appears explicit pension debts, that is the transition costs. It is the government’s obligation to assume the explicit pension debts and find how to finance the debts. For example, the government can choose to impose additional tax on current generations to pay up all the debts, or it can spread the debts to future generations and thus all generations can share the burden. Different ways of funding the transition costs have different effects on capital accumulation and intergenerational equity.
In this paper, we assume that the government assumes all the transition costs accumulated during the reform period $t$ by issuing government bonds. The working age adults buy the government bonds, and will be repaid with the bond principal and resultant interests during their old-age period. The stock of government bonds $D_t$ keeps constant since reform period $t$. The government levies a special consumption tax $\tau_c$ on consumers after reform period $t$ to pay the bond interests.

1.4.2.1 Model Set-Up

(1) Homogeneous Representative Agent

Representative agent works, saves, buys government bonds, and pays social pooling account and individual account contributions at working-age period. During old-age period, instead of immediate retirement, he decides the amount to work before retirement. After retirement, he lives on social account pension benefits, individual account pension benefits, repaid government bonds, and annuity savings. The agent also has to pay the consumption tax to finance the transition costs.

The agent’s lifetime utility function is same as before:

$$U = U(c_{y,t}, c_{o,t+1}, lp_t) = \ln c_{y,t} + \frac{q_t}{1 + \rho} \left[ \ln c_{o,t+1} + \beta \ln (1 - lp_t) \right]$$

The young-age consumption constraint condition now is:

$$(1 + \tau_c)c_{y,t} + s_{y,t} + d_t = (1 - \tau_i)(1 - \tau_{pf})H_tw$$

Where subscript pf means partially funded system, $\tau_{pf}$ is the contribution rate to social pooling account, $\tau_i$ is the contribution rate to individual account, $d_t$ is the government debt per unit of young labor, other variables are same as above.

The old-age consumption constraint condition now becomes:
\[(1 + \tau) c_{a,t+1} = (1 + r_{t+1}) \left( s_{y,t} + d_t \right) + \left( 1 + r_{t+1} \right) \frac{1}{q_t} c_{a,t+1} + (1 - \tau_{yf}) H_t w_t + (1 - \tau_{pf}) H_{t+1} w_{t+1} l p_{t+1} + B_{t+1} \tag{1.33} \]

(1.33) means the old-age agent has four kinds of income to cover his old-age consumption. The first term of RHS is his annuity income and repaid government bonds, the second term is the pension savings deposited at his individual account, the third term is the wage income during old-age period, the last term \( B_{t+1} \) is the pension benefit from the social pooling account.

The agent’s lifetime budget constraint is:

\[
(1 + \tau_c) c_{y,t} + \frac{q_t (1 + \tau_c) c_{a,t+1}}{1 + r_{t+1}} = H_t w_t (1 - \tau_{yf}) + \tau_{yf} H_{t+1} w_{t+1} \left( \frac{1 + n}{1 + r_{t+1}} \right) + \frac{l p_{t+1} H_{t+1} w_{t+1}}{(1 + r_{t+1}) / q_t} \]

(2) Representative Firm

The perfectly competitive firms seek to maximize the profit function as follows:

\[
\pi_t = Y_t - r_t K_t - w_t L_t \tag{1.34} \]

Where \( L_t = H_t (N_{y,t} + N_{a,t} l p_{t}) \). We can get:

\[
r_t = \frac{\partial Y_t}{\partial K_t} = \alpha k_t^{-1} \quad \text{and} \quad w_t = \frac{\partial Y_t}{\partial L_t} = (1 - \alpha) k_t^{\alpha} \tag{1.35} \]

(3) Government: Transition Costs and Transitional Variables

Under a Partially Funded system, government has three responsibilities. Firstly, at the social pooling account pillar, government is responsible for levying contributions from working population and distributing pension benefits to the retired people at the same period. Secondly, at the individual account pillar, government is responsible for managing and investing the individual account of the working people. After working people retire, government guarantees that they get all the accumulated assets. Thirdly, government is responsible for assuming and financing the transition costs.

\[
B_{t+1} = \frac{\tau_{yf} H_{t+1} w_{t+1} N_{y,t+1} + H_{t+1} w_{t+1} \tau_{pf} N_{a,t+1} l p_{t+1}}{N_{a,t+1}} = \frac{\tau_{yf} H_{t} w_{t} \left( 1 + n \right) l p_{t+1}}{q_t} \]

\[25\]
We assume a pension reform from a PAYG system to a Partially Funded system occur at period \( t \) and the government bears the transition costs accumulated at reform period \( t \). \( TC_t \) is the total transition costs, equal to the contributions from working people under PAYG system less social security contributions from working people under the Partially Funded system. \( tc_t \) is the transition cost per unit of effective labor.

\[
TC_t = \tau_{pg} H_t w_t N_{y,t} - \tau_{pf} H_t w_t N_{y,t} = (\tau_{pg} - \tau_{pf}) H_t w_t N_{y,t}
\]

(1.36)

\[
tc_t = \frac{TC_t}{L_t} = (\tau_{pg} - \tau_{pf}) w_t = (\tau_{pg} - \tau_{pf}) w_{pg}^*
\]

(1.37)

How to pay the transition costs becomes an important issue because different policy options have different effects on capital evolution, intergenerational equity, and other economic variables. Here we assume the government bears the transition costs by issuing government bonds. The working-age adults buy the government bonds, and will be repaid with the bond principal and interests during old-age period. The stock of government bonds \( D_t \) keeps constant. In order to pay the bond interests, the government levies a special consumption tax \( \tau_c \) on consumers.

From the assumption above, we can get:

\[
D_t = TC_t = (\tau_{pg} - \tau_{pf}) H_t w_t N_{y,t}
\]

(1.38)

\[
\tau_c = \frac{D_t r_t}{c_{y,t} N_{y,t} + c_{a,t} N_{a,t}} = (\tau_{pg} - \tau_{pf}) H_t w_t r_t
\]

(1.39)

The steady state special consumption tax \( \tau_c^* \) is:

\[
\tau_c^* = \frac{(\tau_{pg} - \tau_{pf}) H^{*} w_{pg}^* r^*}{c_{y}^* + c_{a}^* q^*/(1 + n)}
\]

(1.40)

The new capital condition for the Partially Funded economy with government debts is:

\[
K_{t+1} = s_{y,t} N_{y,t} = \phi_t H_t w_t N_{y,t} - D_t
\]

(1.41)
Where $s'_{y,t}$ is the savings of the agent, the sum of annuity saving and individual account saving.

Under the Partially Funded (PF) economy, not only the agent’s annuity saving but also the individual account pension saving is accumulated as capital through the financial system. That is one of the key differences between a PF system and a PAGY system.

The stock of government debts $D_t$ keeps constant since reform period $t$, i.e.

$$D_t = D_{t+1} = D_{t+2} = \cdots = D_{t+T} = D_{pf} = TC_i = (\tau_{pg} - \tau_{pf})H_ww_{t}N_{y,t}$$

The evolution function of capital per unit of effective labor under the Partially Funded system $k_{t+1}$ is:

$$k_{t+1} = \frac{\phi_iH_ww_{t}N_{y,t}}{L_{t+1}} - \frac{\tau_{pg} - \tau_{pf})(1-\alpha)(1-\tau_{pg})k_{t}}{1+n+q/l_{t+1}(1+g)}\frac{\phi_i(1-\alpha)(1-\tau_{pg})k_{t}}{1+n+q/l_{t+1}(1+g)}$$

**1.4.2.2 Solving the Model**

Solving the model above, we can get steady state capital per unit of effective labor $k_{pf}^*$:

$$k_{pf}^* = \frac{\phi^*(1-\alpha)}{(1+n+q^*lp^*)(1+g)} - \frac{(\tau_{pg} - \tau_{pf})(1-\alpha)k_{pf}^{*a}}{(1+n+q^*lp^*)(1+g)k_{pf}^{*a}}$$

(1.42)

Where $\phi^*$, $lp^*$, and $r^*$ are:

$$\phi^* = \frac{(1+r^*)(q^*\beta\delta + q^*\delta)(1-\tau_{pf}) - (1+g)[\tau_{pf}(1+n) + q^*]}{(1+r^*)(1+q^*\beta\delta + q^*\delta)}$$

(1.43)

$$lp^* = \frac{(1+q^*\delta) - \beta\delta(l+q^*)(1-\tau_{pf})(1+g) - \beta\delta\tau_{pf}(1+n)}{(1+q^*\beta\delta + q^*\delta)}$$

(1.44)

$$r^* = \alpha k_{pf}^{*a-1}$$

(1.45)

(1.42) to (1.45) are an implicit equation group for $k_{pf}^*$, $\phi^*$, $lp^*$, and $r^*$. We can further get other economic variables.$^2$

$^1$ Please see APPENDIX 1.C for detailed calculation of $k_{pf}^*$.

$^2$ Please see APPENDIX 1.D for detailed calculation of the steady state economic variables and transitional variables.
1) Macroeconomic Variables: $k^*_p$, $y^*_p$, $(S/Y)^*_{pf}$, $r^*_p$, and $w^*_p$

$$y^*_p = H^* k^*_p \alpha$$  \hspace{1cm} (1.46)

$$(S/Y)^*_{pf} = \frac{(1-\beta)^*}{\phi^*} \left[ \frac{1}{(1+n)(1+g)} \right] (1+\frac{q^*}{1+n}lp^*) \hspace{1cm} (1.47)$$

$$r^*_p = \alpha k^*_p \alpha^{-1} \hspace{1cm} (1.48)$$

$$\bar{r} = \sqrt{1+r^*_p} - 1 \hspace{1cm} (1.49)$$

$$w^*_p = (1-\alpha)k^*_p \alpha \hspace{1cm} (1.50)$$

2) Individual Welfare Variables: $c^*_{y,pf}$, $c^*_{o,pf}$, $U^*_p$, $REP^*_p$, $I^*_p$, and $IR^*_p$

$$c^*_{y,pf} = \frac{(1+r^*)(1-\tau^*_pf)H^* w^* + H^* w^*(1+g)\left[ \tau^*_pf(1+n) + q^* \right]}{(1+r^*)(1+q^*\beta + q^*\delta)(1+r^*)} \hspace{1cm} (1.51)$$

$$c^*_{o,pf} = \frac{(1+r^*)(1-\tau^*_pf)H^* w^* + H^* w^*(1+g)\left[ \tau^*_pf(1+n) + q^* \right]}{(1+q^*\beta + q^*\delta)(1+r^*)/\delta} \hspace{1cm} (1.52)$$

$$U^*_p = \ln c^*_{y,pf} + \frac{q^*}{1+\rho} \left[ \ln c^*_{o,pf} + \beta \ln(1-lp^*) \right] \hspace{1cm} (1.53)$$

$$REP^*_p = \tau^*_pf(1+g)\left( \frac{1+n}{q^*} + lp^* \right) + \left( \frac{1+r^*}{q^*} \right) \tau^*_i(1-\tau^*_pf) \hspace{1cm} (1.54)$$

$$I^*_p = (1-\tau^*_pf)H^* w^* + H^* w^* \left[ \frac{\tau^*_pf(1+n)(1+g)}{q^*(1+r^*)} + \frac{lp^*(1+g)}{(1+r^*)} \right] \hspace{1cm} (1.55)$$

$$IR^*_p = \frac{\tau^*_i(1-\tau^*_pf)}{q^*} + \frac{\tau^*_pf(1+g)}{1+r^*} \left( \frac{1+n}{q^*} + lp^* \right) - \tau^*_i(1-\tau^*_pf) - \tau^*_pf \hspace{1cm} (1.56)$$

3) Transitional Variables: $tc^*_c$, $T_{C^*}$, and $r^*_c$
We use two variables to measure the scale of transition costs. $t_{c_t}$ is the transition cost per unit of effective labor and $\frac{TC_t}{Y_t}$ is the ratio of transition costs to the output at reform period $t$.

$$t_{c_t} = \frac{TC_t}{L_t} = (\tau_{pg} - \tau_{pf})w_{pg}^*$$

(1.57)

$$\frac{TC_t}{Y_t} = \frac{tc_{L_t}}{y_{pg}^*L_t} = \frac{(\tau_{pg} - \tau_{pf})w_{pg}^*}{y_{pg}^*}$$

(1.58)

The steady state special consumption tax $\tau_{c}^*$ is:

$$\tau_{c}^* = \frac{(\tau_{pg} - \tau_{pf})H^*w_{pg}^*r}{c_n^*(1+n)^T + c_n^*q^*(1+n)^T}$$

(1.59)

### 1.4.3 Simulation Analysis of Pension Reform

#### 1.4.3.1 Parameter Values Selection

The model parameters include ten parameters $n, q^*, \alpha, g^*, H^*, \tau_{pf}^*, \tau_{pg}^*, \delta, \beta$. We assign realistic values resembling of China’s real economy to the models’ parameters.

In reality, China begun the pension reform from PAYG to partial funding since the middle 1990s, yet in this paper, for simplicity, we assume the pension reform begun since 2000 and PAYG economy reached steady state in 2000.

We divide the nine parameters $q^*, \alpha, \tau_{pg}^*, \tau_{pf}^*, \delta, n, g^*, H^*, \beta$ into three categories.

1) **Population Factors: $n$ and $q^*$**

$n$ is the working-age population growth rate for a period lasting 30 years, which we assume a constant in our model. In the next 50 years, China will be in the rapid aging process. According to population data from UN\textsuperscript{1}, the ratio of working population aged 15-64 in China is estimated to be 72% in 2010, 69.8% in 2020, 66.5% in 2030, 62.2% in 2040, and 61% in 2050.

\textsuperscript{1} UN Population Division: World Population Prospects: The 2008 Revision Population Database, Medium Variant Case.
Given the great change in China’s population structure, in order to calculate \( n \) as exactly as possible, we separately calculate the working-age population growth rates from 1990 to 2020 and from 2020 to 2050 by using UN population data, then calculate the average of the two periods’ working-age population growth rates, which is \( n \). From 1990 to 2020, the working-age population increases from 767.981 million to 991.903 million with an average rate 0.292. From 2020 to 2050, the working-age population decreases from 991.903 million to 859.778 million with a negative average growth rate -0.133. Thus, \( n=0.08 \). \(^1\) We also compare the age structure between UN estimates and This Paper in Table 1.2. First, from the column A of the Table, the age group 30-59 accounts for a major ratio of the working population (the age group 15-64). Second, from the column B of the Table, this Paper has an older age structure before 2030, and a younger age structure after then, yet the difference in age structure is mild.

### Table 1.2: Comparison of Age Structure between UN Estimates and This Paper

<table>
<thead>
<tr>
<th>Year</th>
<th>Ratio of aged 30-59/aged 15-64 (Column A)</th>
<th>Ratio of aged 30-59/aged 60+ (Column B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UN Estimates</td>
<td>This Paper</td>
</tr>
<tr>
<td>1990</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>2000</td>
<td>0.65</td>
<td>0.62</td>
</tr>
<tr>
<td>2010</td>
<td>0.65</td>
<td>0.60</td>
</tr>
<tr>
<td>2020</td>
<td>0.67</td>
<td>0.59</td>
</tr>
<tr>
<td>2030</td>
<td>0.64</td>
<td>0.60</td>
</tr>
<tr>
<td>2040</td>
<td>0.64</td>
<td>0.67</td>
</tr>
<tr>
<td>2050</td>
<td>0.63</td>
<td>0.66</td>
</tr>
</tbody>
</table>


We define adult survival rate \( q_i \) as the probability of living at the working-age period (from 25 to 54 years old) and survival to the old age period (from 55 to 84 years old), that is,

\[
q_i = \frac{\sum_{a=55}^{85} N_{a,t+1}}{\sum_{a=25}^{54} \sum_{a,t} N_{a,t}}, \text{ where } N_{a,t} \text{ is the population aged } a \text{ at period } t.
\]

\(1\) As China’s current fertility rate is below the replacement rate due to the “One-Child Policy”, China’s actual working-age population growth rate is probably lower than the assumed 0.08. Yet, as China’s government is adjusting the “One-Child Policy” and permitting the young couples who are the only one child of their family can give birth to two children. So, the fertility rate and population growth rate should become higher later.
dataset on China only covers from 1950 to 2050, we can only calculate three periods adult survival rates: \( q_1, q_2, q_3 \). They are 0.605, 0.746, and 0.759 respectively. The increase in survival rate is high from 1960 to 2020 and becomes much lower from 2020-2050. Thereafter, it is expected the growth will become even flatter.

\( q^* \) is the steady state adult survival rate. It may take several periods or more for the economy after pension reform to reach the steady state. As there is no sufficient data to calculate \( q^* \), we assume \( q^* = 0.8 \) based on the trend of \( q_i \).

2) Economic and Technological Factors: \( \alpha, g, \) and \( H \)

\( \alpha \) is output elasticity with respect to capital. It is difficult to estimate this parameter due to both rapid change of China’s economic structure and insufficient and inaccurate data. Economists use different methods and different data sources, and thus get different estimates for \( \alpha \). For example, a study by OECD (2005)\(^2\) calculates \( \alpha = 0.53 \) during 1978-2003. Cai and Wang (2002) uses FGLS regression method to get an estimated value 0.45 for \( \alpha \) using China’s time-series data during 1978-1998. Additionally, Bentolina and Saint-Paul (2003) analyze the factors explaining the movement of labor share in OECD countries since 1970 and find it is essentially related to the capital-output ratio. Zhao and Liu (2006) estimate the average output elasticity of capital is 0.48 from 1978 to 2004 and find the output elasticity of capital is decreasing while that of labor is increasing. Zhang (2011) finds the output elasticity of capital decreases from 0.51 in 1978 to 0.46 in 2000. Here following Cai and Wang (2002), we assume \( \alpha = 0.4 \) given the value of 0.46 is still a little higher compared with those in other countries.

\( g \) is technological improvement growth during a period. We use Total Factor Productivity (TFP) as an index of technological improvement, thus use the growth of TFP as a proxy for \( g \).

---

1 period 1 means 1960-1990, period 2 means 1990-2020, period 3 means 2020-2050
Same as the case of $\alpha$, different research has different estimates for $\gamma$. Young (2003) shows China’s TFP grows at the yearly rate of 1.4% between 1978-1998. A research by UNIDO (2005)\(^1\) estimates the annual growth rate of China’s TFP is 1% between 1979-2000 (1.5% in 1979-1992 ad -0.8% in 1993-2000) by using a multi-national model and data calculated by the PPP index. Ozyurt (2009) finds capital accumulation has been the main engine of China’s economic growth and annual growth rate of TFP is 0.67% between 1979-2005 (-2.6% in 1979-1992 ad 3.1% in 1993-2005). A Chinese study by Yan and Wang (2004) estimates the annual growth rate of China’s TFP is -0.17% between 1978-1991 and 0.79% between 1992-2001. Here based on the UNIDO (2005)’s study, we assume annual growth rate of technological improvement equal to 1%, thus technological improvement growth during a period (30 years) $g$ is 0.348.

$H$ is the steady state stock of human capital with an arbitrary value. $H$ may affect absolute values of welfare and income variables such as $c_s^*, c_o^*, U^*, I^*$, yet it has no effect on the relative change of these variables. As the main results of this Paper are based on the relative change of these economic variables, the value of $H$ does not affect the main results. Here we assume $H$ is 100 with an indirect reason that the values for the affected variables are positive.

3) Other Parameters: $\tau_{pf}, \tau_i, \tau_{pg}, \delta, \rho, \beta$

$\tau_{pf}$ is Partially Funded system social security contribution rate. $\tau_i$ is Partially Funded system individual account contribution rate. According to the regulations of China’s new partially funded pension system, $\tau_{pf} = 0.2$ and $\tau_i = 0.08$.

$\tau_{pg}$ is PAYG system contribution rate. Under China’s traditional PAYG system, there is no unified regulation on it. For simplicity, we can assume the contribution rates under two pension systems are same, that is, $\tau_{pg} = \tau_i (1 - \tau_{pf}) + \tau_{pf} = 0.264$.

\( \rho \) is the pure rate of time preference during a period and \( \delta \) is the discount rate \((\delta = 1 / (1 + \rho))\). We set the pure rate of time preference per year equal to 1.5%, the same level used in the original Auerbach-Kotlikoff Model. Thus, 
\[
\rho = (1 + 0.015)^{30} - 1 = 0.56 \\
\delta = 1 / (1 + \rho) = 0.64.
\]

\( \beta \) is agent’s preference for leisure. A high value for \( \beta \) may lead to \( lp \leq 0 \). That is, it may cause our Model has no optimal interior solution. Here by following Tomoko (2004) and a research by Wang et al. (2001), we set a medium value of 0.6 for \( \beta \).

Table 1.3 lists the nine parameters and their values.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Values (One Year)</th>
<th>Values (One Period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Growth Rate</td>
<td>( n )</td>
<td>0.0026</td>
<td>0.08</td>
</tr>
<tr>
<td>Steady State Adult Survival Rate</td>
<td>( q^* )</td>
<td>na</td>
<td>0.8</td>
</tr>
<tr>
<td>Economic and Technological Factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Elasticity with respect to Capital</td>
<td>( \alpha )</td>
<td>na</td>
<td>0.4</td>
</tr>
<tr>
<td>Technological Improvement Growth</td>
<td>( g )</td>
<td>0.01</td>
<td>0.348</td>
</tr>
<tr>
<td>Steady State Stock of Human Capital</td>
<td>( H )</td>
<td>na</td>
<td>100</td>
</tr>
<tr>
<td>Other Parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partially Funded System Social Pooling Account Contribution Rate</td>
<td>( \tau_{pf} )</td>
<td>na</td>
<td>0.2</td>
</tr>
<tr>
<td>Partially Funded System Individual Account Contribution Rate</td>
<td>( \tau_{i} )</td>
<td>na</td>
<td>0.08</td>
</tr>
<tr>
<td>PAYG System Contribution Rate</td>
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</tr>
<tr>
<td>Pure Rate of Time Preference</td>
<td>( \rho )</td>
<td>0.015</td>
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<tr>
<td>Discount Rate</td>
<td>( \delta )</td>
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<td>0.64</td>
</tr>
<tr>
<td>Agent’s preference for leisure</td>
<td>( \beta )</td>
<td>na</td>
<td>0.6</td>
</tr>
</tbody>
</table>

1.4.3.2 Simulation Results

Based on the above parameters’ values, now we use Mathematica 6.0 Program to calculate the simulated values of all economic variables under the PAYG economy and PF economy respectively at both the case of endogenous labor force participation of the elderly and

\footnote{One period lasts 30 years.}

33
the case of exogenous labor force participation of the elderly. Table 1.4 and 1.5 list the calculation results for economic variables and transitional variables.

**Table 1.4: Steady State Values and Changes for Important Economic Variables under PAYG and PF Economy**

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>Case of Exogenous LFP</th>
<th>Case of Endogenous LFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PAYG</td>
<td>Partial Funding</td>
</tr>
<tr>
<td>$k^*$</td>
<td>0.0163</td>
<td>0.0182</td>
</tr>
<tr>
<td>$y^*$</td>
<td>19.2</td>
<td>20.1</td>
</tr>
<tr>
<td>$S\left(\frac{Y^*}{Y}\right)$</td>
<td>0.039</td>
<td>0.045</td>
</tr>
<tr>
<td>$\bar{r}$</td>
<td>0.06</td>
<td>0.056</td>
</tr>
<tr>
<td>$w^*$</td>
<td>0.116</td>
<td>0.122</td>
</tr>
<tr>
<td>$c_y^*$</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>$c_o^*$</td>
<td>22.54</td>
<td>22.94</td>
</tr>
<tr>
<td>$lp^*$</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>$U^*$</td>
<td>3.42</td>
<td>3.49</td>
</tr>
<tr>
<td>$REP$</td>
<td>0.48</td>
<td>0.79</td>
</tr>
<tr>
<td>$I^*$</td>
<td>9.478</td>
<td>10.32</td>
</tr>
<tr>
<td>$IR^*$</td>
<td>-0.181</td>
<td>-0.127</td>
</tr>
</tbody>
</table>

**Table 1.5: Values for Transitional Variables from PAYG Economy to PF Economy**

<table>
<thead>
<tr>
<th>Transitional Variables</th>
<th>Symbol</th>
<th>Case of Exogenous LFP</th>
<th>Case of Endogenous LFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Cost per Effective Worker</td>
<td>$tc_e$</td>
<td>0.0077</td>
<td>0.0073</td>
</tr>
<tr>
<td>Ratio of Transition Costs to Output (%)</td>
<td>$\frac{TC}{Y}$</td>
<td>3.91</td>
<td>3.83</td>
</tr>
<tr>
<td>Special Consumption Tax Rate (%)</td>
<td>$\tau^*$</td>
<td>4.5</td>
<td>3.3</td>
</tr>
</tbody>
</table>

It is worth noting that our OLG model is a crude and simple representation of many variables of the Economy such as utility function, economic growth function, age structure, and saving incentive, so the simulated results may be poor characterization of the real values, however, it is a good analytical tool for getting an intuitive understanding of the economic processes.

LFP means labor force participation of the elderly. Please see the Appendix 1.F and Appendix 1.G for the detailed calculations at the case of exogenous labor force participation of the elderly.
1.4.3.3 Comparative Analysis of Simulated Results

At this subsection, we make comparative analysis by using the simulation results listed in Table 1.4 and 1.5. Firstly, we compare the case of endogenous LFP to the case of exogenous LFP. Seen from Table 1.4, the simulated values of most variables except $w^*$, $c^*_o$, REP under the case of endogenous LFP are lower than those under the case of exogenous LFP.

Under the case of endogenous LFP, the level of capital per unit of effective labor $k^*$ is lower. Compared to the case of exogenous LFP, on one hand, due to little change in working-age saving $s^*_y$, the ratio of working-age people’s saving of wage $\phi^*$ is nearly unchanged. On the other hand, the labor force participation of the elderly causes the increase in level of effective labor $L$. Thus, at the steady state, the level of capital per unit of effective labor $k^*$ decreases. A decrease in $k^*$ leads to the decreases in $y^*$ and $(\frac{S}{Y})^*$ correspondingly.

Under the case of endogenous LFP, lower $k^*$ leads to higher $r^*$ and lower $w^*$. Because the elderly can earn more income if they choose to work, the wealth effect causes the increase in old-age consumption $c^*_o$, yet little increase in working-age consumption $c^*_y$. The substitution effect caused by less leisure of the elderly dominates the wealth effect, leading to the decrease in lifetime utility $U^*$. Similarly, the substitution effect caused by higher $r^*$ dominates the wealth effect caused by higher old-age income, leading to lower lifetime income $I^*$. 

Secondly, we compare and analyze the economic effects of China’s pension reform if labor force participation (LFP) of the elderly is endogenous.

1) Macroeconomic Effects: $k^*, y^*, (\frac{s}{Y})^*, \bar{r}^*$ and $w^*$
The steady state capital per unit of effective labor $k^*$ under PF system is 0.0164, up 14% from 0.0144 under PAYG system. The reason for the increase in $k^*$ is under PF system, part of contributions is accumulated as capital invested in the production process instead of being directly transferred to current retirees. With the increase in $k^*$, the output per worker $y^*$ increases by 5.5%, the national saving rate $(\frac{S}{Y})^*$ by 17%. Therefore, China’s pension reform causes deeper capital accumulation, higher output, and more saving.

The steady state annual interest rate $\bar{r}$ decreases from 6.2% under PAYG system to 6% under PF system by 4.8%. Higher saving causes more capital supply, resulting in the decrease in annual interest rate $\bar{r}$, the price of capital. The steady state wage rate $w^*$ rises from 0.11 under PAYG system to 0.116 under PF system, up 5.5%. An increase in $k^*$ causes higher output per worker, and thus a higher wage.

2) Individual Welfare Effects: $c_{y}^*, c_{o}^*, lp^*, U^*, I^*$

After reform, the steady state young-age consumption per unit of labor $c_{y}^*$ rises from 5.9 to 6.26, up 6.1%. The steady state old-age consumption per unit of labor $c_{o}^*$ increases from 23.02 to 22.69, up 1.6%. The steady state labor force participation of the elderly $lp^*$ rises by 4.9%. Due to both increases in young-age consumption and old-age consumption, the agent’s steady state lifetime utility $U^*$ increases from 3.36 to 3.41, up 1.5%. Higher wage $w^*$ and lower interest rate $\bar{r}$ causes the steady state agent’s lifetime income $I^*$ to grow from 9.13 to 10.05, up 10%.

The Pension reform brings about higher $w^*$ and lower $\bar{r}$. A higher $w^*$ increases both young-age consumption and old-age consumption while a lower $\bar{r}$ increases young-age
consumption and decreases old-age consumption. Therefore, the combined positive effects of higher \( w^* \) and lower \( \bar{r} \) cause the increase in young-age consumption bigger. The positive effect of higher \( w^* \) dominates the negative effect of lower \( \bar{r} \), causing the smaller increase in old-age consumption.

In addition, the reform brings higher lifetime income that induces the elderly to work less and lower tax distortion on labor that creates a positive substitution effect on labor supply of the elderly. The positive substitution effect dominates the negative income effect, causing more labor force participation of the elderly.

3) Income Redistribution Effects: \( REP^3 \) and \( IR^R \)

The steady state pension replacement ratio \( REP^3 \) under PF system is 0.84, up 68% from 0.5 under PAYG system. The reason for the big rise is the rate of return for pension- \( r^* \) under PF system is much greater than the rate of return for pension- \((1 + g)(1 + n)\) under PAYG system.

Under both PAYG system and PF system, the present values of income redistribution \( IR^R \) are negative, meaning the current generation makes upward intergeneration transfers to the next generation. In addition, the scale of upward intergenerational transfer under PAYG system is higher than that under PF system. That is, PAYG system has more income redistribution than PF system. The reason is the individual account under PF system has no effect of intergenerational transfer.

4) Transitional Effects: \( tc_t \), \( \frac{TC_t}{Y_t} \), and \( \tau_c \)

From Table 1.5, the transition cost per unit of effective labor \( tc_t \) is 0.0073 and the ratio of transition costs to the output at reform period \( t \) is 3.83%, which mean the transition costs caused by the pension reform is relatively low. The steady state special consumption tax rate
\( \tau_c \) is 3.3\%, which mean the burden of financing the transition costs on producers and consumers is comparatively light.

To sum up, the conclusions from the comparative analysis are as follows. First, China’s pension reform from PAYG system to PF system has significant and positive effects on China’s macro economy, production factors prices, individual welfare, and intergenerational equity. Second, although there are certain transition costs caused by the reform, the government can make appropriate policy measures to financing the transition costs without imposing a heavy fiscal burden on the consumers. Finally, compared to the case of endogenous LFP of the elderly, the simulated values of most variables except \( w^* \), \( c_o^* \), \( RDP \) under the case of exogenous LFP are higher, which may mean the economic effects of China’s pension reform are overestimated under the case of exogenous LFP.

1.4.4 Transitional Path Analysis of Major Variables

Besides comparing the steady state economies under both PAYG system and PF system, it is also important to analyze how the economy evolves from a PAYG steady state to a PF steady state. In this part, we will do the transitional path analysis of macroeconomic variables, individual welfare variables, and income distribution variables by simulating the values of these variables during the transition period from the PAYG steady state to the PF steady state.

Table 1.6 and Figure 1.1 show the transitional paths of macroeconomic variables \( k \cdot y \cdot \left( \frac{S}{Y} \right) \cdot r \) and \( w \). Table 1.7 and Figure 1.2 illustrate the evolution paths of welfare and income variables \( U \cdot c_y \cdot c_o \cdot IR \). In addition, in Figure 1.1 and Figure 1.2, for simplicity to compare, it should be noted that we make the initial (PAYG steady state) values of the corresponding economic variables equal to one.
### Table 1.6  Transitional Paths of Macroeconomic Variables

<table>
<thead>
<tr>
<th>Period</th>
<th>Calculation Value</th>
<th>0 (PAYG Steady State)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>PF Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital per Unit of Effective Labor ( k )</td>
<td>Calculation Value</td>
<td>0.0144</td>
<td>0.0150</td>
<td>0.0155</td>
<td>0.0159</td>
<td>0.0163</td>
<td>0.0164</td>
<td>0.0164</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>29.85</td>
<td>54.73</td>
<td>74.63</td>
<td>93.53</td>
<td>99.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Output per Worker ( y )</td>
<td>Calculation Value</td>
<td>18.31</td>
<td>18.71</td>
<td>18.90</td>
<td>19.08</td>
<td>19.20</td>
<td>19.29</td>
<td>19.31</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>40.00</td>
<td>59.00</td>
<td>77.00</td>
<td>89.00</td>
<td>98.00</td>
<td>100.00</td>
</tr>
<tr>
<td>National Saving Rate ( \frac{S}{Y} )</td>
<td>Calculation Value</td>
<td>0.036</td>
<td>0.0389</td>
<td>0.0395</td>
<td>0.0401</td>
<td>0.0412</td>
<td>0.0419</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>48.33</td>
<td>58.33</td>
<td>68.33</td>
<td>86.67</td>
<td>98.33</td>
<td>100.00</td>
</tr>
<tr>
<td>Wage ( w )</td>
<td>Calculation Value</td>
<td>0.1101</td>
<td>0.1115</td>
<td>0.1133</td>
<td>0.1145</td>
<td>0.1156</td>
<td>0.1159</td>
<td>0.1161</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>23.33</td>
<td>53.33</td>
<td>73.33</td>
<td>91.67</td>
<td>96.67</td>
<td>100.00</td>
</tr>
<tr>
<td>Interest Rate ( r )</td>
<td>Calculation Value</td>
<td>5.09</td>
<td>5.01</td>
<td>4.88</td>
<td>4.79</td>
<td>4.70</td>
<td>4.66</td>
<td>4.65</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>18.18</td>
<td>47.73</td>
<td>68.18</td>
<td>88.64</td>
<td>97.73</td>
<td>100.00</td>
</tr>
</tbody>
</table>

### Figure 1.1 Transitional Path of Macroeconomic Variables

The figure illustrates the transitional paths of the macroeconomic variables over six periods (0-5). Each variable's path is shown with distinct markers, and the x-axis represents the period index from 0 to 6, while the y-axis represents the index values.
Table 1.7 Transitional Paths of Welfare and Income Variables

<table>
<thead>
<tr>
<th>Period</th>
<th>Agent’s Lifetime Utility $U$</th>
<th>Agent’s Young-Age Consumption $C_y$</th>
<th>Agent’s Old-Age Consumption $C_o$</th>
<th>Agent’s Income Redistribution $IR$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculation Value</td>
<td>Calculation Value</td>
<td>Calculation Value</td>
<td>Calculation Value</td>
</tr>
<tr>
<td></td>
<td>3.358</td>
<td>5.85</td>
<td>22.02</td>
<td>-0.154</td>
</tr>
<tr>
<td>0 (PAYG Steady State)</td>
<td>3.348</td>
<td>5.79</td>
<td>21.85</td>
<td>-0.144</td>
</tr>
<tr>
<td>1</td>
<td>3.361</td>
<td>5.89</td>
<td>22.05</td>
<td>-0.136</td>
</tr>
<tr>
<td>2</td>
<td>3.379</td>
<td>6.08</td>
<td>22.35</td>
<td>-0.128</td>
</tr>
<tr>
<td>3</td>
<td>3.398</td>
<td>6.21</td>
<td>22.58</td>
<td>-0.121</td>
</tr>
<tr>
<td>4</td>
<td>3.409</td>
<td>6.25</td>
<td>22.68</td>
<td>-0.117</td>
</tr>
<tr>
<td>5</td>
<td>3.411</td>
<td>6.26</td>
<td>22.69</td>
<td>-0.116</td>
</tr>
<tr>
<td>PF Steady State</td>
<td>0 -15.87</td>
<td>5.66</td>
<td>39.62</td>
<td>96.23</td>
</tr>
<tr>
<td></td>
<td>5.66</td>
<td>75.47</td>
<td>97.56</td>
<td>100.00</td>
</tr>
<tr>
<td></td>
<td>39.62</td>
<td>96.23</td>
<td>97.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75.47</td>
<td>96.23</td>
<td>97.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>96.23</td>
<td>97.56</td>
<td>97.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>97.56</td>
<td>97.56</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

From these tables and figures, we can get several points. First, all the variables reach PF steady state values at period 5, so it takes five periods for the economy to change from PAYG steady state to PF steady state.
Second, the welfare of the generation of the reform period (period 1) is impaired although the welfare of the latter generations is improved, which may brings about a challenge to implementation of the pension Reform.

1.5 Conclusion

China’s pension system has undergone quite a few major reforms and been shifting from a PAYG system to a PF multi-pillar system. This paper develops an extended two-period OLG simulation model in a general equilibrium framework to investigate the macroeconomic and welfare effect of China’s pension reform when population aging and transition costs are considered. We quantitatively simulate the effects of China’s pension reform on capital accumulation, saving, output, wage, interest rate, lifetime utility and income, and income distribution under two cases of both exogenous and endogenous labor force participation of the elderly. Simulation results show impact of China’s pension reform can be quite substantial under both cases. For example, under the cases of endogenous LFP of the elderly, the capital stock rises by 14%, output by 5.5%, national saving rate by 17%, real wage by 5.5%, lifetime income by 9.9%, and pension replacement ratio by 70%. Moreover, the reform significantly improves intergenerational fairness by reducing upward intergenerational transfers by 24%

Compared to the case of exogenous LFP, the simulated values of most variables under the case of endogenous LFP are lower, which may mean the economic effects of China’s pension reform may be overestimated if not considering the LFP of the elderly. In addition, although there are certain transition costs caused by the reform, the government can make such policy measures as imposing special consumption tax on consumer to deal with the challenge of financing the transition costs. Finally, the economy reaches its new steady state five periods after the Reform, yet the future generations gain at the cost of the transition generation’s welfare loss, which may cause a challenge to the implementation of the pension reform.
Our model assumes all the agents are identical, which is not well suited to China’s reality. As one of fastest-growing developing countries, China is facing rapidly widening income gap among its people. Two reasons for the widening income gap are people differ in human capital endowment and in their access to the financial systems. Therefore, it is necessary to extend the model to the case of heterogeneous agents with different income levels to see how China’s pension reform affects the welfare of different agents and intragenerational income distribution. We will do in the next chapter.
Chapter 2: An Extended Dynamic OLG General Equilibrium Model with Heterogeneous Representative Agents

2.1 Introduction

In the past thirty years since 1978, China has made unparalleled economic achievements with an average annual growth rate of GDP per capita being 9.6% (IMF, WEO April 2008). Yet China has been experiencing one of the most rapid increases in income disparities in the world (Salditt et al. 2007). From 1981 to 2004, the Gini coefficient increased from about 0.30 to over 0.47 (ADB, 2007).

Two important reasons for the widening income gap in China are people differ in human capital endowments and in access to financial system. First, China’s workers differ in their human capital endowments that are represented by educational levels in this paper. A research by Li and Ding (2003) shows China’s workers with educational level below senior school account for 80% of total workers in 2000. They find the income gap among workers with different educational levels is rising quickly. The average income for workers with educational level below senior school is 37% lower than that for the workers above senior school in 1990, 44% lower in 1995, 50% lower in 2000.

Second, due to their low wealth and insufficient financial knowledge, plus the undeveloped capital market, undereducated people in China do not have access to the capital market, meaning they do not invest their savings through capital market as capital and thus get no real interest on their savings. Some researchers (Serrano 1998, Malvar 1999) have showed the phenomenon that the undereducated people cannot get access to the capital market in some big

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1 In this paper, we use individual educational level to represent one’s human capital endowment.
2 Educational levels below senior school include illiterate, primary school, and junior school; educational levels above senior school include senior school, college, university, and graduate.
developing countries such as Mexico and Brazil. This phenomenon also exits in China, supported by the evidence as follows.

The first evidence is undereducated people often have little, even no investment idea, knowledge, and skills to make capital investment, so most of them do not have the will to invest. Even though some people have the intent to invest, they do not know where and how to make investment. According to a survey report (Tencent Financial 2009), China’s investors with educational level below senior school only own 8% of all individual investment accounts in 2009.

Secondly, in China, only big urban cities have capital markets. China’s capital market begun to develop only since the early 1990s, after twenty years of rapid development, the market is still very undeveloped. In rural areas and small urban towns where most of the uneducated people live, the investment institutions do not exit at all.

Thirdly, there are high requirements to open and maintain an investment account. Investment institutions often require large initial deposits to open and large balance to maintain an account. Otherwise, there are substantial penalties for keeping low balances. The uneducated people who often have low savings cannot meet the high requirements to open and maintain an investment account.

The introduction of an obligatory funded pension system that gives these undereducated (poor) people access to the financial system may have important effects on capital accumulation and income distribution. Therefore, in order to make our simulation analysis more suited for China’ reality, it is necessary to consider the case of heterogeneous agents with different income levels. This chapter aims to extend the Auerbach-Kotlikoff framework to the case of two heterogeneous agents to see how China’s pension reform affects macro economy and income distribution, especially the welfare of heterogeneous agents and the intragenerational income redistribution.
Quite a few studies have showed that unless a new funded pension system contains explicit redistributive mechanisms, a shift from traditional PAYG system to funded system may have a negative effect on income equality. Yet for the case of China, the situation may be different.

Our simulation results show China’s pension reform from PAYG system to partially-funded system not only has significant and favorable effects on China’s macro economy, individual welfare, but also improves income inequality among heterogeneous agents substantially. Compared with the rich agent, the poor agent benefits much more from the Reform. Additionally, during the reform period (period 1), rich agent’s welfare decreases by -4.2%, while the welfare of the rich agent and the poor agent increase by 32% and 40% at the steady state respectively. Finally, the results show partial funding is better than full funding for China’s pension reform, which compliments the current literature.

The remainder of the paper is divided into seven sections. Section 2.2 reviews current literature regarding effects of pension reform on welfare and income distribution. Section 2.3 details the extended two-period OLG Simulation Model of two heterogeneous agents and then presents the simulation and comparison results. Section 2.4 shows the simulation results of full funding versus partial funding for China’s pension reform. In Section 2.5, we make a sensitivity analysis to measure how the changes in values of key model parameters affect the economic effects of China’s pension reform. Section 2.6 analyzes the transitional path of China’s pension reform. Section 2.7 concludes the paper.

2.2 Literature Review

In the previous chapter, we have reviewed many studies investigating the macroeconomic effects of a transition from PAYG system to funded system. Here we further review other important research emphasizing the effects of pension reform on welfare and income distribution.
Welfare Analysis of Pension Reform. Diamond (1965) and Aaron (1966) imply the welfare change for all generations if a PAYG pension system is introduced. If market interest rate $R >$ wage growth rate $G$, the first generation gains at the loss of later generations. If $R = G$, the first generation gain while there is no change in later generations’ welfare. If $R < G$, all generations gain.

Regarding a pension reform from PAYG to funding, Lindbeck and Persson (2003) make a detailed welfare analysis. First, under a dynamically efficient economy, if individuals’ behavioral adjustments or general equilibrium effect are disregarded, an aggregate income gain, and thus a Pareto improvement are impossible to achieve. That is, as the “free lunch” to the first generation under PAYG system is already given, this gift, namely the implicit pension debt (IPD) has to be paid by later generations anyway when a pension reform happens. It could be paid by either double-taxing current working population, or explicitly recognizing it by issuing government bonds. Second, if allowing for behavioral adjustments and general equilibrium effect, a Pareto improvement is possible when the losers can be compensated by the efficiency gains from the Reform.

Empirically, Kotlikoff (1998) simulates the macroeconomic and welfare effects of privatizing the U.S. social security. The model contains 12 different income groups and assumes endogenous capital formation, labor supply, and factor prices. The results show in the long run, the reform of privatization can increase the capital stock by 37%, lifetime utility by 4.5%, and output per capita by 11%. It need take about 60 years to achieve these effects, yet almost three-quarters of the effects are realized after 30 years in most of the simulations. Additionally, the utility of people aged 54 when the reform is implemented drops by 3.8% while that of those born after the reform increases by 8.1%.

Some empirical studies show a Pareto improvement is possible to achieve. By using Auerbach-Kotlikoff framework, Peter and Westerhout (1994) investigate the welfare effect of
introducing the funded pension plan to the Dutch PAYG system. They find the reform is Pareto welfare improving when the PAYG pensioners are compensated by a part of the returns from the funded system. Hirte and Weber (1997) carry out general equilibrium simulations for Germany. Compared to Kotlikoff (1998), they use income or consumption taxes both to finance the old pensioners’ benefits and to compensate the losers during the transition. When all losers are compensated, they find that an increase of 7% in steady state welfare can be achieved.

**Effect on Income Distribution.** One of the main concerns regarding the pension reform from PAYG to funding is the reform may have negative effects on income distribution as PAYG system include strong redistributions from young to old, from rich to poor, and from men to women (Diamond 1977; Brunner 1996; Barr 1998; Feldstein and Lieberman 2002).

Gruber and Wise (2002) argue except correcting the financial imbalance, increasing national saving, strengthening economic efficiency, the fourth economic goals that a pension reform should pursue is improving income distribution. James (1997) emphasizes unless the new funded pension system contains explicit redistributive mechanism, income equality may deteriorate, and more theoretical research is needed to have a clearer idea of how pension reform affects income distribution.

Casarico and Devillanova (2008) develop a theoretical two-period OLG model and analyze the general equilibrium implications of increasing funding in a closed economy characterized by heterogeneous agents, human capital investment, and capital–skill complementarity. They show the introduction of a funded system not only raises savings, increases the long run physical and human capital and therefore higher output, but also causes higher across-group wage and income inequality.

Empirically, Kotlikoff (1998)’s paper also simulates the income redistributive effect of the pension reform. In the case of consumption-tax financed transition, the poorest income groups gain about 50% more than the highest income groups in the long run. Serrano (1998) develops an
extended Auerbach-Kotlikoff model with heterogeneous agents and explores how a shift from a PAYG system to fully funded (FF) system in Mexico may affect capital accumulation and income distribution. He finds that the pension reform increases the level of physical capital, saving rate, and output significantly. The higher is the fraction of poor population, the larger are the effects of the reform. In addition, the reform has an ambiguous effect on income distribution due to two opposite effects on poor agents. First, there is no redistributive effect in the new fully funded system. Second, the transition also gives poor agents the opportunity to access to financial systems and earn interests on their pension savings. The effect of the reform on income distribution depends on the relative strength of the two competing effects.

The studies above all assumes the PAYG systems are general ones that have a redistributive advantage over funded systems due to wealth transferring from the rich to the poor. Yet, for some countries like China having special PAYG systems where the pensioners’ retirement benefits are not flat but in proportion to last few years’ salary, the effect of introducing a funded system on income equality may be ambiguous, which resorts to our simulation analysis.

To sum up, studies show a Pareto improvement is possible only if the loser generation could be compensated the loss when a pension reform from PAYG to funding happens. Additionally, unless a new funded pension system contains explicit redistributive mechanisms, the pension reform may have a negative effect on income equality. Yet for the case of China, the situation may be different.

2.3 An Extended OLG Model with Two Heterogeneous Representative Agents

In this Section, we develop an extended two-period OLG general equilibrium model with two heterogeneous agents in each generation. The two agents differ in two ways. First, they have different human capital endowments. Second, under PAGY system, one type (type 2) agent does not have access to the financial system, thus has no interest income on his savings. After the
Reform, he can deposit all their savings into the new partially funded system, and thus earn interests on their savings.

2.3.1 The Economy under PAYG System

2.3.1.1 Model Set-Up

(1) Heterogeneous Representative Agents

There are two types of agents in each generation. Type 1 agent owns higher human capital and can get access to capital market, while type 2 agent owns lower human capital and cannot get access to financial system\(^1\). Total population \(N\) in the economy is the sum of population of type 1 agent and type 2 agent. Of the total, the ratio of type 1 agent is \(\eta\) and the ratio of type 2 agent is \(1-\eta\). The total human capital in the economy is \(H\). Agent of type 1 owns \(\gamma\) of the total stock while agent of type 2 owns \(1-\gamma\) (\(\gamma > 0.5\)). That is:

\[
N_t = N^1_t + N^2_t, \quad \text{where} \quad N^1_t = \eta N_t, \quad N^2_t = (1-\eta)N_t
\]

\[
H_t = H^1_t + H^2_t, \quad \text{where} \quad H^1_t = \gamma H_t, \quad H^2_t = (1-\gamma)H_t
\]

Two generations (the youth and the elderly) coexist at the same period. Each person lives up to two periods. He lives during working-age period (period 1), yet only survives to old-age period (period 2) with the survival rate \(q_t\). There are two types of representative agents for each generation. The representative agent \(i \ (i=1, 2)\) decides the optimal amount of working-age consumption, old-age consumption, and labor force participation by maximizing the following lifetime utility function.

\[
U^i = U^i(c^i_{y,t}, c^i_{o,t}, \ell p_t) = \ln c^i_{y,t} + \frac{q_t}{1+\rho} \left[ \ln c^i_{o,t} + \beta \ln(1-\ell p_t) \right] \quad i=1, 2
\]

During working-age period, the agent \(i\) works, saves, and pays PAYG payroll tax, so the working-age lifetime budget constraint is:

\(^1\) As type 1 agent is richer than type 2 agent, type 1 agent is also called as rich agent while type 2 agent called as poor agent.
\[ c_{i,t}^i + s_{i,t}^i = (1 - \tau_{pg}) H_t^i w_t^i \quad i = 1, 2 \] (2.4)

During old-age period, representative agent \( i \) provides \( lp^i \) unit of labor and then retires. After retirement, he gets pension benefits \( B_{i,t}^i \) from the current working generation. As type 2 agent cannot participate in the capital market, his saving cannot get the interests. The old-age lifetime budget constraints for agent 1 and 2 are:

\[
c_{o,t+1}^1 = \left(1 + r_{t+1}\right) s_{p,t+1}^1 + (1 - \tau_{pg}) H_{t+1}^1 w_{t+1}^1 lp_{t+1}^1 + B_{t+1}^1 \tag{2.5}
\]

\[
c_{o,t+1}^2 = s_{p,t+1}^2 + (1 - \tau_{pg}) H_{t+1}^2 w_{t+1}^2 lp_{t+1}^2 + B_{t+1}^2 \tag{2.6}
\]

As we said, one feature of China’s PAYG system different from other countries’ pension system is in China, the retiree’s pension benefits are in proportion to his working-age wage income, that is, \( B_{i,t}^i / B_{o,t}^i = H_t^i w_t^i / H_t^i w_t^i = \gamma / (1 - \gamma) \). Under PAYG system, as the total pension benefits are equal to total pension contributions at the same period, we can get \( B_{t+1}^2 \) and \( B_{t+1}^2 \):

\[
B_{t+1}^1 N_{o,t+1} + B_{t+1}^2 N_{o,t+1}^2 = \tau_{pg} W_{t+1}^1 (H_{t+1}^1 N_{p,t+1}^1 + H_{t+1}^2 N_{p,t+1}^2)
\rightarrow B_{t+1}^1 N_{o,t+1} + B_{t+1}^2 (1-\eta) N_{o,t+1} = \tau_{pg} W_{t+1}^1 (1+n) H_{t+1}^1 N_{p,t+1}^1 [\gamma \eta + (1-\gamma)(1-\eta)] \tag{2.7}
\rightarrow B_{t+1}^2 = \tau_{pg} W_{t+1}^1 H_{t+1}^1 (1-\gamma)(1+n) / q_t \text{ and } B_{t+1}^2 = \tau_{pg} W_{t+1}^1 H_{t+1}^1 \gamma (1+n) / q_t
\]

Thus, we can get the following lifetime budget constraints for agent 1 and agent 2:

\[
c_{t}^1 + c_{o,t}^1 (1+r_{t+1})/q_t = (1 - \tau_{pg}) \gamma H_t^1 w_t^1 + \frac{\gamma H_t^1 w_t^1 lp_t^1 (1-\tau_{pg})}{(1+r_{t+1})/q_t} + \frac{\gamma H_t^1 w_t^1 \tau_{pg} (1+n)}{(1+r_{t+1})} \tag{2.8}
\]

\[
c_{t}^2 + c_{o,t}^2 = (1 - \tau_{pg}) (1-\gamma) H_t^2 w_t^2 + (1-\gamma) H_t^2 w_t^2 lp_t^2 (1-\tau_{pg}) + \frac{(1-\gamma) H_t^2 w_t^2 \tau_{pg} (1+n)}{q_t} \tag{2.9}
\]

(2) Representative Firm

The representative firm maximizes its profits with a Cobb-Douglas production function:

\[ \gamma_t = k_t^\alpha (L_t)^{1-\alpha} \]
At this case, the total effective labor input in the economy $L_t$ is the sum of labor input provided by two types of agents, that is, $L_t = H_t^1(N_{1,t} + N_{1,t}^2 + N_{2,t}^1 + N_{2,t}^2) + H_t^2(N_{0,t}^1 + N_{0,t}^2) = H_t N_t$.

where $L_t = \frac{1 + q_{t}^1 + N_{1,t}^1 + N_{2,t}^2 + \gamma \eta}{1 + n} + \frac{1 + q_{t}^2 + N_{0,t}^1 + N_{0,t}^2}{1 + n} - \gamma(1 - \eta)$.

(3) Government

Government is responsible for levying the payroll tax from working population and distributing pensions to the retired population. All contributions are paid out and no reserves are accumulated in the same period. Therefore, government budget is balanced under PAYG system.

2.3.1.2 Solving the Model

Now, agent 1 and 2’s utility maximization problems are:

Maximizes $U^1 = \ln c_{y,t}^{1} + \frac{q_t}{1 + \rho} \left[ \ln c_{o,t+1} + \beta \ln (1 - l p_t) \right]$

s.t. $c_{y,t}^{1} + \frac{c_{o,t+1}}{(1 + r_{t+1})/q_t} = (1 - \tau_{pg}) H_t w_t + \frac{\gamma H_t w_t l p_{t+1} (1 - \tau_{pg})}{(1 + r_{t+1})/q_t}$

Maximizes $U^2 = \ln c_{y,t}^{2} + \frac{q_t}{1 + \rho} \left[ \ln c_{o,t+1} + \beta \ln (1 - l p_t^2) \right]$

s.t. $c_{y,t}^{2} + c_{o,t+1} = (1 - \tau_{pg})(1 - \gamma) H_t w_t + (1 - \gamma) H_t w_t l p_{t+1} (1 - \tau_{pg}) + \frac{(1 - \gamma) H_t w_t \tau_{pg} (1 + n)}{q_t}$

Solving the maximization problems above, we can get the agent’s optimal working-age consumption $c_{y,t}^1$, old-age consumption during $c_{o,t+1}$, and working-age saving $s_{y,t}$, and labor force participation $l p_{t+1}$ for agent 1 and agent 2 respectively:

For Agent 1:

$c_{y,t}^{1} = \frac{(1 + r_{t+1})(1 - \tau_{pg}) H_t w_t + \gamma H_t w_t l p_{t+1} \tau_{pg} (1 + n) + (1 - \tau_{pg}) q_t}{(1 + q_t)(1 + q_t \beta \delta + q_t \delta)}$ (2.10)

$c_{o,t+1} = c_{y,t}^{1} (1 + r_{t+1}) \delta = \frac{(1 + r_{t+1})(1 - \tau_{pg}) \gamma H_t w_t + \gamma H_t w_t l p_{t+1} \tau_{pg} (1 + n) + q_t (1 - \tau_{pg})}{(1 + q_t \beta \delta + q_t \delta)/\delta}$ (2.11)
\[ l p_{t+1}^i = \frac{1 - \beta \delta (1 + r_{t+1}) c_{s,t}}{\gamma H_{t+1} w_{t+1}(1 - \tau_{pg})} \]

\[ s_{y,t}^i = \frac{(1 + r_{t+1})(q_i \beta \delta + q_i)\gamma H_{t} w_{t} - \gamma H_{t+1} w_{t+1}\left[ \tau_{pg} (1 + n) + q_i (1 - \tau_{pg}) \right]}{(1 + r_{t+1})(1 + q_i \beta \delta + q_i \delta)} \]

(2.12)

For Agent 2:

\[ c_{s,t}^i = \frac{(1 - \tau_{pg})(1 - \gamma)H_{t} w_{t} + (1 - \gamma)H_{t+1} w_{t+1}\left[ \tau_{pg} (1 + n) / q_i + (1 - \tau_{pg}) \right]}{(1 + q_i \beta \delta + q_i \delta)} \]

(2.13)

\[ c_{o,t+1}^i = c_{y,t}^i q_i \delta \]

(2.14)

\[ l p_{t+1}^2 = 1 - \frac{q_i \delta \beta c_{s,t}^2}{(1 - \gamma)H_{t+1} w_{t+1}(1 - \tau_{pg})} \]

(2.15)

\[ s_{y,t}^2 = \frac{(1 - \gamma)H_{t} w_{t}(q_i \beta \delta + q_i \delta)(1 - \tau_{pg}) - (1 - \gamma)H_{t+1} w_{t+1}\left[ \tau_{pg} (1 + n) / q_i + (1 - \tau_{pg}) \right]}{(1 + q_i \beta \delta + q_i \delta)} \]

(2.16)

Both \( c_{y,t}^i \) and \( c_{o,t+1}^i \) (\( i = 1, 2 \)) depend positively on \( H_i, w_i, n \) and negatively on \( q_i, \beta, \delta \) and \( \tau_{pg} \). Yet the big difference is \( c_{y,t}^2 \) has no relationship with \( r_{t+1} \) as the type 2 agent does not participate in the financial system.

The total savings in the economy \( S_i \) are the sum of the working population saving \( S_{y,t}^i \) and retired population saving \( S_{o,t}^i \) of type 1 agent: \( S_i = S_{y,t}^i + S_{o,t}^i = s_{y,t}^i N_{y,t}^i - s_{y,t}^i N_{o,t}^i \)

The national saving rate \( S_i / Y_t \) is:

\[ S_i / Y_t = \frac{s_{y,t}^i N_{y,t}^i - s_{y,t}^i N_{o,t}^i}{L k^\alpha H_t b_i k^\alpha} = \frac{\phi_i \omega \gamma \eta H_{t+1}}{1 + n} = \frac{\gamma \eta (1 - \alpha)}{H_{t+1} b_i k^\alpha} \]

(2.17)

Where: \( \phi_i = s_{y,t}^i w_{t+1}^i H_{t+1} \), \( b_i = (1 + q_i l p_{t+1}^i) \gamma \eta + (1 + q_i l p_{t+1}^i)(1 - \gamma)(1 - \eta) \)

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The capital condition for PAYG economy is:

$$K_{t+1} = s_{y,t}^1N_{y,t}^1$$

That is, only savings of type 1 agent are invested through the financial system as capital.

$$-k_{t+1} = s_{y,t}^1N_{y,t}^1 = \frac{\phi_t H_t w_t N_{y,t}^1}{H_{y,t} N_{y,t} b_{t+1}} = \frac{\phi_t (1-\alpha) \gamma \eta k^*_t}{(1+n)(1+g)b_{t+1}} \quad (2.18)$$

At steady state, the capital per unit of effective labor at PAYG system $k^*_p$ is:

$$k^*_{p} = \frac{\phi^* (1-\alpha) \gamma \eta}{(1+n)(1+g)b^*} \quad (2.19)$$

Where:

$$\phi^* = \frac{(1+r^*)(q^* \beta \delta + q^* \delta)(1-\tau_{pg}) - (1+g)[\tau_{pg} (1+n) + (1-\tau_{pg})q^*]}{(1+r^*)(1+q^* \beta \delta + q^* \delta)}$$

$$b^* = (1 + \frac{q^* l p^1}{1+n}) \gamma \eta + (1 + \frac{q^* l p^2}{1+n})(1-\gamma)(1-\eta) \quad (2.20)$$

$$l p^1 = 1 - \frac{\beta \delta (1+r^*) c^1}{\gamma H^* w^* (1-\tau_{pg})}$$

$$l p^2 = 1 - \frac{q^* \delta \beta c^2}{(1-\gamma)H^* w^* (1-\tau_{pg})}$$

$$r^* = \alpha k^*_{p}^{\alpha-1} w^*_p = (1-\alpha) k^*_{p}^\alpha$$

(2.19) and (2.20) are an implicit equation group, we cannot directly solve the expression for $k^*_p$, yet we can know $k^*_p$ is dependent on the nine parameters: $q^* \cdot \alpha \cdot \tau_{pg} \cdot \rho \cdot \beta \cdot \eta \cdot n \cdot g \cdot \gamma$.

Now we further calculate other important economic variables to simulate the steady state economy under PAYG pension system. As we did before, we organize these variables into two groups: macroeconomic variables group and individual welfare variables group.

3) Macroeconomic Variables: $k^*_p$, $y^*_p$, $(\frac{S}{Y})^*_p$, $r^*_p$, and $w^*_p$

$$k^*_{p} = \frac{\phi^* (1-\alpha) \gamma \eta}{(1+n)(1+g)b^*}$$
\[ y^*_p = H^*_k^* \alpha \] (2.21)

\[ \left( \frac{S}{Y} \right)^* = \frac{\gamma \eta(1-\alpha)\phi^* \left[ 1 - \frac{1}{(1+n)(1+g)} \right]}{b^*} \] (2.22)

\[ r^* = \alpha k^* \alpha^{-1} \] (2.23)

\[ r_\text{pg} = \sqrt{3} \left( 1 + r^* \right) - 1 \] (2.24)

\[ w^*_p = (1-\alpha) k^* \alpha \] (2.25)

From the equations above, we know \( \frac{\partial y^*}{\partial k^*} > 0, \frac{\partial \left( \frac{S}{Y} \right)^*}{\partial k^*} < 0, \frac{\partial r^*}{\partial k^*} < 0, \frac{\partial w^*}{\partial k^*} > 0 \). The more is the steady-state capital per unit of effective labor \( k^*_p \), the bigger are the steady state output per worker \( y^*_p \), and the steady state wage rate \( w^*_p \), the less are the steady-state national saving rate \( \left( \frac{S}{Y} \right)^*_p \) and steady state interest rate \( r^*_p \).

4) Individual Welfare Variables: \( c_{Y,p}^*, c_{o,p}^*, U_{pg}^*, RE_{pg}^*, I_{pg}^*, \) and \( IR_{pg}^* \)

The steady state young-age consumption per unit of labor \( c_{Y,p}^* \) is:

\[ c_{1,Y,p}^* = \frac{(1 + r^*_p)(1 - \tau^*_p)\gamma H^* w^*_p + \gamma H^* w^*_p \left[ \tau^*_p (1+n) + q^* \right]}{(1 + r^*_p)(1 + q^* \beta \delta + q^* \delta)} \] (2.26)

\[ c_{2,Y,p}^* = \frac{(1 - \tau^*_p)(1 - \gamma) H^* w^*_p + (1 - \gamma) H^* w^*_p \left[ \tau^*_p (1+n)/q^* + (1 - \tau^*_p) \right]}{1 + q^* \beta \delta + q^* \delta} \]

The steady state old-age consumption per unit of labor \( c_{o,p}^* \) is:
Due to \( k^*_y > 0 \) and \( k^*_o > 0 \), we get \( \frac{\partial c^{i,*}_{y,pg}}{\partial k^*_{pg}} > 0 \) and \( \frac{\partial c^{i,*}_{o,pg}}{\partial k^*_{pg}} > 0 \). The more steady-state capital is put into production, the more steady-state output is produced, the young-age and old-age people consume more. Another feature is \( r^*_{pg} \) does not affect \( c^{2,*}_{y,pg} \) and \( c^{2,*}_{o,pg} \) that reflects our assumption that the type 2 agent does not participate in the financial system.

The steady state lifetime utility \( U^{i,*}_{pg} \) is:

\[
U^{i,*}_{pg} = \ln c^{i,*}_{i,pg} + \frac{q^*}{1 + \rho} \left[ \ln c^{i,*}_{o,pg} + \beta \ln (1 - lp^{i,*}) \right] \quad (i=1,2) \tag{2.28}
\]

Due to \( \frac{\partial c^{i,*}_{y,pg}}{\partial k^*_{pg}} > 0 \) and \( \frac{\partial c^{i,*}_{o,pg}}{\partial k^*_{pg}} > 0 \). The more is \( k^*_i \), the bigger is \( c^{i,*}_{i,pg} \).

The pension replacement ratios of type 1 agent and type 2 agent are:

\[
REP^1_{pg} = REP^2_{pg} = \frac{\tau_{pg} w_{pg} H_{w_{pg}} (1+n)/q_i}{H_{w_i}} = \tau_{pg} (1+g)(1+n)/q_i.
\]

The pension replacement ratios of type 1 agent and type 2 agent are same, which reflects the feature of China’s PAYG system that the retiree’s pension benefit is in proportion to his wage income before retirement.

The steady state pension replacement ratio \( REP^{i,*}_{pg} \) is:

\[
REP^{i,*}_{pg} = \tau_{pg} (1+g)(1+n)/q^* \quad (i=1,2) \tag{2.29}
\]

The steady state lifetime income \( I^{i,*}_{pg} \) is:
If \( lp^* = lp^2 \), then \( \frac{I_1^*}{I_2^*} = \gamma / (1 - \gamma) \). As \( \gamma > 0.5 \), \( \frac{I_1^*}{I_2^*} > 1 \), that is, type 1 agent has higher lifetime income than type 2 agent. So we can call type 1 agent as rich agent, type 2 agent as poor agent. Due to \( k_k > 0 \), we get \( \frac{\partial I_1^*}{\partial k} > 0 \). The more \( k_k \), the bigger \( I_1^* \) is.

The present value of income redistribution \( IR_{r_k} \) is a variable measuring the income redistribution effect of PAYG system. \( IR_{r_k} = \left( \frac{H^t_{r+1} W_j}{H^t_{r+1} W_j} \right) \), so the steady state present value of income redistribution \( IR_{r_k}^{1,*} \) is:

\[
IR_{r_k}^{1,*} = IR_{r_k}^{2,*} = \frac{\tau_{r_k} (1 + g)(1 + n)}{(1 + r^*_w)} q^* - \tau_{r_k} (1 + g)(1 + n)q^* - 1
\]

\( IR_{r_k}^{1,*} = IR_{r_k}^{2,*} \) means under China’s PAYG pension system, there is no intragenerational income redistribution, which is different from those of other countries. In addition, if \( (1 + n)(1 + g) / q^* < \gamma > (1 + r^*_w) \), then \( IR_{r_k}^{1,*} < \gamma > 0 \), the current generation gives (receives) intergenerational transfer to (from) other generations. \( \frac{\partial r^*}{\partial k} < 0 \rightarrow IR_{r_k}^{1,*} > 0 \), the more \( k_k \) is, the more intergenerational transfer \( IR_{r_k}^{1,*} \) is.

### 2.3.2 The Economy under Partially Funded System

At the reform period \( t \) when the PAYG economy reaches steady state, the government decides to reform the pension system from PAYG to partial funding (PF). Under the new PF...
system, workers pay social account contribution and individual account contribution during working-age period. After retirement, accordingly, the retirees get both the social account pension and the individual account pension. Additionally, type 2 individuals who could not get access to financial system in the old PAGY system now can deposit all their savings into the new three-pillar Partially Funded pension system, and thus earn interests on their savings.

We also analyze the economy considering the transition path and transition costs. As we assume before, the government bears all the transition costs accumulated during the reform period t by issuing government bonds. The working-age adults buy the government bonds, and will be repaid with the bond principal and resultant interests during the old-age period. The stock of government bonds $D_t$ keeps constant since reform period t. The government levies a special consumption tax $\tau_c$ on consumers to pay the bond interests.

### 2.3.2.1 Model Setting-Up

(1) Heterogeneous Representative Agents

Now the heterogeneous agents face new budget constraints:

\[
(1 + \tau_{c,i})c_{t,1} + s_{t,1} + d_i = (1 - \tau)(1 - \tau_{pf,i})H_i w_i^t
\]

\[
(1 + \tau_{c,i})c_{o,t+1} = \left(\frac{1 + r_{t,1}}{q_t}\right)\left[s_{t,1} + d_i + \tau_i (1 - \tau_{pf,i})H_i w_i^t\right] + (1 - \tau_{pf,i})H_i w_i^{t+1} + B_{t+1}
\]

\[(i=1,2) \quad (2.32)\]

Where $\tau_{pf,i}, \tau_i$ are contribution rates to social account and to individual account respectively, $d_i$ is the government debt per unit of effective labor. $B_{t+1}$ is the social account pension, same for two agents.

\[
B_{t+1} = \tau_{pf,i} \left(\frac{H_i w_i^{t+1} N_i^1 + H_i w_i^{t+1} N_i^2}{N_{o,t+1}}\right) / N_{o,t+1} = \tau_{pf,i} a H_i w_i^{t+1} (1 + n) / q_s, \quad \text{where} \quad a = \gamma + (1 - \gamma)(1 - \eta).
\]

The agents' lifetime utility maximization problem is:
Maximizes \( U^i = U(c^i, c_{t+1}^i, l_p^i) = \ln c^i + \frac{q_i}{1 + \rho} \left[ \ln c_{t+1}^i + \beta \ln (1 - l_p^i) \right] \) \quad (i = 1, 2) (2.33)

s.t. \( (1 + \tau_c) c^i + \frac{q_i(1 + \tau_c) c_{t+1}^i}{1 + \tau_c} = H^i w(t) (1 - \tau_p) + \tau_p H^i w_{t+1} \frac{(1 + n)a}{1 + \tau_c} + \frac{(1 - \tau_p) H^i w_{t+1} l_p^i}{(1 + \tau_c)/q} \)

(2) Representative Firm

The perfectly competitive firms seek to maximize the profit function as follows:

\( \pi_t = Y_t - r_t K_t - w_t L_t \), where \( L_t = N_t h_t \) (2.34)

(3) Government and Transition Costs

From the assumption above, we can get:

\[ D_t = TC_t = (\tau_{pg} - \tau_{pf}) w_{pg}^* \left( H^i_{pg} N_{pg}^{i1} + H^i_{pg} N_{pg}^{i2} \right) \] (2.35)

\[ \tau_{c,t+1} = D_t r_{c,t+1} = \frac{\tau_{pg} - \tau_{pf} H^i_{pg} w_{pg}^* r_{c,t+1} a}{c_{c,t+1} (1 + n) + \tau_{c,t+1} q_b} \] (2.36)

The steady state special consumption tax \( \tau_c^* \) is:

\[ \tau_c^* = \frac{\theta (\tau_{pg} - \tau_{pf}) H^i w_{pg}^* r_{c} a}{c_{c} (1 + n)^{\gamma + \tau_{c} q} (1 + n)^{\gamma - 1}} \] (2.37)

The new capital condition for the Partially Funded economy with government debts is:

\[ K_{t+1} = \delta_{i,j}^{c1} N_{i,j}^{c1} + \delta_{i,j}^{c2} N_{i,j}^{c2} = \phi_i^c H^i w_i N_{i}^{c1} + \phi_i^c H^i w_i N_{i}^{c2} - D_{c,t+1} \] (2.38)

Where \( \delta_{i,j}^{c1} \) is the savings of the agent \( i \) (\( i = 1, 2 \)), the sum of annuity saving \( \delta_{i,j}^{c1} \) and individual account saving \( \tau_i (1 - \tau_{pf}) H^i w_i \). Compared with the old PAYG system, under the new system, not only individual account contributions but also the savings of type 2 agent are invested as new capital.

The evolution function of capital per unit of effective labor under the Partially Funded system \( k_{t+1} \) is:

\[ k_{t+1} = \frac{\phi_i^c H^i w_i N_{i,j}^{c1} + \phi_i^c H^i w_i N_{i,j}^{c2} L_{i,t+1}}{L_{i,t+1} - \frac{\phi_i^c \gamma \eta + \phi_i^c (1 - \gamma)(1 - \eta)}{b_{i,t+1} (1 + n)(1 + g)} (1 - \alpha) k_{i,t+1}^c \} + \frac{(\tau_{pg} - \tau_{pf}) w_{pg}^*}{b_{i,t+1} (1 + n)(1 + g)} \] (2.39)
2.3.2.2 Solving the Model

Solving the model above, we get steady state capital per unit of effective labor $k^*_{pf}$:

$$k^*_{pf} = \frac{\phi^{i*}\gamma \eta w^*_{pf} + \phi^{2*}(1-\gamma)(1-\eta)w^*_{pf}}{b^* (1+n)(1+g)} - \frac{(\tau_{pfr} - \tau_{pf})w^*_{pf}a}{(1+g)^T (1+n)^T b^*}$$ (2.40)

Where $\phi^{i*}$, $lp^{i*}$, $r^*$, $w^*$, and $b^*$ are:

$$\phi^{i*} = \frac{(1+r^*)(q^* \beta \delta + q^* \delta)(1-\tau_{pf}) - (1+g)\left[ \tau_{pfr} (1+n)a/\gamma + q^* (1-\tau_{pf}) \right] \gamma}{(1+r^*)(1+q^* \beta \delta + q^* \delta)} \beta \delta (1+r^*)$$ (2.41)

$$\phi^{2*} = \frac{(1+r^*)(q^* \beta \delta + q^* \delta)(1-\tau_{pf}) - (1+g)\left[ \tau_{pfr} (1+n)a/\gamma + q^* (1-\tau_{pf}) \right]}{(1+r^*)(1+q^* \beta \delta + q^* \delta)} \beta \delta (1+r^*)$$ (2.42)

$$lp^{i*} = \frac{1 - \beta \delta (1+r^*)}{(1+g)^T (1+q^* \beta \delta + q^* \delta)} - \frac{\beta \delta \left[ q^* (1-\tau_{pf}) + \tau_{pfr} (1+n)a \right]}{(1+g)^T (1+q^* \beta \delta + q^* \delta)}$$ (2.43)

$$lp^{2*} = \frac{1 - \beta \delta (1+r^*)}{(1+g)^T (1+q^* \beta \delta + q^* \delta)} - \frac{\beta \delta \left[ (1-\gamma)q^* (1-\tau_{pf}) + \tau_{pfr} (1+n)a \right]}{(1+g)^T (1+q^* \beta \delta + q^* \delta)}$$ (2.44)

$$r^* = \alpha k^*_{pf}^{\alpha} - 1$$ (2.45)

$$w^* = (1-\alpha)k^*_{pf}^{\alpha}$$

We can further calculate other economic variables that are divided into two groups: macroeconomic variables group and individual welfare variables group.

4) Macroeconomic Variables: $k^*_{pf}$, $y^*_{pf}$, $(s_{Y})^*_{pf}$, $r^*_{pf}$, and $w^*_{pf}$

$$y^*_{pf} = k^*_{pf}^{\alpha}$$ (2.46)

$$\left( s_{Y} \right)^*_{pf} = \frac{\gamma \phi^{i*}(1-r^*)^T}{b^*/(1-\alpha)} \left[ \frac{1}{(1+n)(1+g)^T} + (1-\gamma)(1-\eta) \phi^{2*} \right] \left[ \frac{1}{(1+n)(1+g)} \right]$$ (2.47)

1 Please see APPENDIX 2.A for detailed calculation of $k^*_{pf}$.
2 Please see APPENDIX 2.B for detailed calculation of the steady state economic variables and transitional variables.
\[ r^* = \alpha k^{*^2} - 1 \]  
(2.48)

\[ \bar{r} = \sqrt{\frac{1}{1+r^*}} - 1 \]  
(2.49)

\[ w^*_{pf} = (1-\alpha)k^{*^2} \]  
(2.50)

5) Individual Welfare Variables: \( c^i_{y,pf}, c^i_{o,pf}, U^i_{pf}, REP^i_{pf}, I^i_{pf} \), and \( IR^i_{pf} \)

\[ c^i_{y,pf} = \frac{\gamma H \ast w^*(1+r^*_{pf})(1-\tau_{pf}) + H \ast w^* [\tau_{pf} (1+n)a + \gamma q^* (1-\tau_{pf})]}{(1+r^*_{pf})(1+q^* \beta \delta + q^* \delta)(1+\tau^*_{pf})} \]  
(2.51)

\[ c^i_{o,pf} = c^i_{y,pf} (1+r^*_{pf}) - \frac{\gamma H \ast w^*(1+r^*_{pf})(1-\tau_{pf}) + H \ast w^* [\tau_{pf} (1+n)a + \gamma q^* (1-\tau_{pf})]}{(1+r^*_{pf})(1+q^* \beta \delta + q^* \delta)(1+\tau^*_{pf})} \]  
(2.52)

\[ U^i_{pf} = \ln c^i_{y,pf} + \frac{q^*}{1+\rho} [\ln c^i_{o,pf} + \beta \ln(1-lp^i_{pf})] \quad (i=1,2) \]  
(2.53)

\[ REP^1_{pf} = \tau_{pf} (1+n)(1+g)a/\gamma + \tau_i(1-\tau_{pf})(1+r^*)/q^* \]  
(2.54)

\[ REP^2_{pf} = \tau_{pf} (1+n)(1+g)a/(1-\gamma) + \tau_i(1-\tau_{pf})(1+r^*)/q^* \]  
(2.55)

\[ I^1_{pf} = H \ast w^* \left[ (1-\tau_{pf})^\gamma + \frac{\tau_{pf} (1+n)(1+g)}{q^* (1+r^*_{pf})} + \frac{lp^1_{pf} \gamma (1+g)(1-\tau_{pf})}{(1+r^*_{pf})} \right] \]  
(2.56)

\[ I^2_{pf} = H \ast w^* \left[ (1-\tau_{pf})^\gamma + \frac{\tau_{pf} (1+n)(1+g)}{q^* (1+r^*_{pf})} + \frac{lp^2_{pf} \gamma (1+g)(1-\tau_{pf})}{(1+r^*_{pf})} \right] \]  
(2.57)

\[ IR^1_{pf} = \frac{\tau_{pf} (1+n)(1+g)}{(1+r^*_{pf}) q^* \gamma} - \tau_{pf} + \tau_i(1-\tau_{pf})(\frac{1}{q^*} - 1) \]  
(2.58)

\[ IR^2_{pf} = \frac{\tau_{pf} (1+n)(1+g)}{(1+r^*_{pf}) q^* \gamma} - \tau_{pf} + \tau_i(1-\tau_{pf})(\frac{1}{q^*} - 1) \]  
(2.59)

From the algebraic formulations of the economic variables above, we can know:
First, like PAYG case, all the steady state variables but interest rate and pension replacement ratio have positive relationships with steady state capital per capita $k^*_p$.

Second, different from the PAYG case, the interest rate $r^*_p$ has negative effect on working age consumption and positive effect on old-age consumption for the type 2 agent as he can deposit his savings in the financial system and get the interests.

Third, compared with PAYG system where the pension replacement ratios are same, the pension replacement ratio of type 2 agent is bigger than that of type 1 agent, and the income ratio of two agents $I^*_p / I^*_p$ is less than $\gamma / (1 - \gamma)$, which reflects China’s Partial-Funded system has the effect of partial income redistribution.

6) Transitional Variables: $tc_t$, $TC_t / Y_t$, and $\tau^*_c$

At reform period $t$, the transition cost per unit of effective labor $tc_t$ and the ratio of transition costs to the output $TC_t / Y_t$ are:

$$tc_t = \frac{TC_t}{L_t} = (\tau^*_p - \tau^*_p) w^*_p a / b^*_p$$  (2.57)

$$\frac{TC_t}{Y_t} = \frac{(\tau^*_p - \tau^*_p) w^*_p (H^*_p N^*_p + H^*_p N^*_p)}{Y^*_p} = \frac{(\tau^*_p - \tau^*_p) w^*_p a}{y^*_p b^*_p}$$  (2.58)

The steady state special consumption tax $\tau^*_c$ is:

$$\tau^*_c = \frac{(\tau^*_p - \tau^*_p) H^*_p w^*_p r^*_a}{c_y^*(1 + n)^t + c_q^*(1 + n)^{t-1}}$$  (2.59)

2.3.3 Simulation Analysis of Pension Reform

We first set up a base-case scenario and later adjust some values of the parameters to make sensitivity analysis to investigate how the changes in the key parameters affect the economic effects of the Reform.
2.3.3.1 Parameter Values Selection for the Base-Case Scenario

Besides the nine old parameters \( n, q^*, \alpha, g, H^*, \tau_{pf}, \tau_{pg}, \delta, \theta, \beta \), our model include two new ones- type 1 agent’s ratio of the total working population \( \eta \) and the ratio of the total human capital \( \gamma \) \((\gamma > 0.5)\). In this paper, we use educational level to represent human capital endowment. The workers with education level equal to or higher than senior high school are considered as type 1 workers.

In 2006, China’s workers with educational level below senior high school account for 80.5% of total workers while workers above senior school account for 19.5% of total workers\(^1\) (National Bureau of Statistics of China, China Labor Statistical Yearbook 2007). So we set \( \eta = 0.2 \).

We further use educational years and ratios of total workers\(^2\) to calculate the ratio of total human capital \( \gamma \) for type 1 workers. As calculated in the following table, we get \( \gamma = 0.65 \)

| Educational Level | Type 2 Workers | | | Type 1 Workers | | |
|-------------------|----------------|----------------|----------------|----------------|----------------|
| Educational Years | Illiterate     | Primary School | Junior School  | Senior School  | University     | Graduate       |
| 0                 | 9.1            | 38.7           | 52.2           | 70.1           | 28.8           | 1.1            |
| Ratio of Workers (\%) | 7.02        | 13.23          | | | | |

Source: The data are from “China Labor Statistical Yearbook 2007.”

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\(^1\) Educational levels below senior school include illiterate, primary school, and junior school; educational levels above senior school include senior school, college, university, and graduate.

\(^2\) These data are from China Labor Statistical Yearbook 2007 of National Bureau of Statistics of China.
In summary, Table 2.1 lists all the parameters and their values under base scenario.

### Table 2.1  List of Model Parameters under Baseline Scenario

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbol</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Growth Rate</td>
<td>$n$</td>
<td>0.08</td>
</tr>
<tr>
<td>Steady State Adult Survival Rate</td>
<td>$q^*$</td>
<td>0.8</td>
</tr>
<tr>
<td>Type 1 Agent’s Ratio of Total Working Population</td>
<td>$\eta$</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Economic and Technological Factors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Elasticity with respect to Capital</td>
<td>$\alpha$</td>
<td>0.4</td>
</tr>
<tr>
<td>Technological Improvement Growth</td>
<td>$g$</td>
<td>0.348</td>
</tr>
<tr>
<td>Steady State Stock of Human Capital</td>
<td>$H^*$</td>
<td>100</td>
</tr>
<tr>
<td>Type 1 Agent’s Ratio of Total Human Capital</td>
<td>$\gamma$</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>Other Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partially-Funded system Social Security Contribution Rate</td>
<td>$\tau_{pf}$</td>
<td>0.2</td>
</tr>
<tr>
<td>Partially-Funded System Individual Account Contribution Rate</td>
<td>$\tau_i$</td>
<td>0.08</td>
</tr>
<tr>
<td>PAYG System Contribution Rate</td>
<td>$\tau_{pg}$</td>
<td>0.264</td>
</tr>
<tr>
<td>Pure Rate of Time Preference</td>
<td>$\rho$</td>
<td>0.56</td>
</tr>
<tr>
<td>Discount Rate</td>
<td>$\delta$</td>
<td>0.64</td>
</tr>
<tr>
<td>Agent’s Preference for Leisure</td>
<td>$\beta$</td>
<td>0.6</td>
</tr>
</tbody>
</table>

#### 2.3.3.2 Simulation Results

We still use Mathematica 6.0 Program to calculate the simulated values of all economic variables. Table 2.2 and Table 2.3 list the calculation results.
Table 2.2  Steady State Values and Changes for Important Economic Variables under PAYG and Partially-Funded Economy

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>Case of Heterogeneous Agents and Endogenous LFP</th>
<th>PAYG</th>
<th>Partially-Funded</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Macroeconomic</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k*</td>
<td></td>
<td>0.00451</td>
<td>0.00826</td>
<td>83.1%</td>
</tr>
<tr>
<td>y*</td>
<td></td>
<td>11.5</td>
<td>14.68</td>
<td>27.5%</td>
</tr>
<tr>
<td>S</td>
<td></td>
<td>0.0142</td>
<td>0.0279</td>
<td>96.5%</td>
</tr>
<tr>
<td>r</td>
<td></td>
<td>0.081</td>
<td>0.069</td>
<td>-14.8%</td>
</tr>
<tr>
<td>w*</td>
<td></td>
<td>0.069</td>
<td>0.088</td>
<td>27.5%</td>
</tr>
<tr>
<td>Individual Welfare</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c_{y}^{1,*}</td>
<td></td>
<td>2.01</td>
<td>2.70</td>
<td>34.3%</td>
</tr>
<tr>
<td>c_{o}^{1,*}</td>
<td></td>
<td>14.44</td>
<td>17.51</td>
<td>21.3%</td>
</tr>
<tr>
<td>U^{1,*}</td>
<td></td>
<td>1.84</td>
<td>2.46</td>
<td>33.7%</td>
</tr>
<tr>
<td>I^{1,*}</td>
<td></td>
<td>3.76</td>
<td>4.97</td>
<td>32.2%</td>
</tr>
<tr>
<td>REP^{1,*}</td>
<td></td>
<td>0.43</td>
<td>0.83</td>
<td>93.0%</td>
</tr>
<tr>
<td>IR^{1,*}</td>
<td></td>
<td>-0.196</td>
<td>-0.172</td>
<td>12.2%</td>
</tr>
<tr>
<td>c_{y}^{2,*}</td>
<td></td>
<td>2.43</td>
<td>1.48</td>
<td>-39.1%</td>
</tr>
<tr>
<td>c_{o}^{2,*}</td>
<td></td>
<td>1.25</td>
<td>9.61</td>
<td>668.8%</td>
</tr>
<tr>
<td>U^{2,*}</td>
<td></td>
<td>0.74</td>
<td>1.55</td>
<td>109.5%</td>
</tr>
<tr>
<td>I^{2,*}</td>
<td></td>
<td>2.04</td>
<td>2.87</td>
<td>40.7%</td>
</tr>
<tr>
<td>REP^{2,*}</td>
<td></td>
<td>0.43</td>
<td>0.98</td>
<td>127.9%</td>
</tr>
<tr>
<td>IR^{2,*}</td>
<td></td>
<td>-0.196</td>
<td>-0.146</td>
<td>25.5%</td>
</tr>
<tr>
<td>I^{1,<em>}/I^{2,</em>}</td>
<td></td>
<td>1.84</td>
<td>1.739</td>
<td>-5.5%</td>
</tr>
</tbody>
</table>
Table 2.3 Calculation Values for Transitional Variables from PAYG Economy to Partially Funded Economy

<table>
<thead>
<tr>
<th>Transitional Variables</th>
<th>Symbol</th>
<th>Case of Heterogeneous Agents and Endogenous LFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Cost per Effective Worker</td>
<td>$t_{c}$</td>
<td>0.0056</td>
</tr>
<tr>
<td>Ratio of Transition Costs to Output (%)</td>
<td>$\frac{TC_{t}}{Y_{t}}$</td>
<td>1.71</td>
</tr>
<tr>
<td>Special Consumption tax Rate (%)</td>
<td>$\tau_{c}^{*}$</td>
<td>3.36</td>
</tr>
</tbody>
</table>

2.3.3.3 Comparative Analysis of Both Pension Systems under the Steady State

From the tables 2.2 and 2.3, we find that compared with the PAYG system, in addition to bringing about certain transition costs, the new PF pension system causes notable changes in macroeconomic economy, factor prices, individual welfare, and income distribution.

1) Macroeconomic Effects: $k^{*} \cdot y^{*} \cdot \left(\frac{S}{Y}\right)^{*} \cdot \tau^{*} \text{ and } w^{*}$

From Table 2.2, $k^{*}$ increases from 0.00451 under PAYG system to 0.00826 under Partially-Funded system, up 83.1%. The national saving rate $\left(\frac{S}{Y}\right)^{*}$ grows from 0.014 to 0.028 by 96.5%. There are at least three effects explaining the big increases: the efficiency effect from less labor market distortion, the structural effect from less social pension tax and higher return rate of pension deposits, and the recognition effect that the reform will cause the poor agents (type 2) to save more.

An increase in $k^{*}$ raises the output per worker $y^{*}$ by 27.5%, the steady state wage rate $w^{*}$ by 27.5%, and the decrease in the steady state annual interest rate $\tau^{*}$ by 14.8%.

2) Individual Welfare Effects: $c_{y}^{*} \cdot c_{o}^{*} \cdot U^{*} \cdot I^{*} \cdot REP^{*}$

We can find the Reform has different effects on individual welfare for different types of workers. For the type 1 workers, after reform, the steady state young-age consumption $c_{y}^{1*}$ rises
from 2.01 to 2.70, up 34.3%; the steady state old-age consumption $C^*_o$ increases from 14.4 to 17.5, up 21%; the steady state lifetime utility $U^*_1$ grows from 1.84 to 2.36, up 34%; For the type 2 workers, the Reform lowers $C^*_y$ from 2.43 to 1.48 by 36.6%, raises $C^*_o$ from 1.25 to 9.6 by 669%, and $U^*_2$ from 0.74 to 1.55 by 110%. Compared with the rich agent, the poor agent gains 70% higher from the Reform in the long run.

The pension reform brings about higher $w^*$ and lower $\bar{r}$. A higher $w^*$ increases both young-age consumption and old-age consumption. $\bar{r}$ has a negative effect on young-age consumption and a positive effect on old-age consumption, while it has no effect on both young-age consumption and old-age consumption under PAYG system for the type 2 workers as they do not participate in the financial system. Therefore, for the type 1 workers, the combined positive effects of higher $w^*$ and lower $\bar{r}$ cause the strong increase in young-age consumption. The positive effect of higher $w^*$ dominates the negative effect of lower $\bar{r}$, causing the smaller increase in old-age consumption. The increases in both young-age consumption and old-age consumption explain the rise in $U^*_1$. For the type 2 workers, the strong negative effect of $\bar{r}$ dominates the positive effect of a higher $w^*$, leading to the decline in young-age consumption, while the combined positive effects of $\bar{r}$ and higher $w^*$ cause the very strong rise in old-age consumption, which outpaces the decrease in young-age consumption, explaining the strong increase in $U^*_2$.

As a result of higher wage $w^*$ and lower interest rate $\bar{r}$, type 1 workers’ steady state lifetime income $I^*_1$ increases from 3.76 to 4.97 by 32.2%, and type 2 workers’ steady state lifetime income $I^*_2$ rises from 2.04 to 2.87 by 40.7%.
In addition, type 1 workers’ steady state pension replacement ratio $\text{REP}^1$ under Partially Funded system is 0.83, up 93% from 0.43 under PAYG system; Type 2 workers’ steady state pension replacement ratio $\text{REP}^2$ increase from 0.43 to 0.98 by 128%. The main reason for the big rises is the rate of return for pension-$r^*$ under Partially Funded system is much greater than the rate of return for pension-$(1+g)(1+n)$ under PAYG system.

3) Income Redistribution Effects: $I^1 / I^2$, and $\text{IR}^*$

As we discussed before, one of the main issues concerning the pension reform from PAYG to Funded is that income equality may deteriorate as the income redistribution mechanism may not exist or be weakened. One main purpose of this Paper is to study this issue.

Here we use two variables to measure income redistributions including intragenerational and intergenerational income redistributions. One is the lifetime income ratio of type 1 agent over type 2 agents $I^1 / I^2$. Under China’s PAYG system, $I^1_p / I^2_p \approx \gamma / (1 - \gamma)$. That is, agents’ lifetime income ratio is equal to the ratio of their human capital levels. As $\gamma > 0.5$ (which we assumed), $I^1 / I^2 > 1$, type 1 agent gets higher lifetime income than type 2 agent.

Under the new PF system, $I^1_p / I^2_p = (1 - \tau_p)q^*(l + r^*) + \beta^2\gamma(l + g)(1 - \tau_p)q^*(l + n)(1 + g) / (1 - \gamma)(1 - \gamma)q^*(l + r^*) + \beta^2\gamma(l + g)(1 - \tau_p)q^*(l + n)(1 + g)$.

It is easy to find: $I^1_p / I^2_p$ is not only determined by labor earnings, but also by capital income and by the design of the PF pension system. In addition, $I^1_p / I^2_p < I^1_p / I^2_p$. Actually, under the baseline scenario, the lifetime income ratio declines from 1.84 under PAYG system to 1.74 under PF system by 5.5%. That is, China’s pension reform improves the intragenerational income distribution, a result different from James (1997)’ claim that the privatization of PAYG system may deteriorate income equality. The reason is China’s original PAYG pension system has no function of intragenerational income redistribution, which is different from the general PAYG
systems in the world. After the Reform, the PAGY-based social account restores the intragenerational income redistribution function, that is, the poor agent can get intragenerational transfers from the rich agent, thus leading to the narrowing of the income gap between the poor and the rich.

The other variable measuring the extent of income redistribution is the present value of income redistribution $IR^{i,t}$. Under PAYG system, $IR^{1,pg}_p = IR^{2,pg}_p = -0.02$, both agents’ present values of income redistribution are equal and negative. First, $IR^{1,pg}_p = IR^{2,pg}_p$ means China’s original PAYG system has no intragenerational income redistribution function, a result consistent with the one above. Second, both values for $IR^{i,t}$ are negative, meaning the current generation make outward intergenerational transfers to the next generations.

Under the new PF system, $IR^{1, pf}_p = -0.17$, $IR^{2, pf}_p = -0.15$. First, in terms of absolute value, $IR^{1, pf}_p > IR^{2, pf}_p$ means the poor agent gets intragenerational transfers from the rich agent. Second, both values are negative and less than the ones under PAGY system, meaning the current generation still makes outward transfers to the next generations, yet the scale of outward intergenerational transfers is reduced as the individual account under new Partially-Funded system has no effect of intergenerational transfer.

Thus, before the Reform, China’s PAYG system has no intra-generational income redistribution, yet has strong outward inter-generational income redistribution; after the Reform, the new PF system has both intra-generational and outward inter-generational income redistributions, yet the level of outward intergenerational transfer decreases. That is, Partially-Funded system is economically fairer than PAYG system.

4) Transitional Effects: $tc_i$, $\frac{TC_i}{Y_i}$, and $\tau_c$
From Table 2.3, at reform period t, the transition cost per unit of effective labor $tC_t$ is 0.006, and the ratio of transition costs to the output $\frac{tC_t}{X_t}$ is 1.7%. The steady state special consumption tax rate $\tau_c$ is 3.4%.

To sum up, firstly, China’s pension reform from PAYG to partial funding has significant and favorable effects on China’s macro economy, production factors prices, individual welfare, and economic fairness. Secondly, for the poor agent (type 2 agent), the Reform not only raises his welfare greatly, but also improves income inequality substantially. Compared with the rich agent, the poor agent benefits much more from the Reform. Finally, the Reform causes certain transitional costs, yet the tax burden on the consumers to finance the transitional costs imposed is relatively light.

2.4 Full Funding VS Partial Funding

In 1981, Chile implemented the first kind of pension reform from PAYG to full funding that many researchers (Holzmann 1996; Schmidt-Hebbel 1999; Samwick 2000; Coronado 2002) found has positive and significant effects on labor market, saving, and economic growth, thus some countries like Mexico and Argentina have followed case. What if “Chilean Experience” applied to China’s pension reform? How the steady state capital per unit of effective labor $k^*$ corresponds to the change in funding ratio $f$? We define $f = (\tau_{pf} - \tau_{pg})/\tau_{pg}$, where $\tau_{pg}$ is PAYG system contribution rate, $\tau_{pf}$ is Partially Funded System social account contribution rate ($0 \leq \tau_{pf} \leq \tau_{pg}$).

“Chilean Experience” Applied to China. Table 2.4 shows the simulation results of full funding ($\tau_{pf}=0$) versus partial funding ($\tau_{pf}=0.2$).
Table 2.4  Full Funding VS Partial Funding

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>Full Funding</th>
<th>Partial Funding</th>
<th>Change</th>
<th>Full Funding</th>
<th>Partial Funding</th>
<th>Change</th>
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<tr>
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<td>After-reform</td>
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<td>After-reform</td>
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<td>Variables</td>
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<td></td>
</tr>
<tr>
<td>k*</td>
<td>0.00451</td>
<td>0.00659</td>
<td>46.12%</td>
<td>0.00451</td>
<td>0.00826</td>
<td>83.15%</td>
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<tr>
<td>y*</td>
<td>11.51</td>
<td>13.33</td>
<td>15.81%</td>
<td>11.51</td>
<td>14.68</td>
<td>27.54%</td>
</tr>
<tr>
<td>(S/Y)*</td>
<td>0.0142</td>
<td>0.032</td>
<td>125.35%</td>
<td>0.0142</td>
<td>0.0279</td>
<td>96.48%</td>
</tr>
<tr>
<td>r</td>
<td>0.081</td>
<td>0.078</td>
<td>-3.70%</td>
<td>0.081</td>
<td>0.069</td>
<td>-14.81%</td>
</tr>
<tr>
<td>w*</td>
<td>0.069</td>
<td>0.082</td>
<td>18.84%</td>
<td>0.069</td>
<td>0.088</td>
<td>27.54%</td>
</tr>
<tr>
<td>Welfare</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U1.*</td>
<td>1.84</td>
<td>2.32</td>
<td>26.09%</td>
<td>1.84</td>
<td>2.46</td>
<td>33.70%</td>
</tr>
<tr>
<td>I1.*</td>
<td>3.76</td>
<td>4.87</td>
<td>29.52%</td>
<td>3.76</td>
<td>4.97</td>
<td>32.18%</td>
</tr>
<tr>
<td>REP1*</td>
<td>0.43</td>
<td>0.78</td>
<td>81.40%</td>
<td>0.43</td>
<td>0.83</td>
<td>93.02%</td>
</tr>
<tr>
<td>IR1.*</td>
<td>-0.196</td>
<td>0</td>
<td>-100.0%</td>
<td>-0.196</td>
<td>-0.172</td>
<td>-12.24%</td>
</tr>
<tr>
<td>U2.*</td>
<td>0.74</td>
<td>1.46</td>
<td>97.30%</td>
<td>0.74</td>
<td>1.55</td>
<td>109.46%</td>
</tr>
<tr>
<td>I2.*</td>
<td>2.04</td>
<td>2.73</td>
<td>33.82%</td>
<td>2.04</td>
<td>2.87</td>
<td>40.69%</td>
</tr>
<tr>
<td>REP2*</td>
<td>0.43</td>
<td>0.96</td>
<td>123.26%</td>
<td>0.43</td>
<td>0.98</td>
<td>127.91%</td>
</tr>
<tr>
<td>IR2.*</td>
<td>-0.196</td>
<td>0</td>
<td>100.0%</td>
<td>-0.196</td>
<td>-0.146</td>
<td>-25.51%</td>
</tr>
<tr>
<td>I*/I2*</td>
<td>1.843</td>
<td>1.784</td>
<td>-3.20%</td>
<td>1.843</td>
<td>1.732</td>
<td>-6.02%</td>
</tr>
</tbody>
</table>

Firstly, similar to the Reform of partial funding, the Reform of full funding also has favorable and notable effects on macroeconomic economy, individual welfare, and income distribution. For example, capital stock rises by 46%, national saving rate by 126%, real wage by 19%, agent 2’s lifetime income by 33%, and agents’ income gap decreases by 3.2%.

Secondly, the case of full funding causes much higher transitional costs and heavier tax
burden, yet much weaker macroeconomic and welfare effects. For instance, under the case of full funding, the ratio of transition costs to the output and the steady state special consumption tax rate are 13.9% and 14.3% respectively, much higher than 1.7% and 2.4% under the case of partial funding. Additionally, output increases by 16%, agent 2’s lifetime income by 34%, and agents’ income gap by 3.2%, much lower than 28%, 41%, and 6.0% respectively under the case of partial funding.

**Comparative Analysis of \( k_{pf}^* \) with regard to funding ratio \( f \).** For simplicity, we use the following implicit equation group (1.42) - (1.45) to make the comparative analysis.

\[
k_{pf}^{*1-\alpha} = \frac{\phi^*(1-\alpha)}{(1+n+q^*lp^*)(1+g)} - \frac{(\tau_{pg} - \tau_{pf})k_{rs}^{*\alpha}}{(1+n+q^*lp^*)(1+g)k_{rs}^{*\alpha}} \tag{1.42}
\]

\[
\phi^* = \frac{(1+r^*)(q^*\beta\delta + q^*\delta)(1-\tau_{\mu}) - (1+g)[\tau_{pf}(1+n)+q^*]}{(1+r^*)(1+q^*\beta\delta + q^*\delta)} \tag{1.43}
\]

\[
lp^* = \frac{(1+q^*\delta) - \beta\delta(1+r^*)(1-\tau_{\mu})/(1+g) - \beta\delta\tau_{pf}(1+n)}{(1+q^*\beta\delta + q^*\delta)} \tag{1.44}
\]

\[r^* = \alpha k_{pf}^{*\alpha - 1} \tag{1.45}
\]

From (1.42), we can further get:

\[
k_{pf}^* = \frac{\phi^*(1-\alpha)k_{rs}^{*\alpha}}{(1+n+q^*lp^*)(1+g)} - \frac{(\tau_{pg} - \tau_{pf})k_{rs}^{*\alpha}}{(1+n+q^*lp^*)(1+g)k_{rs}^{*\alpha}} = \frac{(1-\alpha)\phi^*k_{rs}^{*\alpha} - (\tau_{pg} - \tau_{pf})k_{rs}^{*\alpha}}{(1+n)(1+g)} \tag{2.60}
\]

\[
\frac{\partial k_{pf}^*}{\partial \tau_{pf}} = \frac{(1-\alpha)\frac{\partial \phi^*}{\partial \tau_{pf}}k_{rs}^{*\alpha} + \phi^* \alpha k_{rs}^{*\alpha - 1} + k_{rs}^{*\alpha} + k_{rs}^{*\alpha}}{(1+n)(1+g)} = \frac{(1-\alpha)\frac{\partial \phi^*}{\partial \tau_{pf}}k_{rs}^{*\alpha} + k_{rs}^{*\alpha}}{(1+n)(1+g) - \phi^* \alpha k_{rs}^{*\alpha - 1}} \tag{2.61}
\]
From (2.60), the value of $k^*_{pf}$ depends on the difference of two terms $p, q$, where we assume 
\[
p = \frac{\phi^*(1-\alpha)k^*_{pf}}{(1+n+q^*lp^*)(1+g)} \text{ and } q = \frac{(\tau_{pg} - \tau_{pf})k^*_{pg}}{(1+n+q^*lp^*)(1+g)}.
\] Term $p$ represents the saving effect and term $q$ represents the debt effect.\(^1\)

As $f = (\tau_{pg} - \tau_{pf})/\tau_{pg}$, we get \[
\frac{\partial k^*_{pf}}{\partial f} = -\frac{\partial k^*_{pf}}{\partial \tau_{pf}}. \] So if we know the sign of $\frac{\partial k^*_{pf}}{\partial \tau_{pf}}$, the sign of $\frac{\partial k^*_{pf}}{\partial f}$ is just the opposite. From (1.43), it is easy to get $\frac{\partial \phi^*}{\partial \tau_{pf}} < 0$, yet to determine the sign of $\frac{\partial k^*_{pf}}{\partial \tau_{pf}}$ from (2.61), we also need the values of $\alpha, n, g, \phi^*, k^*_{pg}, k^*_{pf}, r^*$.

Based on the parameter values in Table 1.3 and the simulated results, we find the sign of the numerator of (2.61) is positive, yet the sign of dominator is negative when $\tau_{pf}$ is greater than the critical value $\tau_{pf}^\wedge$, and becomes positive when $\tau_{pf}$ is less than the critical value $\tau_{pf}^\wedge$:

\[
\frac{\partial k^*_{pf}}{\partial \tau_{pf}} < 0 \quad \text{if } \tau_{pf} < \tau_{pf}^\wedge < \tau_{pf}
\]

\[
\frac{\partial k^*_{pf}}{\partial \tau_{pf}} > 0 \quad \text{if } 0 < \tau_{pf} < \tau_{pf}^\wedge
\]

That is, when $\tau_{pf} < \tau_{pf} < \tau_{pf}^\wedge$, with the decrease in $\tau_{pf}$, $k^*_{pf}$ increases. When $\tau_{pf}$ decreases to $\tau_{pf}^\wedge$, $k^*_{pf}$ increases to its maximum value. When $0 < \tau_{pf} < \tau_{pf}^\wedge$, with the decrease in $\tau_{pf}$, $k^*_{pf}$ decreases.

---

\(^1\) In economic terms, the saving effect means the capital accumulating effect due to the savings invested as capital, while the debt effect means the capital decumulating effect due to the 1-1 replacement of debt to the wealth, that is, every unit of debt replaces one unit of wealth, then one unit of capital.
Figure 2.1 shows how the values of $k_{pf}^*$, $p$ (saving effect), $q$ (debt effect) respond to the change in funding ratio $f$. When $\tau_{pf}=0.2$, $f=24\%$, which is the China’s partial-funded case, $k_{pf=0.2}^*=0.0164$, while $\tau_{pf}=0.0$, $f=100\%$, which is the Chilean full-funded case, $k_{pf=0}^*=0.016$. As $k_{pf=0.2}^*>k_{pf=0}^*$, the result shows partial funding is better than full funding for China.

The dynamic effect on $k_{pf}^*$ is charted in Figure 2.1. With the increase in funding ratio $f$, more funding causes more saving $p$ and bigger debt $q$, yet the positive effect of higher saving $p$ outpaces the negative effect of bigger debt $q$, leading to the increase in increase in $k_{pf}^*$. When $f$ increases to the critical value $\hat{f}$ ($\hat{f} = 0.55$), $k_{pf}^*$ reaches the maximum value $k_{pf}^{\hat{f}}$ ($k_{f=0.55}^{\hat{f}} = 0.019$).

Thereafter, when $f > \hat{f}$, more funding still causes more saving $p$ and bigger debt $q$, however, the negative effect of bigger $q$ outpaces the positive effect of higher $p$, leading to the decrease in increase in $k_{pf}^*$.

The economic dynamics of the model can also be explained in terms of wealth. In an economy, the capital level depends on the accumulated wealth. With the increase in funding ratio
f, more funding causes more savings that accumulate the wealth and bigger debts that decumulate the wealth. When the initial wealth level is low, the wealth accumulating effect dominates the wealth decumulating effect, that is, the net wealth effect is positive, leading to the increase in wealth level, thus the increase in capital level. When the wealth level increases to the critical value, due to the law of decreasing marginal effect on wealth of savings\textsuperscript{1}, the wealth accumulating effect of savings begins to be dominated by the wealth decumulating effect of debts, that is, the net wealth effect becomes negative, causing the decrease in net wealth, thus the decrease in capital level.

However, it is worth noting the finding above is based on the selected parameter values and simulated results that are determined by China’s specific situation. If the situation has changed, that is, the values in $\alpha, \phi^*, n, g, k^*, k^*, r^*$ change accordingly, the analysis of sign of (2.61) may be different, so the finding that partial funding is better than full funding should be considered with caution.

In sum, for China, the world’s biggest developing country with fastest economic growth, highest national saving rate, and rapidest and largest-scale population aging, the adoption of “Chilean Experience” would make the huge implicit pension debt (IPD) explicit, thus bringing up huge transition costs, amounting to 14% of the output, and heavy tax burden, which decrease the growth potentials for capital accumulation and output, lower workers’ wage rate and lifetime income, and widen workers’ income gap. Therefore, based on China’s specific situations, partial funding is better than full funding for China’s pension reform, which compliments the current literature.

\textsuperscript{1}From Equation (2.60), $\frac{\partial P}{\partial f} > 0, \frac{\partial^2 P}{\partial f^2} < 0$, that is, the marginal effect of savings $p$ on wealth is decreasing.
2.5 The Case of Complete Access to Financial System of Poor Agent

We now consider the case that inequality in the human capital endowments still exists, yet the difference in access to the financial system is removed, that is, both rich agents and poor agents can get access to the financial system. This case will resemble a more advanced economy with a developed financial system. Additionally, as we said before, China’s PAYG system is different from the general PAYG system in that China’s PAYG system has no feature of intragenerational income redistribution while the general PAYG system does have. Thus, we consider two cases to assess whether the main results regarding China’s pension reform will be changed when poor agents can get access to the financial system under the PAYG economy.

Table 2.5 shows the simulated results for the two cases that the poor agent can get access to the financial system under PAYG economy. First, compared with the case that poor agent can not get access to the financial system, the two cases of Table 2.5 have much weaker macroeconomic and welfare effects, however, the main results that China’s pension reform has significant favorable effects on macroeconomic economy and individual welfare still hold.

Second, the implications for income inequality between agents of both types are different under the two cases. The Reform decreases the income inequality under the case of China’s PAYG system, while increases the income inequality under the case of general PAYG system. The reason is China’s original PAYG pension system has no function of intragenerational income redistribution. After the Reform, the PAGY-based social account restores the intragenerational income redistribution function, that is, the poor agent can get intragenerational transfers from the rich agent, thus leading to the narrowing of the income gap between the poor and the rich.

However, for the general PAYG case, the reform decreases the effect of intragenerational income redistribution by adding funded individual account, causing the increase in income inequality between the rich and the poor agents. Thus, if China’s original PAYG system was a general PAYG system, the income inequality would deteriorate under the new assumption that poor agents can get full access to the financial system.
Table 2.5 The Simulated Results for the Cases of Poor Agent’ Access to Financial System

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>China’s PAYG Case</th>
<th>General PAYG Case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-reform</td>
<td>After-reform</td>
</tr>
<tr>
<td>k*</td>
<td>0.00727</td>
<td>0.00826</td>
</tr>
<tr>
<td>y*</td>
<td>13.94</td>
<td>14.68</td>
</tr>
<tr>
<td>(S/Y)*</td>
<td>0.0218</td>
<td>0.0279</td>
</tr>
<tr>
<td>r</td>
<td>0.074</td>
<td>0.069</td>
</tr>
<tr>
<td>w*</td>
<td>0.084</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Macroeconomic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Pre-reform</th>
<th>After-reform</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1*</td>
<td></td>
<td>2.389</td>
<td>2.461</td>
<td>3.01%</td>
</tr>
<tr>
<td>I1*</td>
<td></td>
<td>4.34</td>
<td>4.97</td>
<td>14.52%</td>
</tr>
<tr>
<td>REP1*</td>
<td></td>
<td>0.43</td>
<td>0.83</td>
<td>93.02%</td>
</tr>
<tr>
<td>IR1*</td>
<td></td>
<td>-0.196</td>
<td>-0.172</td>
<td>-12.24%</td>
</tr>
<tr>
<td>U2*</td>
<td></td>
<td>1.486</td>
<td>1.55</td>
<td>4.31%</td>
</tr>
<tr>
<td>I2*</td>
<td></td>
<td>2.34</td>
<td>2.87</td>
<td>22.65%</td>
</tr>
<tr>
<td>REP2*</td>
<td></td>
<td>0.43</td>
<td>0.98</td>
<td>127.91%</td>
</tr>
<tr>
<td>IR2*</td>
<td></td>
<td>-0.196</td>
<td>-0.146</td>
<td>-25.51%</td>
</tr>
<tr>
<td>I* / I*</td>
<td></td>
<td>1.847</td>
<td>1.732</td>
<td>-6.23%</td>
</tr>
</tbody>
</table>

Welfare Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Pre-reform</th>
<th>After-reform</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>w</td>
<td></td>
<td>0.084</td>
<td>0.088</td>
<td>4.76%</td>
</tr>
<tr>
<td>r</td>
<td></td>
<td>0.074</td>
<td>0.069</td>
<td>-6.76%</td>
</tr>
<tr>
<td>S(Y)</td>
<td></td>
<td>0.0218</td>
<td>0.0279</td>
<td>27.98%</td>
</tr>
<tr>
<td>k</td>
<td></td>
<td>0.00727</td>
<td>0.00826</td>
<td>13.62%</td>
</tr>
<tr>
<td>y</td>
<td></td>
<td>13.94</td>
<td>14.68</td>
<td>5.31%</td>
</tr>
</tbody>
</table>

2.6 Sensitivity Analysis on \(\eta\), \(\gamma\) and \(q^*\)

In this part, we adjust the values of type 1 agent’s ratio of total working population \(\eta\), type 1 agent’s ratio of total human capital \(\gamma\), and then adult survival rate \(q^*\) to see how the changes in the key parameters’ values affect the simulated economic effects of the Reform. Our baseline scenario set \(\eta=0.2, \gamma=0.65\), and \(q^*=0.8\). We will change the values of \(\eta\) to 0.1, 0.5, 0.8, and the values of \(\gamma\) to 0.55 and 0.85, the values of \(q^*\) to 0.7 and 0.9 respectively.
2.6.1 Sensitivity Analysis on $\eta$ and $\gamma$

2.6.1.1 Effects on Capital Level $k^*$ and National Saving Rate $(\frac{S}{Y})^*$

Table 2.6 shows the effects of the Reform on macroeconomic variables like $k^*$ and $(\frac{S}{Y})^*$ for different combinations of $\eta$ and $\gamma$.

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>$k^*_{pg}$</th>
<th>$k^*_{pf}$</th>
<th>Change (%)</th>
<th>$(\frac{S}{Y})^*_{pg}$</th>
<th>$(\frac{S}{Y})^*_{pf}$</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>0.000931</td>
<td>0.00595</td>
<td>539.10</td>
<td>0.007</td>
<td>0.021</td>
<td>205.35</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>0.00172</td>
<td>0.00686</td>
<td>298.84</td>
<td>0.010</td>
<td>0.023</td>
<td>130.69</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>0.00521</td>
<td>0.0102</td>
<td>95.78</td>
<td>0.022</td>
<td>0.034</td>
<td>54.55</td>
</tr>
<tr>
<td>$\eta = 0.2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>0.00262</td>
<td>0.00778</td>
<td>196.95</td>
<td>0.013</td>
<td>0.025</td>
<td>92.31</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td><strong>0.00451</strong></td>
<td><strong>0.00826</strong></td>
<td><strong>83.15</strong></td>
<td><strong>0.014</strong></td>
<td><strong>0.028</strong></td>
<td><strong>96.57</strong></td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>0.00913</td>
<td>0.0143</td>
<td>56.63</td>
<td>0.027</td>
<td>0.037</td>
<td>37.04</td>
</tr>
<tr>
<td>$\eta = 0.5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>0.00842</td>
<td>0.0133</td>
<td>57.96</td>
<td>0.026</td>
<td>0.034</td>
<td>30.77</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>0.0108</td>
<td>0.0158</td>
<td>46.30</td>
<td>0.031</td>
<td>0.038</td>
<td>22.58</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>0.0145</td>
<td>0.0189</td>
<td>30.34</td>
<td>0.036</td>
<td>0.042</td>
<td>16.67</td>
</tr>
<tr>
<td>$\eta = 0.8$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>0.0142</td>
<td>0.0178</td>
<td>25.35</td>
<td>0.035</td>
<td>0.041</td>
<td>15.30</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>0.0151</td>
<td>0.0187</td>
<td>23.84</td>
<td>0.037</td>
<td>0.042</td>
<td>13.82</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>0.0167</td>
<td>0.0201</td>
<td>20.36</td>
<td>0.038</td>
<td>0.044</td>
<td>15.79</td>
</tr>
</tbody>
</table>

First, with the increase in $\eta$ or $\gamma$, the steady state capital per unit of effective labor $k^*$ and national saving rate $(\frac{S}{Y})^*$ under both pension systems become larger and larger. The reason is if $\eta$ or $\gamma$ become larger, meaning the ratio of type 1 agent to the total population or the ratio to the total human capital are higher, more savings can be invested as capital, causing higher $k^*$ and $(\frac{S}{Y})^*$. 
Second, in all cases, after the Reform, levels in $k^*$ and $(\frac{S}{Y})^*$ under PF system are higher than those in PAYG system, meaning the Reform has a positive and significant effect on macro economy. Third, with the increase in $\eta$ or $\gamma$, the positive effects of the Reform on $k^*$ and $(\frac{S}{Y})^*$ become smaller and smaller. For example, compared to the baseline scenario where $k^*$ increases by 83%, under the case $\eta=0.8, \gamma=0.85$, the Reform only raises $k^*$ by 20%. The higher $\eta$ or $\gamma$ is, after the Reform, the less is the increase in savings accumulated as capital, the smaller is the effect of the Reform.

2.6.1.2 Effects on Agent 1’s Lifetime Income $I_{1}^{1,*}$ and Agent 2’s Lifetime Income $I_{1}^{2,*}$

Table 2.7 shows the effects of the Reform on individual welfare variables $I_{1}^{1,*}$ and $I_{1}^{2,*}$ for different values of $\eta$ and $\gamma$.

First, with the increase in $\eta$, the steady state agent 1’s lifetime income $I_{1}^{1,*}$ and agent 2’s lifetime income $I_{1}^{2,*}$ under both pension systems increase. In addition, the increase in $\gamma$ causes higher $I_{1}^{1,*}$ and lower $I_{1}^{2,*}$. Bigger $\eta$ and $\gamma$ causing higher labor productivity and wage, explaining for the strong increase in $I_{1}^{1,*}$, yet the negative effect of higher $\gamma$ dominates the positive effect of higher wage, causing the decrease in $I_{1}^{2,*}$.

Second, under all scenarios, both two type agents are better off after the Reform, meaning the Reform has a positive and significant effect on individual welfare. Third, in most cases, with bigger $\eta$ or $\gamma$, after the Reform, the improvement in agents’ welfare become less.
Table 2.7  Effects on $I_{1}^{*}$ and $I_{2}^{*}$ with Different Values of $\eta$ and $\gamma$

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>$I_{pg}^{1,*}$</th>
<th>$I_{pf}^{1,*}$</th>
<th>Change (%)</th>
<th>$I_{pg}^{2,*}$</th>
<th>$I_{pf}^{2,*}$</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>1.52</td>
<td>3.70</td>
<td>143.42</td>
<td>1.24</td>
<td>3.08</td>
<td>148.15</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>2.26</td>
<td>4.69</td>
<td>107.52</td>
<td>1.21</td>
<td>2.59</td>
<td>114.05</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>4.85</td>
<td>7.09</td>
<td>46.08</td>
<td>0.90</td>
<td>1.67</td>
<td>85.22</td>
</tr>
<tr>
<td>$\eta = 0.2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>3.76</td>
<td>4.97</td>
<td>32.29</td>
<td>2.04</td>
<td>2.87</td>
<td>40.64</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>2.32</td>
<td>4.15</td>
<td>78.79</td>
<td>2.10</td>
<td>3.46</td>
<td>64.62</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>6.16</td>
<td>8.04</td>
<td>30.52</td>
<td>1.09</td>
<td>1.96</td>
<td>79.36</td>
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<tr>
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<td>3.85</td>
<td>5.23</td>
<td>35.77</td>
<td>3.15</td>
<td>4.39</td>
<td>39.27</td>
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<td>6.44</td>
<td>28.80</td>
<td>2.69</td>
<td>3.78</td>
<td>40.52</td>
</tr>
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<td>9.10</td>
<td>20.53</td>
<td>1.33</td>
<td>2.30</td>
<td>72.71</td>
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</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>4.83</td>
<td>6.02</td>
<td>24.64</td>
<td>3.95</td>
<td>5.08</td>
<td>28.48</td>
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<td>7.34</td>
<td>24.62</td>
<td>3.17</td>
<td>4.43</td>
<td>39.62</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>8.04</td>
<td>9.42</td>
<td>17.13</td>
<td>1.42</td>
<td>2.39</td>
<td>68.31</td>
</tr>
</tbody>
</table>

2.6.1.3 Effects on Agents’ Lifetime Income Ratio $\tilde{\bar{r}}/\tilde{\bar{p}}$ and Agent 2’s Income Redistribution $IR^{2,*}$

Table 2.8 shows the effects of the Reform on income distribution variables $I^{*}/\tilde{I}^{*}$ and $IR^{2,*}$ for different values of $\eta$ and $\gamma$. 
First, higher $\eta$ has no effect on $I_{pg}^{1,*}/I_{pg}^{2,*}$ that is equal to $\gamma/(1-\gamma)$ and a weak negative effect on $I_{pf}^{1,*}/I_{pf}^{2,*}$ while higher $\gamma$ has a strong positive effect on $I_{pg}^{1,*}/I_{pg}^{2,*}$ under both systems. In addition, with the increase in $\eta$ or $\gamma$, $IR_{pf}^{2,*}$ decreases gradually, even becomes positive in some cases, meaning there are more and more intra-generational transfers from rich agent to poor agent.

Second, in all cases, the Reform leads to lower levels in $I_{pg}^{1,*}/I_{pg}^{2,*}$ and $IR_{pf}^{2,*}$, meaning the Reform improves the income inequality between two agents through income redistribution.

Third, with the increase in $\gamma$ or $\eta$, the income redistribution effect of the Reform becomes stronger and stronger. The higher is $\gamma$ or $\eta$, after the Reform, the more is the income redistribution from type 1 agent to type 2 agent, the stronger is the income redistributive effect of the Reform.

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>$I_{pg}^{1,<em>}/I_{pg}^{2,</em>}$</th>
<th>$I_{pf}^{1,<em>}/I_{pf}^{2,</em>}$</th>
<th>Change (%)</th>
<th>$IR_{pg}^{2,*}$</th>
<th>$IR_{pf}^{2,*}$</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta = 0.1$</td>
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<td></td>
<td></td>
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<td>$\gamma = 0.55$</td>
<td>1.23</td>
<td>1.20</td>
<td>-1.90</td>
<td>-0.22</td>
<td>-0.16</td>
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<td>4.25</td>
<td>-21.13</td>
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<td>-0.13</td>
<td>35.23</td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>1.22</td>
<td>1.20</td>
<td>-1.65</td>
<td>-0.21</td>
<td>-0.16</td>
<td>26.19</td>
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<tr>
<td>$\gamma = 0.65$</td>
<td>1.84</td>
<td>1.73</td>
<td>-5.94</td>
<td>-0.20</td>
<td>-0.15</td>
<td>25.50</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
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<td>4.11</td>
<td>-27.23</td>
<td>-0.18</td>
<td>-0.09</td>
<td>51.96</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>1.22</td>
<td>1.19</td>
<td>-2.52</td>
<td>-0.18</td>
<td>-0.14</td>
<td>24.31</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>1.86</td>
<td>1.70</td>
<td>-8.34</td>
<td>-0.18</td>
<td>-0.11</td>
<td>35.43</td>
</tr>
<tr>
<td>$\gamma = 0.85$</td>
<td>5.68</td>
<td>3.96</td>
<td>-30.21</td>
<td>-0.22</td>
<td>0.03</td>
<td>111.93</td>
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<td>$\eta = 0.8$</td>
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</tr>
<tr>
<td>$\gamma = 0.55$</td>
<td>1.22</td>
<td>1.19</td>
<td>-2.99</td>
<td>-0.17</td>
<td>-0.12</td>
<td>26.06</td>
</tr>
<tr>
<td>$\gamma = 0.65$</td>
<td>1.86</td>
<td>1.66</td>
<td>-10.75</td>
<td>-0.16</td>
<td>-0.06</td>
<td>63.21</td>
</tr>
<tr>
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<td>5.66</td>
<td>3.94</td>
<td>-30.41</td>
<td>-0.22</td>
<td>0.13</td>
<td>161.01</td>
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</table>
2.6.1.4 Effects on Transition Variables $t_c$, $\frac{TC_i}{Y_i}$, $\tau_c$

Table 2.9 shows the effects of the Reform on transition variables $t_c$, $\frac{TC_i}{Y_i}$, $\tau_c$, and $\tau^*$ for different combinations of $\eta$ and $\gamma$.

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th>$t_c$</th>
<th>$\frac{TC_i}{Y_i}$ (%)</th>
<th>$\tau_c$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\eta = 0.1$</td>
<td>$\gamma = 0.55$</td>
<td>0.0023</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.65$</td>
<td>0.0029</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.85$</td>
<td>0.0047</td>
<td>1.74</td>
</tr>
<tr>
<td>$\eta = 0.2$</td>
<td>$\gamma = 0.55$</td>
<td>0.0035</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.65$</td>
<td><strong>0.0056</strong></td>
<td><strong>1.74</strong></td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.85$</td>
<td>0.0059</td>
<td>1.74</td>
</tr>
<tr>
<td>$\eta = 0.5$</td>
<td>$\gamma = 0.55$</td>
<td>0.0057</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.65$</td>
<td>0.0062</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.85$</td>
<td>0.0070</td>
<td>1.74</td>
</tr>
<tr>
<td>$\eta = 0.8$</td>
<td>$\gamma = 0.55$</td>
<td>0.0070</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.65$</td>
<td>0.0072</td>
<td>1.74</td>
</tr>
<tr>
<td></td>
<td>$\gamma = 0.85$</td>
<td>0.0075</td>
<td>1.74</td>
</tr>
</tbody>
</table>

Seen from Table 2.8, with the increase in $\eta$ or $\gamma$, the transition cost per unit of effective labor $t_c$ increases, the ratio of transition costs to the output $\frac{TC_i}{Y_i}$ keeps constant, and the special consumption tax rate $\tau_c$ decreases, yet the decrease is little, meaning very low sensitivity to the change in $\eta$ or $\gamma$.

2.6.2 Sensitivity Analysis on Aging Variable $q^*$
Table 2.10 shows the macroeconomic and welfare effects of the Reform for different values of q*.

### Table 2.10  Macroeconomic and Welfare Effects with Different Values of q*

<table>
<thead>
<tr>
<th>Economic Variables</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k*</td>
<td>S/Y</td>
<td>r</td>
<td>w*</td>
<td>I1*I'</td>
<td>IR1*I'</td>
</tr>
<tr>
<td></td>
<td>0.0043 0.0078 79.8%</td>
<td>0.013 0.024 84.6%</td>
<td>0.084 0.072 -14.3%</td>
<td>0.0681 0.0842 23.6%</td>
<td>3.61 4.65 28.8%</td>
<td>-0.191 -0.164 -14.1%</td>
</tr>
<tr>
<td>Macroeconomic</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
</tr>
<tr>
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<td>q*</td>
<td>q*</td>
</tr>
<tr>
<td></td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
<td>q*</td>
</tr>
<tr>
<td></td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>0.0046 0.0083 82.4%</td>
<td>0.015 0.028 86.7%</td>
<td>0.079 0.0689 -12.8%</td>
<td>0.0692 0.0891 28.7%</td>
<td>3.85 5.03 30.6%</td>
<td>-0.204 -0.178 -12.8%</td>
</tr>
<tr>
<td>Welfare</td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
</tr>
<tr>
<td>Variables</td>
<td>1.78 2.41 35.4%</td>
<td>2.24 3.08 37.5%</td>
<td>2.24 3.08 37.5%</td>
<td>2.24 3.08 37.5%</td>
<td>2.24 3.08 37.5%</td>
<td>2.24 3.08 37.5%</td>
</tr>
<tr>
<td></td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
</tr>
<tr>
<td></td>
<td>-0.191 -0.141 -26.2%</td>
<td>-0.204 -0.155 -24.0%</td>
<td>-0.204 -0.155 -24.0%</td>
<td>-0.204 -0.155 -24.0%</td>
<td>-0.204 -0.155 -24.0%</td>
<td>-0.204 -0.155 -24.0%</td>
</tr>
<tr>
<td></td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
<td>I1*I'</td>
<td>IR1*I'</td>
</tr>
<tr>
<td></td>
<td>2.03 1.93 -4.86%</td>
<td>1.72 1.63 -4.98%</td>
<td>1.72 1.63 -4.98%</td>
<td>1.72 1.63 -4.98%</td>
<td>1.72 1.63 -4.98%</td>
<td>1.72 1.63 -4.98%</td>
</tr>
<tr>
<td>Transitional</td>
<td>Ic'/Ic (%)</td>
<td>1.98</td>
<td>1.72</td>
<td>3.55</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td>Ic'/Ic (%)</td>
<td>1.98</td>
<td>1.72</td>
<td>3.55</td>
<td>3.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
<td>Pre-reform</td>
<td>After-reform</td>
<td>Change</td>
</tr>
<tr>
<td></td>
<td>0.0051</td>
<td>0.0059</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First, with the increase in q*, k*, (S/Y)*, w*, and I1*I' under both pension systems become larger while I1*I' becomes less. The higher is the aging value q*, more savings are invested as capital, causing the changes of the variables above.

Second, with the increase in q*, the positive macroeconomic and welfare effects of the Reform become stronger and stronger. However, the increases on the variables are little, meaning low sensitivity to the change in q*. To sum up, the sensitivity analysis above shows how the change in η, γ, and q* affect the simulated economic effects of the Reform. That is, the
effects of the Reform on macroeconomic economy, individual welfare, and income distribution
are sensitive to the change in values of $\eta$ or $\gamma$ while little sensitive to $q^*$.

2.7 Analysis of Transitional Path

The analysis above only simulates and compares the steady state economies under both
PAYG and PF systems. It is also important to investigate how the economy evolves from PAYG
steady state to PF steady state. This part will do so by analyzing the transitional paths of
macroeconomic variables, individual welfare variables, and income distribution variables under
the baseline scenario.

Based on the capital evolution equation (2.39), using the steady state capital per unit of
effective labor $k^*$ and the transition costs as the initial values, we can obtain the capital level for
each successive period after the Reform $k_{t+1} (t \geq 0)$, and then calculate all other economic
variables until the economy finally reaches steady state under PF system.

Table 2.11 and Figure 2.2 describe the evolution paths of macroeconomic variables $k$, $y$,
(S/Y), $r$, and $w$. Table 2.12 and Figure 2.3 show the transitional paths of welfare and income
variables $I_1^1$, $I_2^2$, $(I_1^1/I_2^2)$, $IR_1^1$, $IR_2^2$.

First, all the variables reach their steady state values under PF system at period 9,
meaning the economy reaches its new steady state nine periods after the Reform that begins from
period 1.

Second, most the changes happen before the end of the fourth period (period 4). For
example, the Reform causes $k$ to increases from 0.00451 under PAYG system to 0.00826 under
partially-funded system, up 82.7%. As of the end of period 2, period 3, period 4, the change ratio
reaches 24%, 51%, 75% respectively.

---

1 In Figure 2.1 and Figure 2.2, for simplicity, we make the initial (PAYG steady state) values of the corresponding
economic variables equal to one.
Third, during the reform period (period 1), although there is a little increase in $k$ (up 4.53%), the high consumption tax rate (5.1%) causes the decrease in Agent 1’s welfare (down 4.2%), which may brings about a challenge to the pension Reform.

**Table 2.11  Transitional Paths of Macroeconomic Variables**

<table>
<thead>
<tr>
<th>Period</th>
<th>Calculation Value</th>
<th>0 (PAYG Steady State)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>9</th>
<th>PF Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital per Unit of Effective Labor $k$</strong></td>
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<td>0.00451</td>
<td>0.00468</td>
<td>0.00544</td>
<td>0.00647</td>
<td>0.00742</td>
<td>0.00826</td>
<td>0.00826</td>
</tr>
<tr>
<td>Ratio of Transitional Extent (%)</td>
<td></td>
<td>0</td>
<td>4.53</td>
<td>24.80</td>
<td>52.27</td>
<td>77.60</td>
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<td>100.00</td>
</tr>
<tr>
<td><strong>Output per Worker $y$</strong></td>
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<td>11.5</td>
<td>11.8</td>
<td>12.4</td>
<td>13.3</td>
<td>14.0</td>
<td>14.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Calculation Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio of Transitional Extent (%)</td>
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<td>9.38</td>
<td>28.13</td>
<td>56.25</td>
<td>78.13</td>
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<td>100.00</td>
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<tr>
<td>Ratio of Transitional Extent (%)</td>
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<td>0</td>
<td>83.33</td>
<td>79.71</td>
<td>75.36</td>
<td>82.61</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Wage $W$</strong></td>
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<td>0.0779</td>
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<td>0.0881</td>
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<tr>
<td>Ratio of Transitional Extent (%)</td>
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<td>10.58</td>
<td>19.58</td>
<td>46.03</td>
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<tr>
<td>Ratio of Transitional Extent (%)</td>
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<td>17.68</td>
<td>41.80</td>
<td>66.88</td>
<td>84.89</td>
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<td>100.00</td>
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</table>
Table 2.12  Transitional Paths of Welfare and Income Variables

<table>
<thead>
<tr>
<th>Period</th>
<th>0 (PAYG Steady State)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>9</th>
<th>PF Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent 1’s Lifetime Utility $U^{1,*}$</td>
<td>Calculation Value</td>
<td>1.84</td>
<td>1.81</td>
<td>1.91</td>
<td>2.02</td>
<td>2.17</td>
<td>2.46</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>-4.19</td>
<td>11.29</td>
<td>29.03</td>
<td>53.23</td>
<td>100.00</td>
</tr>
<tr>
<td>Agent 2’s Lifetime Utility $U^{2,*}$</td>
<td>Calculation Value</td>
<td>0.74</td>
<td>0.85</td>
<td>0.98</td>
<td>1.13</td>
<td>1.29</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0</td>
<td>13.58</td>
<td>29.63</td>
<td>48.15</td>
<td>67.90</td>
<td>100.00</td>
</tr>
<tr>
<td>Lifetime Income Ratio $I^{1,<em>}/I^{2,</em>}$</td>
<td>Calculation Value</td>
<td>1.841</td>
<td>1.779</td>
<td>1.751</td>
<td>1.741</td>
<td>1.74</td>
<td>1.739</td>
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<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0.00</td>
<td>59.80</td>
<td>87.25</td>
<td>97.06</td>
<td>98.04</td>
<td>100.00</td>
</tr>
<tr>
<td>Agent 1’s Income Redistribution $IR^1$</td>
<td>Calculation Value</td>
<td>-0.196</td>
<td>-0.178</td>
<td>-0.175</td>
<td>-0.173</td>
<td>-0.172</td>
<td>-0.171</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0.00</td>
<td>75.00</td>
<td>87.50</td>
<td>95.83</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Agent 2’s Income Redistribution $IR^2$</td>
<td>Calculation Value</td>
<td>-0.196</td>
<td>-0.159</td>
<td>-0.151</td>
<td>-0.15</td>
<td>-0.148</td>
<td>-0.147</td>
</tr>
<tr>
<td></td>
<td>Ratio of Transitional Extent (%)</td>
<td>0.00</td>
<td>75.51</td>
<td>91.84</td>
<td>93.88</td>
<td>97.96</td>
<td>100.00</td>
</tr>
</tbody>
</table>
2.8 Conclusion

This paper presents an extended OLG General Equilibrium Model with heterogeneous agent to study China’s pension reform from PAYG system to PF system. We assume that agents differ in their human capital endowments and in their access to the financial system. We first quantitatively simulate the economic effects of China’s pension reform on macro economy, individual welfare, income distribution, and transition costs, then we discuss the sensitivity level of the simulated results to the important parameters $\eta$ and $\gamma$, finally we analyze the specific transition path of the Reform.

We conclude five points. First, China’s pension reform from PAYG system to Partially-Funded system not only has significant and favorable effects on China’s macro economy, individual welfare, but also improves income inequality substantially. Compared with the rich agents, the poor agents benefit much more from the Reform. Second, the larger are $\eta$ or $\gamma$, the smaller the favorable economic effects of the Reform become. Additionally, in terms of sensitivity level, the effects of the Reform on macroeconomic economy, individual welfare, and income distribution are sensitive to the change in values of $\eta$ or $\gamma$ while the transitional cost variables are little sensitive. Third, the economy reaches its new steady state nine periods after the Reform. However, a majority of the changes happen before the end of the fourth period (period 4). Fourth, during the first period after the Reform (period 1), Agent 1’s welfare decreases by -4.2%,
which may pose a challenge to the pension Reform. Also, China’s pension reform improves both intragenerational and intergenerational income distribution, a result different from James (1997)’ claim that privatization of PAYG system may deteriorate income equality. Finally, the results show partial funding is better than full funding for China’s pension reform, which compliments the current literature.

Our model assumes the agents are rational, forward-looking, and have no liquidity constraints. Moreover, in the model, people save only for pension motive, and other saving motives such as bequest saving and precaution saving are ignored. In addition, our model only considers two coexistent generations. Such simplifications suggest that the conclusion of the model should be taken with caution and further discussions of these issues are necessary.
Chapter 3: China’s Pension System Facing Rapid Aging: Progress, Challenge, and Reform Option

3.1 Introduction

After 30 years of rapid economic growth and social development since 1978, China has transformed from a once centrally planned economy and poorest country to a market economy and one of world’s biggest economic powers (Salditt et al. 2008). In 2008, China’s GDP was $7,916 billion based on PPP, the second largest in the world, with the highest annual growth rate of 9.7% between 1980 and 2008 (IMF, World Economic Outlook 2009). Poverty has fallen substantially over time– from 30.7% of the total population in 1978 to 3% in 2006 (People’s Daily Online, 03/07/2008). Despite unprecedented economic and social achievements, China is still a relatively poor country with GDP per capita being $5,962 in 2008, only 13% of USA, 18% of Japan, and 60% of Russia (IMF, WEO 2009).

Meanwhile, China witnessed dramatic demographic changes featuring increasing life expectancy, falling fertility, and rapid aging (World Bank 1997). The Chinese life expectancy at birth has risen from 40.8 years in 1950 to 73 years in 2008. The total fertility rate was projected 1.73 in 2005-10, compared to 6.22 in 1950-55 (UN, World Population Prospects 2009).

China’s population is aging rapidly. Since 2000, China joined the aging countries. From 2005 to 2050, the share of the elderly (65 and older) of the total population is projected to increase from 7.6% (100 million) to 23.6% (330 million), about 25% of the world's elderly; the old-age dependency ratio to increase from 11% to 39% (Figure 3.1); the median age to rise from 32.5 years to 48 years, higher than that in India and the U.S., yet lower than in Japan (Figure 3.2). More challenging is China aging more rapidly than many developed countries at a much lower

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1 China’s official poverty line is set at an annual per-capita income of 668 Yuan (81 US dollars) in 2006, far below the international poverty standard—$1 per capita per day for developing countries. According to The Human Development Report (08/2007) by UNDP, population living under 1 dollar (PPP) a day in China in 2005 is 9.9%.
2 The population data in this paper is from World Population Prospects: The 2008 Revision Population Database, Medium Variant Case by UN Population Division.
3 The share of the elderly aged 60 and older reached 10.5% (National Bureau of Statistics, China's 2000 census).
4 It equals to the ratio of the elderly population aged 65 and older divided by working population aged 15-64.
per capita income level, earning China the title of “old before rich country”. Figure 3.3 shows when the median age is about 33, China’s GDP per capita is $5,700 (2005), while those in Japan (1980), U.S. (1990), South Korea (2000) are $9,500, $23,000, and $16,200 respectively (UN, World Population Prospects 2009; IMF, WEO 2009).

Source: Figure 3.1 and Figure 3.2: United Nations (2009), World Population Prospects: The 2008 Revision Population Database (medium variant case)

Figure 3.3: United Nations (2009), World Population Prospects: The 2008 Revision Population Database (medium variant case); IMF (2009), World Economic Outlook
Against the rapid economic development and drastic demographic changes, since the early 1990s, China’s urban pension system has undergone a few major reforms: 1991 reform, 1995 reform, 1997 reform, 2000 reform, and 2006 reform, especially the crucial 1997 reform, which transformed an unfunded Pay-As-You-Go (PAYG) system into a partially funded (PF) multi-pillar one. Additionally, a new rural pension pilot system subsidized by the governments is making some progress since Sep 2009.

This paper aims to provide a detailed description and review of the evolution of China’s urban and rural pension systems, and to investigate the progress it has made so far and the challenges facing the systems, and then to simulate the quantitative impact of further parametric pension reform options.

Our paper shows despite notable institutional and other progress, China’s pension system is facing many challenges such as high implicit pension debt (IPD) and empty individual account, a fragmented and decentralized system, low coverage rate, low pension fund investment returns and inefficient fund management, high contribution rate and low retirement age.

We make two kinds of simulation analysis to evaluate the effects of possible parametric reform options. One is to apply Generational Accounting method to assess the intergenerational fiscal effects of four pension reforms. The results show under the current pension policy, the fiscal burden facing future generations is 35% higher than that facing the newborns in 2000. Higher contribution rate and retirement age, lower pension benefits, and subsidy from state-owned asset interest can decrease the fiscal burden on future generations significantly at the certain cost of current generations.

The other is to use an extended simulation model adapted to China’s partially funded pension system to simulate the impact of four reform options on the replacement ratio. The simulation results indicate under the current pension policy, the replacement ratio is 45.6%, 30% lower than the promised 59% by China’s government. The results also show the low return of pension investment is the main reason for the low replacement ratio and the robust impact of the
four reform options in increasing pension benefits, among which, diversifying pension investment is the most effective and viable one.

Based on the critical analysis and simulation results, possible parametric pension reform alternatives such as raising the retirement age, expanding pension coverage, building a unified system across the nation, and diversifying the pension fund investment are proposed in order to build a unified, efficient, sustainable system that can accommodate China’s 330 million old-age population by 2050.

The article is structured as follows. Section 2 briefly describes the evolution of China’s pension system since the 1950s. Section 3 discusses current pension arrangements, followed by a detailed investigation of the major challenges facing China’s pension system in the coming years. In Section 4, we present two simulation models and the empirical results of possible reform alternatives. Section 5 lists some policy recommendations for improving China’s pension system. Section 6 concludes the paper.

3.2 Evolution of China’s Public Urban System and Rural Pension System

From its foundation in 1949 to 1991, China only maintained a public urban pension system that covered urban state-owned enterprise (SOE) and large collective-owned enterprises (COE) employees. It was not until 1992 that a separate rural pension system was introduced to cover rural population.

The Evolution of Urban Pension System. Since its inception in the early 1950s, China’s urban pension system has undergone quite a few regulations or reforms: 1951 regulation, 1966 regulation, 1991 reform, 1995 reform, 1997 reform, 2000 reform, and 2006 reform. Generally, China’s urban pension system history can be divided into three stages: PAYG system stage, pension reform stage, and partially funded three-pillar system stage.

In 1951, following the pension model of the former Soviet Union, the newborn People’s Republic of China (PRC) released “A Regulation on Labor Insurance,” the first labor insurance regulation, which built a PAYG-based pension system in China.\(^1\) Later, there happened some important changes: before 1954, local labor unions administered the pension system and pooled pension fund at municipal level. From 1954 to 1966, the All China Federation of Trade Union (ACFTU) took the responsibility to administer and pool pension fund at national level, which was advanced in terms of risk-sharing across regions and enterprises, yet was abandoned in 1966. From 1966 to 1991, individual enterprise began to be responsible for providing pension to its retired employees out of the enterprise’s current revenue, and social pooling function across enterprises did not exist any more (Wang 2006).

In essence, the pension system during this period was a PAYG system with three features. First, the system was only funded by enterprise contributions out of enterprise’s current revenue. Second, the retired employee received pension from his enterprise, with the pension benefit closely related to the actual wage of the employee before retirement. That is, the system had no intragenerational income redistribution function. Third, depending on how long the retiree has worked for the enterprise, the replacement ratio ranged from 50%-70%, a relatively high ratio (James 2002).

(2) The Period of 1991-2000: Pension Reform Stage

Since the late 1970s, more workers retired earlier due to higher benefits and easier accessibility\(^2\) thus the state-owned enterprises (SOEs) bore a heavy pension burden. For example, from 1978 to 1988, the number of pensioners increased from 2.14 million to 21.2 million and

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\(^1\)The new pension system was public, PAYG-based, yet only covered urban enterprise employee, which required a contribution rate of 3% of wage bill from enterprise and 25/20 qualifying years for man/woman. Since then, the rural farmers, a majority of the workforce in China has been excluded from the urban pension system. It was not until 1992 that a rural pension system was introduced to cover rural population (Salditt et al. 2008).

\(^2\) The replacement ratio increased from 50-70% to 60-75% and the qualifying years decreased from 25/20 to 10 years to provide more employment opportunities for young workers who just return to cities from villages (Salditt et al. 2008).
nominal pension expenditure rose about 20 times (NBS, China’s Statistical Yearbook 2009). To relieve the SOEs of the heavy pension burden and to address the challenge of population aging, the Chinese government implemented a series of major fundamental reforms to build a new partially funded multi-pillar system (Sin 2005).

In 1991, the State Council, China’s central government, released “No. 33 State Council Resolution on Pension Reform for Enterprise Employees” with main contents as follows. First, both enterprises and individual workers should pay contributions to the system. Second, the new system included three pillars. Pillar I was a mandatory PAYG-based basic pension plan. Pillar II was a supplementary enterprise-based plan and Pillar III was a voluntary individual saving account.

In 1995, the State Council released “No. 6 State Council Circular on Deepening Pension Reform for Enterprise Employees.” The No. 6 Circular emphasized the direction of the reform was to combine social pooling account with individual account. It also introduced two detailed initiatives to help local authorities put the No. 33 Resolution into practice.

In 1997, based on the pension model recommended by World Bank (World Bank 1994, 1997), the State Council released “No. 26 State Council Resolution on Establishing a Unified Basic Pension System for Enterprise Employees”, a crucial and decisive pension reform regulation that built the framework of a partially funded multi-pillar system in China.

First, the new system is a three-pillar system. Pillar I, the core of the system, comprises IA-social pooling account and IB-individual account. Pillar IA works on PAYG basis and is only funded from employers with contribution rate of 17% of employee’s wage. Pillar IB is a fully funded individual account financed by contributions of 3% from enterprise and 8% from individual. Pillar I is compulsory with at least 15 contributing years and the expected replacement

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1 NBS: China’s National Bureau of Statistics that published China’s Statistical Yearbook and other statistics yearbook.
2 All these pension reforms initiated in China supplant each other, that is, the newer one always displaces the older one. Please see the official website of Ministry of Labor and Social Security (http://www.molss.gov.cn/gy/ywzn/yfby.htm) for detailed information on the government’s regulations of each pension reform.
ratio being 58%. Pillar II, an enterprise annuity, similar to an occupational pension in western countries, is a voluntary and supplementary contribution-based pension plan financed by payments from both employees and employers. Pillar III is a voluntary and complementary individual saving plan designed for people who want to save more to get higher pension benefits. Second, the goal of this reform was to establish a unified pension system within the whole country by 2000. Third, for the purpose of security, the Resolution requires the pension funds only be invested in bank deposits and government bonds.

During this period of 1991-2000, China’s pension system was in the transition from an unfunded PAYG system to a new partially funded three-pillar system. As of the end of 2000, despite some shortcomings, the framework of a new three-pillar pension system at the national level was built¹.

(3) The Period of 2000-Present: Partially Funded Multi-Pillar System Stage

Since 2000, the focus of the Reform has shifted to improving the newly-built partially funded three-pillar system. On December 2000, in order to solve the problem of “empty” individual account², the State Council released “No. 42 State Council Circular on the Pilot Program for Improving Urban Pension System”.³ In 2006, based on the experience of pilot provinces, the State Council released “No. 38 State Council Resolution on Improving the Basic Pension System for Enterprise workers” regulating some important changes. For example, pillar IA was financed only by 20% enterprise’s contribution and pillar IB only by 8% employee’s contribution, and individual account IB must be strictly separated from social account IA to avoid fund diversion from individual account to social account.

In late 2000, in order to finance future social security deficit caused by the rapid population aging, the National Social Security Fund (NSSF) was created as a national strategic

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¹ Please see the Appendix Table 3.1 for basics of China’s Partially Funded Three-Pillar Pension System.
² The reason why funded individual account IB becomes empty is the assets accumulated in this account are diverted to pay current retirees’ pension benefits due to insufficient funds in social pooling account, thus the account IB is nominally funded.
³ The pilot program was first implemented in Liaoning province and later extended to other ten provinces.
reserve fund for social security\(^1\) (Trinh 2006). The NSSF assets mainly come from four sources: fiscal transfers from the central government budget (50% in 2008), 10% of proceeds from state share sales in SOEs (20%), lottery sale income (5%), and investment income (25%) (SSF, Annual Report 2009).

**The Evolution of Rural Pension System.** Compared with the urban pension system, the rural pension system has received much less attention and financial aid from China’s government (Shi 2006). For example, from 1991 to 2009, there were five major and ten supplementary regulations instructing urban pension reform, yet only three regulations: 1992, 1998, and 2009 to address rural pension reform.

Before 1992, only poor old rural people without any familial support could get the “Five Guarantees”\(^2\) to ensure their minimum livings. It was not until 1992 that the Ministry of Civil Affairs released “The Basic Program for Rural Pension at County Level” to introduce a rural social pension system, where a voluntary individual account out of individual contribution and supplemental contribution from the collective was built. However, the government had no subsidy obligation. In 1998, the newly-born Ministry of Labor and Social Security (MOLSS) took the responsibility, yet considered the rural social pension system not to be sustainable by current rural economic conditions, and thus replaced it with a commercial insurance program in 1999 (Shi 2006). Since then, more than 20 million farmers chose to withdraw from the system and the rural pension system is actually stagnating\(^3\).

On Sep 2009, the State Council released “No. 32 The Guideline for Building New Rural Pension Pilot Programs” to launched a new rural pension pilot system that is planned to cover 10% of China’s rural population by the end of 2009, 20% by the end of 2010, and expand to all by 2020. The biggest difference from the old one is the new system combines a government–funded social account out of government subsidy with an individual account funded by individual

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\(^1\) Currently, there are no official rules on the conditions and timing under which the NSSF will be released to make payments.

\(^2\) “Five Guarantees” is to guarantee food, clothing, medical care, housing, and burial expenses by the government.

\(^3\) Rural participants decreased from 75 million in 1997 to 56 million in 2008 (NBS, China’s Statistical Yearbook 2009).
contribution. That is, for the first time, the central and local governments subsidize rural pension system, a major step for China’s government to overhaul the lagging rural system (People’s Daily Online, 06/24 /2010).

3.3 Progress and Challenges Facing China’s Pension System

3.3.1 Status Quo of China’s Urban and Rural Pension Systems

A series of fundamental pension reforms were successfully implemented over the past two decades, which have transformed China’s urban pension system from the old PAYG system into a partially funded three-pillar system. A major institutional progress is the establishment of the three-pillar system—the mandatory basic pension plan, the voluntary and supplemental enterprise annuity plan and individual saving plan— that lays a basis for further parametric pension reforms (Salditt et al. 2008).

Besides the major institutional progress, since 1997, the new urban pension system has made other progress in coverage expansion, pension revenue/spending, and pension fund accumulation.

Pension Coverage Expansion. As shown in Figure 3.4, the contributors, the recipients, and the coverage rate of the new urban pension system are expanding. From 1997 to 2008, contributors increased from 86.7 million to 165.9 million, up 91%; recipients from 25.3 million to 53.0 million, up 109%; the coverage rate of urban employment\(^1\) from 42% to 55%\(^2\), up 32%. Additionally, the ratio of contributor to recipient decreases in the early 1990s, and kept stable around 3.3 since 1997.

\(^{1}\) The urban employment does not include the rural migration worker that is estimated to be about 150 million (Shi 2006).
\(^{2}\) Yet the pension coverage rate of China’s total employment was as low as 21%, still a long way to achieve a full coverage and the data in this section is from China’s Statistical Yearbook 2009 published by National Bureau of Statistics of China (NBS).
Figure 3.4 Urban Pension Coverage (1995-2008)

Source: China’s Statistical Yearbook (2009)

Basic Pension Revenue/Spending. With the increase in contributors/ recipients, the basic pension revenue/spending rise. In 2008, basic pension revenue/spending reached 974/739 billion Yuan (3.2%/2.5% of GDP), compared with 134/125 billion Yuan (1.7%/1.6% of GDP) in 1997. Since 1989, there has been continuously surplus pension budget due to revenue higher than spending, causing a larger and larger cumulative pension assets balance (Figure 3.5).

Figure 3.5 Basic Pension Revenue/Expenditure/Balance (1995-2008)

Source: China’s Statistical Yearbook (2009)
**Pension Benefit.** From 1997 to 2008, basic pension benefit grew from 5,842 Yuan to 12,960 Yuan with an average yearly growth rate of 7.5%. However, it was lower than average GDP per capita growth of 9.8% over this period, causing the ratio of pension benefit to GDP per capita to decrease from around 83% before 1997 to 60% in 2008 (NBS, China’s Statistical Yearbook 2009 and China’s Labor Statistical Yearbook 2009).

**Pension Asset Balance.** The pension reserves have increased rapidly. The basic pension asset increases from 68 billion in 1997 to 993 billion (134% of the pension spending) in 2008 with an average yearly growth rate of 27%. The NSSF asset grew from 81 billion in 2001 to 480 billion in 2008 with an average yearly growth rate of 29%. As of the end of 2008, the total pension assets reached 1,765 billion Yuan (6% of GDP), in which basic pension asset, NSSF asset, enterprise pension asset, and rural pension asset accounted for 56%, 39%, 2.8%, and 2.2% respectively (NBS, China’s Statistical Yearbook 2009 and Labor Statistical Yearbook 2009).

**Rural Pension System.** The rural pension system has made much less progress than the urban system. After MOLSS took responsibility for rural pension system and replaced it with a commercial insurance program in 1998, participants decreased from 75 million (15.3% of rural working population) in 1997 to 56 million (11.8%) in 2008. Only 5% of the rural elderly aged 60 or older (5.1 million) received the rural pension benefits with average pension of 840 Yuan per year, while 86% (87.7 million) still relied on their children for support in 2008 (NBS, China’s Labor Statistical Yearbook 2009).

The new rural pension pilot system created by the 2009 reform has improved the participating incentives of rural residents greatly due to the government subsidy. As of the end of 2009, the new system had extended to 10% of China's rural regions with 52 million rural participants joining the new rural pension system and 16 million rural elderly have begun to receive pensions from the new system 1 (People’s Daily Online, 06/24/2010).

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1 The government subsidy is 55 Yuan/month and the pension is 150 Yuan/month in 2009 (People’s Daily Online, 06/24/2010).
3.3.2 Challenges Facing China’s Pension System

Despite institutional and other progress, China’s urban pension system still suffers from the challenges including high IPD and low coverage rate, a fragmented and decentralized system, low returns on pension funds, high contribution rate, and low retirement age. These problems are being aggravated by rapid population aging, which may necessitate further parametric pension reforms (Friedman et al. 1996, Feldstein 1998, James 2002, Trinh 2006, Salditt et al. 2008).

3.3.2.1 High IPD and Empty Individual Account

Implicit pension debt (IPD) is measured as the sum of the present value of pension benefits that have to be paid to current retirees and all pension rights that current workers have already earned if the current PAYG pension system is replaced by a new funded system (Holzmann et al. 2004).

There is a range of estimates regarding the amount of IPD in China. World Bank (1997) estimated China’s IPD ranging from 46% to 69% of GDP in 1994. Wang et al. (2001) calculated China’s IPD at around 71% of GDP in 2000. Sin (2005) provided a detailed estimate of IPD at 141% of 2001 GDP (about US$ 1.6 trillion), of which 111% of GDP belonged to social account liability and the rest 30% to individual account debt. The divergent estimates of the IPD are mainly due to different assumptions about economic and demographic factors (Wang et al. 2001).

Compared with many OECD countries having IPD ranging from 100% to 200% of GDP, China has a relatively smaller IPD, higher economic growth, and more state assets, then should be easier to solve the IPD problem. However, from the beginning, China’s pension reform deliberately ignored the old pension debt issue, that is, the government had not made any measure to finance the transition costs, which in turn caused larger and larger IPD and less public confidence in the system (James 2002).
Empty Individual Account. While China’s IPD as a whole may be 70-90% of GDP, in some regions that have much lower system support ratio (the ratio of contributor to recipient)\(^1\), the IPD relatively to local GDP could be much higher than 100%. In these regions, after a pension reform from PAYG to partial funding, the social account funds alone cannot meet current pension claims due to no government funding to cover IPD. Thus, the funds accumulated in individual account are diverted to cover the shortfall in the social account funds, leaving the individual accounts empty—with no real assets, merely a nominal number (Sin 2005). According to the statistics from MOLSS, the asset scale of the empty individual accounts was 14 billion Yuan in 1997, up to 200 billion Yuan in 2000, rising to 1.1 trillion Yuan in 2008 (MOLSS, Statistics Report 2008). The empty individual account erodes public trust in the system, and thus encourages incentives of contribution evasion from the pension system.

3.3.2.2 A Fragmented and Decentralized Pension System

China’s urban pension system is characterized by large fragmentation and variations (Trinh 2006). First, pension administration is fragmented with several different government ministries responsible for pension administration. For example, the Ministry of Labor and Social Security (MOLSS) supervises public urban and rural pension systems; the Ministry of Personnel (MOP) manages a special pension system for civil servants and public institution employees; and the National Council for Social Security Fund (SSF) administers the National Social Security Fund (NSSF).

Second, the current pooling unit of China’s pension system is provincial-level. While most countries’ pension systems in the world have already achieved national-level pooling, it was not until the end of 2009 that China upgraded its pooling unit from municipal-level pooling to provincial-level pooling. As China is a geographically large and economically varied country, it

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\(^1\) For example, in 2008, while the average system support ratio in China is 3.3, the ones are 1.9 in Shanghai, 2.5 in Liaoning, 4.5 in Sichuan, 6.3 in Guangdong respectively (China’s Labor Statistical Yearbook 2009)
is expected to be still a long way to realize national-level pooling within its pension system (China Daily Online, 10/13/2010).

Third, the decentralized set-up of the pension system causes large variations in pension provisions across the country. In China, there is no national law to stipulate nationally uniform pension provisions. Instead, the central government only developed key principles through issuing operational guidelines while leaving the specifics regulated by local governments to adapt to local situations, thus creating huge variations within the system (Ma and Zhai 2001). For example, due to large variations in old-age dependency ratio, pension contribution rate of social account varied across different regions (20% of payroll in Beijing, 25% in Shanghai, and 10% in Shenzhen in 2008) (MOLSS, Statistics 2008).

The fragmented and decentralized pension system may cause large disparities across regions and enterprises that is not conducive to fair market competition, significant intransparency that increases the possibility of misusing pension funds, and the lack of portability of pension claims that encourages migrant worker’s evasion incentive (Trinh 2006). Portability allows an employee to transfer his pension rights freely when changing his job, which is particularly important for China’s 150 million rural migrant workers who often move and change their jobs across provinces (Shi 2006).

3.3.2.3 Low Returns on Pension Fund Investment

During 1997-2005, average real wages grew by 8.5% annually in the manufacturing sectors while the average real return on the pension funds was only 1.5%, much lower than an average international return of about 6% on long-term pension funds (Wang 2006). Two issues contribute to the problem. Firstly, due to the volatile and undeveloped domestic financial market, the current pension regulations require that the fund assets of basic pension plan can only be invested in government bonds and bank deposits, which restricts the returns of the pension funds (Feldstein 1998). Secondly, at present, different from international practices, China’s social
security agencies are responsible not only for the pension management and investment, but also for the surveillance of pension funds, which may cause inefficiency, mismanagement, and even appropriation and corruption due to lack of monitoring and weak information disclosure (Ma and Zhai 2001).

Low returns on pension funds and poor fund management lower participants’ trust in the public pension system. In addition, it may threaten to meet the targeted replacement ratio. James (2002) calculated how the return rate of the pension fund affects the replacement ratio. Assuming an employee contributes 8% of his wage to individual account for 40 years and receives pension for 20 years with a real wage growth rate of 3%, a real return of 2% would only yield a replacement ratio of 16% of final wage, while a real return of 5% is needed to meet the targeted replacement ratio of 38%.

3.3.2.4 High Contribution Rate and Low Retirement Age

Compared to the contribution rate of 13.6% in Japan, 12.4% in USA, 10% in Chile, and 4.3% in Mexico (Social Security Administration 2004), the contribution rate of 28% (employer 20% plus employee 8%) in China is quite high. Furthermore, if adding contributions for other social security programs including unemployment (3%), health care (8%), work injury (2%), maternity (1%), and housing provident fund (14%), the total contribution rate is as high as 56% (employer 38% and employee 18%) (Table 3.2) (MOLSS, Statistics Report 2008). Such a heavy financial burden may lower enterprises’ competitiveness and cause low compliances in many enterprises (Sin 2005).

China’s official retirement age is age 60 for men or age 55 for women. However, the actual retirement age in many regions and sectors is 55 for men and 50 for women (James 2002).

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1 There are cases of pension fund appropriation and corruption in China. The scandal of Shanghai pension fund appropriation on August 2006 that 3 billion Yuan pension assets were appropriated is just one major case (China Daily Online, 10/19/2006).

2 One main reason for the high contribution rate is China’s government intends to siphon the fund surplus from the social account IA to cover the high IPD inherited from the previous PAYG system, i.e. the transitional costs (Holzmann et al. 2004).
Given China’s current average life expectancy at birth reaches 72 years, this actual retirement age is pretty low. An average pension period of 17-22 years for a retiree at an expected replacement ratio of 59% \(^1\) may pose a challenge to the financial sustainability of China’s pension system (Salditt et al. 2008).

### 3.3.2.5 Low Coverage Rate

As of the end of 2008, there are 166 million contributors to the urban pension system with the coverage rate of 55% among urban employment and 56 million contributors to the rural pension system with the coverage rate of 11.8% among rural employment (NBS, China’s Statistical Yearbook 2009). However, the overall coverage rate among the total working population was as low as 21%, much lower than the average coverage rate of 47% among emerging countries (Claramunt 2004).

The challenges listed above may explain the low coverage in China, especially in Rural China. High IPD and empty individual account worry workers about the availability of pension when they retire. Fragmented and decentralized administration results in high administrative costs that erode fund investment return and lack of portability of pension rights that hinders rural migrant workers’ participation incentives. A contribution rate as high as 56% exerts heavy financial pressure on both employers and employees, encouraging their evasion incentives from the system.

The low overall coverage rate of 21% means about 79% Chinese workers (most are rural workers) not covered by the pension system have to depend on limited private savings and breaking-down familial support to sustain their post-retirement lives, actually leaving many rural elderly without adequate resources for their old-age insurance (Shi 2006). In addition, low coverage and widespread evasion impose heavy burdens on current contributors, increase

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\(^1\) The expected pension replacement ratio promised by China’s government is 59%, among which, the expected replacement ratios from the social account and individual account are 35% and 24% respectively (Salditt et al. 2008).
financial difficulty of the system, and limit the scale of risk pooling, which would further discourage new participants (Ma and Zhai 2001).

3.3.2.6 Challenges Facing Rural Pension System

Although the rural pension system shares many similar challenges such as low return, system fragmentation, inefficient fund management, and low coverage, it also has to deal with some other difficulties (Shi 2006). One is the low level of the rural pension benefit. The average pension was 80 Yuan/month in the old rural pension system and 150 Yuan/month in the new rural pension pilot system in 2009, yet the average urban pension was 1,080 Yuan/month, 13.5 times and 7.2 times higher respectively (MOLSS, Statistics Report 2009). Such a big difference in pension benefit is unfair for the rural pensioners. Another challenge is the financial sustainability of the government subsidy. The social account of the new rural pension system is funded by government subsidy. The current subsidy is 660 Yuan/year, if the new system extends to cover all the old-age farmers ¹ by 2020, the government will at least subsidize 80 billion Yuan each year, which may impose a financial burden on the government budget (People’s Daily Online, 06/24/2010).

3.4. Simulation Analysis of Possible Parametric Pension Reform Options

In this section, we make two kinds of simulation analysis to evaluate the effects of parametric reform options. One is to use Generational Accounting method to measure the intergenerational fiscal effects of four pension reforms such as increasing contribution rate, lowering pension benefits, raising retirement age, and subsidizing by state-owned assets. The other is to use an extended simulation model to simulate the impact on the pension replacement

¹ The rural farmers aged 60 and older in 2008 amounted to 120 million (NBS, China’s Labor Statistical Yearbook 2009).
ratio¹ of four parametric reforms including changes in coverage rate, retirement age, administration cost, and fund investment strategy.

3.4.1 The Generational Accounting Approach

Auerbach, Gokhale, and Kotlikoff (1991) developed the Generational Accounting method to assess the fiscal burden imposed by government’s policies on different generations, and then to evaluate the fiscal sustainability of these policies². Later, many studies including Auerbach, Gokhale, and Kotlikoff (1991, 1992, 1994), Kotlikoff (1992), and Kotlikoff and Leibfritz (1999) applied this method to analyze the sustainability of the government policies such as social security policy, tax policy, health care policy in quite a few countries³. They also analyze the effect of intergenerational distribution of fiscal burden on saving. For example, if the marginal propensity to consume out of lifetime income rises with age, policies that decrease social security benefits may tend to increase domestic savings.

3.4.1.1 Model Set-Up

Generational accounting is based on the government’s inter-temporal budget constraint, as shown in equation (3.1), meaning the present value of current and future generations’ remaining lifetime net tax payments⁴ must be sufficient to cover the present value of the government’s future expenditure plus its initial net debt (Auerbach et al. 1991).

\[
\sum_{k=t-D}^{t} N_{t,k} + \sum_{k=t+1}^{\infty} N_{t,k} \prod_{j=t+1}^{k} \frac{1}{1 + r_j} = \sum_{s=t}^{\infty} G_s \prod_{j=t+1}^{s} \frac{1}{1 + r_j} - W_j \tag{3.1}
\]

In the left-hand side of equation (3.1), the first summation is the sum of the generational accounts of existing generations running from the newborn generation to the oldest one (D is the

¹ The pension replacement ratio is the sum of the replacement ratio of PAYG-based social account and the replacement ratio of fully funded individual account due to the features of China’s partially funded pension system.

² “The method was developed to determine the fiscal burden that a country’s current policies will impose on different generations, and whether these current fiscal policies are sustainable - whether they can be maintained without requiring future generations to pay higher net taxes than existing policy would require.” (Auerbach, Gokhale, and Kotlikoff 1991)


⁴ The “net tax payments” are the differences between the tax paid to the government and the transfers received from the government during each generation’s remaining lifetime.
age of the oldest living generation). \(N_{t,k}\) is the generational account of the generation born at year \(k\), that is, the present value of remaining lifetime net payments (taxes paid minus transfer received) made by the generation born in year \(k\) discounted to the base year \(t\). The second summation on the left side of equation (1) sums up the present values of generational accounts of future generations.

The first summation on the right-hand side of equation (3.1) is the present value of government expenditure, among which, \(G_s\) is the government’s expenditure in year \(s\), and \(r_j\) is the rate of return in year \(j\). The second term on the right-hand side \(W_t\) is the government’s net wealth in year \(t\).

The equation (3.1) denotes the zero-sum nature of a change in intergenerational fiscal policy such as PAYG pension policy. That is, holding the right-hand side of the equation (3.1) fixed, a decrease (increase) in the net tax payments of current generations caused by a policy change necessitates an increase (decrease) in the net tax payments from future generations.

The generational account \(N_{t,k}\) is calculated by equation (3.2):

\[
N_{t,k} = \sum_{s=\max(t,k)}^{k+D} T_{s,k} P_{s,k} \prod_{j=t+1}^{s} \frac{1}{1 + r_j}
\]  

Where \(T_{s,k}\) is the average net payment made in year \(s\) by a member of the generation born in year \(k\). \(P_{s,k}\) is the number of surviving members of the generation born in year \(k\) at year \(s\). For generation born before year \(t\) (\(k<t\)), the summation begins in year \(t\) and for generations born after year \(t\) (\(k>t\)), the summation begins in year \(k\). The summation is discounted to base year \(t\).

Once the right-hand side and the first term on the left-hand side of equation (3.1) are determined, the value of the second term on the left-hand side of equation (3.1), which is the total net payments of future generations, can be calculated as a residual. From this amount, we can further calculated the average per capita lifetime net tax payment of each future generation by
assuming it increases at the rate of productivity growth\textsuperscript{1}. Then, we can compare the growth-adjusted generational accounts of future generations, on a per capita basis, with those of existing generations, especially the current newborns to analyze the effect of current fiscal policy such as social security policy on intergenerational fiscal burden. Furthermore, we can assess how the reform options of current fiscal policy affect the fiscal burden facing current and future generations.

It is worth noting generational account is not each generation’s total lifetime net payment, but remaining lifetime net payment. Also, generational accounting method does not incorporate behavioral effects induced by the fiscal policy change, thus, it does not show the entire economic effects of the policy change, but rather the intergenerational fiscal effect.

3.4.1.2 Generational Accounting Application to China’s Social Security System

As this paper intends to analyze the effect of China’s pension policy on intergenerational fiscal burden, and some data on China’s fiscal system is unavailable, herein the generational accounting analysis is only concerned with the taxes, transfers, expenditure directly related to China’s social security system including pension, health, unemployment, work injury, and education, not to the whole public sectors. In fact, the social security system plays a key role in China’s public sectors (World Bank 1997, Wang et al. 2001). First, compared to the contribution rate of 13.6\% in Japan, 12.4\% in USA, 10\% in Chile, and 4.3\% in Mexico (Social Security Administration 2004), the pension contribution rate of 28\% (employer 20\% plus employee 8\%) in China is already quite high. If adding contributions for unemployment (3\%), health care (8\%), work injury (2\%), and maternity (1\%), the total contribution rate to the social security system is as high as 42\% of the employee’s payroll (employer 31\% and employee 11\%), the highest in the world (Appendix Table 3.2 and Table 3.3) (MOLSS, Statistics Report 2008).

\textsuperscript{1} That is, we assume controlling for a growth adjustment, the lifetime net tax payments (generational accounts) of all future generations per capita are equal, meaning the lifetime net tax payments a constant share of their lifetime income.
Secondly, the social security revenue and expenditure account for a high ratio of China’s fiscal revenue and expenditure. For example, in 2000, with the low overall pension coverage rate of 15%, the ratio of social security revenue and expenditure of China’s fiscal revenue and expenditure was 35.3% and 37.7% respectively. With the coverage expansion of the social security system and rapid population aging, the role of social security system in public sector would become much more important.

Third, the fiscal health of pension system is of key importance to China’s fiscal health (James 2003). Three benchmarks to measure the fiscal soundness of the pension system are implicit pension debt (IPD), the financing gap, and the required contribution rate (Sin 2005). China’s implicit pension debt (IPD) is estimated as high as ranging from 70%-140% of GDP (World Bank 1997, Wang et al. 2001, Sin 2005). With the coverage expansion of the social security system and rapid population aging, China’s IPD may become larger and lager. If the increasing IPD included in China’s public debts, China’s fiscal health would deteriorate substantially (Salditt et al. 2008). Furthermore, Sin (2005) calculated the financing gap around 95% of the GDP in 2001 and the required contribution rate to balance the pension system would have to increase from the current 28% to 37% of the wage bill in China, further indicating serious fiscal weakness of China’s pension system. Please see Box 3.1 in Appendix for the literature on estimates of China’s IPD and fiscal health.

3.4.1.3 Description of Data Source and Assumptions

To calculate generational accounts, we require the projections of population, the base year, the discount rate, the growth rate, and the age-specific taxes and transfers, government expenditures, initial government wealth that are directly related to the social security system including pension, health insurance, unemployment insurance, work injury insurance, maternity insurance, and education.
We assume the base year is 2000 when China’s pension system just completed the major transition from PAYG to partial funding. We use UN Population Database that covers the period 2000-2050. After 2050, we extrapolate the population projection using the assumed fertility rates and mortality rates by following Du et al. (2005). There are two assumed values for the productivity growth rate $g$: 2.5% and 4% and three values for the discount rate $r$: 4%, 6% and 8%. The case of $g=4\%$ and $r=6\%$ is our baseline case. We use the Chinese Urban Household Survey (UHS) conducted by China’s National Bureau of Statistics in 2000 to derive the age-profile of wage earning (Figure 3.7) and age-profiles of all types of tax payments and transfer receipts including pension, health insurance, unemployment insurance, work injury insurance, and maternity insurance. Based on these age-profiles, we then determine the age-specific average values of each type of tax and transfer by benchmarking against the aggregate amounts reported in China’s Statistical Yearbook until 2008. For future years when the aggregate amounts are unavailable, the age-specific average values for each tax and transfer are assumed to rise at the rate of productivity growth. The data regarding social security-related government wealth and government expenditure including educational expenditure are from China’s Statistical Yearbook. Here, government educational expenditure is regarded as a transfer to younger cohorts, rather than the government expenditure. Please see the Box 3.2 in the Appendix for the details on GA model assumption, data description, parameter value selection, and GA calculations.

3.4.1.4 Simulation Results

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1 Please see Table 3.1 in the Appendix for the detailed rules regarding the contributions and benefits of PAYG-based social account in China’s new partially funded pension system.
2 UN Population Division, World Population Prospects: The 2008 Revision Population Database, Medium Variant Case
3 We use the cohort-component population projection method by following Du et al. (2005). We assume the total fertility rate is 1.8 between 2050-2075, and 1.85 until 2100 due to the possible easing of “one child policy”. The life expectancy at birth for male and female are 77.4 years and 81.3 years between 2050-2075, and 80 years and 83.8 years until 2100.
4 The UHS provides detailed household-level information on income, consumption, asset, transfers, and expenditures. It also provides demographic and employment information about household members, living conditions, and a number of other household characteristics. The UHS in 2000 covers 24,650 urban households.
5 For example, in 2000, the aggregate revenue/expenditure for pension were 227.8 / 211.5 billion, for health insurance were 17/12.4 billion, for unemployment insurance were 16/12.3 billion respectively(NBS, China’s Statistical Yearbook 2001).
What is the fiscal burden on living and future generations under current social security policy? What is the main source for the fiscal burden imbalance on current and future newborns? How would the alternative pension reforms affect the fiscal burden facing current and future generations? Those are main issues addressed in this section. As shown in Table 3.4-Table 3.9, we first present the simulated generational accounts under current pension policy, and then the results regarding the intergenerational fiscal impact of four reform options equalizing the fiscal burden facing current and future newborns.

**Generational Accounts of Current Social Security Policy.** Table 3.4 shows the generational accounts of different cohorts arranged by cohort’s age in 2000 for different combinations of growth rate and discount rate under the current pension policy. The generational accounts show a hump-shaped pattern with respect to age, which is consistent with the typical generational account pattern (Auerbach et al. 1991). First, the generational accounts of current young and middle-aged generations are positive, meaning the taxes these generations pay exceed the transfers they receive, while those of existing generations older than 50 are negative, indicating these old generations receiving more than paying.

Second, the cohort at age 20 who just begins working pays the most and the one aged 60 who just retires receives the most. For example, under the baseline case (g=4%,r=6%), the age 20 account is RMB 124.5 thousand Yuan while the age 60 account is RMB -64.1 thousand Yuan.

Third, under all cases, the generational accounts of future generations are all positive and at least 35% higher than that of zero-age generation in 2000. For example, for the baseline case, the tax burden on future generations is RMB 123.0 thousand Yuan, 45% higher than RMB 89.9 thousand Yuan, the tax burden on zero-age generation. A study by Kotlikoff and Leibfritz (1999) compares generational accounts in 14 OECD countries and 3 developing countries. It finds fiscal burdens facing future generations are at least 50% larger than those of current newborns in 8 countries such as the U.S., Japan, and Germany (the severely higher cases), and 30%-50% higher in 5 countries such as France, Australia, Argentina (the substantially higher cases). The
calculation results show under China’s current pension policy, the future generations face a substantially higher fiscal burden than the current newborns.\footnote{According to Auerbach et al. 1991, this implies if current social security policy remains unchanged, the generations born after 2000 may have to pay much more social security contributions, or will receive much less benefits (or a combination of both), than newborns in 2000 in order to suffice to balance the government’s budget.}

Table 3.5 compares two hypothetical scenarios with the baseline case. If the full government asset were used instead of the social security-related assets\footnote{In the base year 2000, the social security-related government asset was 133 billion Yuan and the total state-owned asset reached around 10 trillion Yuan, 101\% of 2000 GDP (Xinhua, 06/19/2002). However, as China is still the biggest developing country that needs vast financial resources to solve many other developing challenges, the Chinese government never promises how much resource could be put into the social security system. Actually, as the estimated total public debt including huge hidden debts is 96\% of GDP in 2010 (Bloomberg, 03/02/2010), it is very difficult for China’s government to use much assets.} in the equation (3.1), fiscal burden on future generations would be 16\% lower than those of 2000 newborns. A higher government asset means the government has more resources to balance its intertemporal budget constraint, thus reducing the net payments from future generations. Also, if the population structure of each cohort kept constant since 2000, unborn generations would pay 8\% less than 2000 newborns, meaning rapid population aging may explain why fiscal burden on future generations are much higher than those of current newborns.

**The Effect of Higher Contribution Rate by 2.2 Percent Point.** Table 3.6 reports the case of an increase on contribution rate by 2.2 percent point. The policy change increases the net payments from existing generations aged 0-60 as they contribute more and receive same benefits, while it has no effect on generations older than 60 as they retired and do not contribute any more. Additionally, it significantly reduces the burden on future generations: under the baseline case, the generational accounts of future generations decrease to RMB 78.0 thousand Yuan and the account ratio between future generations and current zero-age generation decreases from 1.45 to 1.02.

**The Impact of Higher Retirement Age to 65.** To calculate net payments of current and future generations under the new scenario, we need make some adjustments to the old-age profiles of contributions and benefits in 2000. First, the values of wage for age 0-60 keep...
constant while those for age 60-age 65 are assumed to increase at the rate of productivity growth. Based on the new age profile of wage, the age profiles of payments for pension, health, unemployment, and maternity are changed accordingly. Second, the age profiles of benefits of pension and unemployment are also adjusted to capture the age composition of benefits of higher retirement age of 65 from 60.

Table 3.7 lists the generational accounts when the retirement age increasing from 60 to 65. The generational accounts of existing generations aged 0-65 increase significantly due to longer contribution period and shorter benefit period. More importantly, the fiscal burden on current and future newborns equalizes. For instance, under the baseline case, the generational accounts of future generations are RMB 75.1 thousand Yuan, only 1% higher than that of current zero-age generation.

The Effect of Lowering Pension Benefits by 11%. Table 3.8 presents the impact on intergenerational fiscal burden of lowering pension benefits by 11%. The net tax payments of existing generations rise due to lower pension benefits during retirement period, while those of future generations decrease substantially. Under the baseline case, the fiscal burden on the future generations is RMB 76.7 thousand Yuan, 3% higher than that on the 2000 newborn generation.

The Impact of Subsidizing by State-Owned Asset Interests. Table 3.9 shows the impact of subsidizing the social security system by yearly state-owned asset interests on generational accounts. It is well known that China government has huge state-owned assets. In 2000, the total state-owned asset balance reached around 10 trillion Yuan, 101% of 2000 GDP (Xinhua News Online, 06/19/2002). We assume the annual return rate is 6%, so the yearly asset interests available for subsidizing the social security system is 600 billion Yuan. Table 3.9 finds this policy change has no effect on the generational accounts of existing generations, yet significantly reduces those of future generations. Under the baseline case, the net tax burden on future generations is RMB 77.6 thousand Yuan, 8% higher than that of current zero-age generation.
Table 3.10 Generational Accounts Comparison of Five Scenarios under the Baseline Case

<table>
<thead>
<tr>
<th>Generation's Age in 2000</th>
<th>Current Pension Policy</th>
<th>Higher Tax by 2.2 Percent Point</th>
<th>Higher Retirement Age to 65</th>
<th>Lower Pension Benefit by 11%</th>
<th>Subsidizing with State-Owned Asset Interests</th>
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<td>1.03</td>
<td>1.01</td>
<td>1.03</td>
<td>1.08</td>
</tr>
</tbody>
</table>

Note: a. All scenarios are under the baseline case (g=4% and r=6%).
   b. The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.

Comparison of Four Policy Options Above. Table 3.10 that presents generational accounts comparison of all scenarios under the baseline case shows each of the four pension reform alternatives above reduces the fiscal burden imbalance between current and future newborns, yet has different effect on intergenerational distribution of fiscal burden. Table 3.11 lists the additional tax burden imposed on existing and future generations due to the four pension policy changes (under the baseline case). First, the four policy changes bring limited additional tax burden on current generations. Take the case of higher tax by 2.2 percentage points as an example: the additional net tax payment is 6,800 Yuan (up 5%) for the generation aged 20 and
1,000 Yuan for generation aged 60 (up 1.5%). Compared with the old-age generations, the working-age generations bear much bigger tax burden increase.

Second, although the policy changes bring certain costs to current generations, the gains to future generations are quite substantial. In the same example as before, the tax burden on future generations decreases by 26.2 thousand Yuan (down 21.4%). That is, if current generations pay a little more now, the future generations could pay much less later.

Third, the additional burden imposed on different generations under different policy change can vary considerably. For example, the generation aged 60 pays only 1,000 Yuan more under the tax increase policy while pay additional 5,100 Yuan under the higher retirement age policy and additional 4,800 Yuan under the benefit cut policy. The generation aged 20 pays additional 6,800 Yuan under the tax increase policy while pay additional 5,900 Yuan under the higher retirement age policy and additional 5,400 Yuan under the benefit cut policy. That is, under the policies of higher retirement age and lower pension benefit, the hump-shaped patterns of the generational accounts become much flatter as young-age generations pay less and old-age generations receive less. Thus, these two police changes improve the intergenerational fiscal burden distribution.

**Sensitivity Analysis.** Seen from the Table 3.4-Table 3.9, for the different combinations of growth rate and discount rate, the amounts of generational accounts are different, that is, the generational accounts are sensitive to the changes in the growth rate and the discount rate. However, the main results regarding the intergenerational fiscal effects of the current policy and four pension reforms are robust.

To sum up, under the current pension policy, due to the rapid population aging, the fiscal burden facing future generations is more than 35% higher than that facing the newborn generation in 2000. Higher contribution rate and retirement age, lower pension benefits and subsidy from state-owned asset interest can decrease the fiscal burden on future generations significantly at the
certain cost of current generations, among which, raising retirement age and lowering pension benefits are more appropriate to improve intergenerational fiscal burden distribution.

3.4.2 An Extended Simulation Model

McCarthy and Zheng (1996) use a simulation model to study the impact of introducing a fully funded pension scheme on China’s pension fund balance. Alier and Vittas (2000) employ a similar model to evaluate the effects of different investment strategies on the pension benefits in the U.S. Both of their models are based on fully funded pension system. Here, this paper develops an extended simulation model to adapt to China’s partially funded pension system.

Friedman et al. (1996) simulate the effects of parametric reforms like reducing the pension benefits, using price indexation, and raising the retirement age on the contribution rate and find these are necessary but not sufficient to make China’s PAYG pension system sustainable. James (2002) investigates how the return rate of China’s pension fund affects the replacement ratio and calculates a real return of 5% is needed to meet the targeted pension replacement ratio. This paper extends these studies by analyzing the quantitative effects on the replacement ratio of more policy variables including coverage rate, administration cost, and contribution rate as these variables have sizeable impact on China’s pension system (McCarthy and Zheng 1996; Wang et al. 2001; Salditt et al. 2008).

3.4.2.1 Model Set-Up

A representative adult born at the year $t_0$ starts working at age $N_1$ (the year $t_1$), retires at age $N_2$ (the year $t_2$), and dies at age $N_3$ (the year $t_3$). He makes pension contributions to both PAYG-based social account and fully funded individual account during the working period, and receives social pension from social account and pension annuity from individual account by participating in a perfect annuity during the retirement period. Also, he saves only for the pension motive, no bequest motive.
For the PAYG-based social account, total pension payments are equal to total pension contributions at the same period. When the representative adult retires in the year $t_2$, the social pension benefit from the social account $P^t$ can be calculated as:

$$P^t = \sum_{a=N_1}^{N_2} \left[ c_{t_2,a} L_{t_2,a} W_{t_2,a} \tau^t (1 - AC^t) \right] / \sum_{a=N_2+1}^{D} c_{t_2,a} L_{t_2,a} R_{N_2+1,a}$$  \hspace{1cm} (3.3)$$

where the numerator of (3) means the total pension contributions subtracting the administration costs, while the denominator is the weighted number of pensioners. $L_{t_2,a}, W_{t_2,a}$ are the population and the real wage of adults aged $a$, and $c_{t_2,y}, c_{t_2,o}$ are the social account coverage rates of young-age adults aged from 20 to 60 and of old-age adults older than 60 respectively in the year $t_2$. $\tau^t$, the contribution rate to social account, is the ratio of the pension contribution to social account of the wage. $AC^t$, the administration cost of social account, is the ratio of administrative costs to the revenue of the social account. $D$ is the age of the oldest living adult, and $R_{N_2+1,a}$ is the ratio of pension benefit of the generation aged $a$ to the generation aged $N_2+1$ in the year $t_2$.

For the fully funded individual account, the representative adult accumulates pension assets before retirement. After retiring, he decumulates the pension assets until his death. The year-end balance of the pension asset is showed in equation (3.4) and (3.5). Equation (3.4) gives year-end balance of the accumulated pension assets in the individual account at the retirement age $N_2$ (the year $t_2$), equal to all the pension contributions plus the resultant interests during the working period. Equation (3.5) describes the year-end balance of the decumulated pension assets in the individual account from the post-retirement year $t_2+1$ to the death year $t_1$.

\[\begin{align*}
\sum_{a=N_1}^{N_2} \left[ c_{t_2,a} L_{t_2,a} W_{t_2,a} \tau^t (1 - AC^t) \right] = \sum_{a=N_1}^{D} c_{t_2,a} L_{t_2,a} \Rightarrow P^t = \sum_{a=N_1}^{N_2} \left[ c_{t_2,a} L_{t_2,a} W_{t_2,a} \tau^t (1 - AC^t) \right] / \sum_{a=N_2+1}^{D} c_{t_2,a} L_{t_2,a} R_{N_2+1,a} \\
\end{align*}\]

\[\begin{align*}
c_{t_2,y} = \sum_{a=20}^{N_2} L_{t_2,a} W_{t_2,a}, c_{t_2,o} = \sum_{a=61}^{D} L_{t_2,a}, N_{t_2,a}, \text{ where } N_{t_2,a} \text{ is the adults aged } a \text{ covered by the pension system who either are contributors or pensioners.} \\
\end{align*}\]
\[
A_{t_1} = \sum_{i=t_1}^{t_3} \left[ r^i (1 - AC^i) W_{r, i} \prod_{\eta=t_1+1}^{t_3} (1 + r_\eta) \right] 
\]  
\[
A_t = (1 + r_t) A_{t-1} - P^i \prod_{\eta=t+1}^{t_2} (1 + \pi_\eta), \quad t \in [t_2 + 1, t_3] 
\]

Where \(A_t\) is the year-end asset balance of individual account in the year \(t\), \(r^i\) and \(AC^i\) are the contribution rate and the administration cost of individual account, \(P^i\) is the pension annuity from individual account indexed with inflation rate \(\pi\), and \(r\) the annual return rate of pension fund investment.

Furthermore, we derive the mathematical expression of \(A_t\) from Equation (3.5) by making some algebraic transformations as follows:

\[
A_{t_2+1} = (1 + r_{t_2+1}) A_{t_2} - P^i \prod_{\eta=t_2+1}^{t_3} (1 + \pi_\eta)
\]

\[
A_{t_2+2} = (1 + r_{t_2+2})(1 + r_{t_2+1}) A_{t_2} - (1 + r_{t_2+2}) P^i \prod_{\eta=t_2+1}^{t_3} (1 + \pi_\eta) - P^i \prod_{\eta=t_2+1}^{t_2+2} (1 + \pi_\eta)
\]

\[
A_{t_2+3} = (1 + r_{t_2+3})(1 + r_{t_2+2})(1 + r_{t_2+1}) A_{t_2} - (1 + r_{t_2+3})(1 + r_{t_2+2}) P^i \prod_{\eta=t_2+1}^{t_3} (1 + \pi_\eta)
\]

\[
- (1 + r_{t_2+3}) P^i \prod_{\eta=t_2+1}^{t_2+2} (1 + \pi_\eta)
\]  

Finally, we can get:

\[
A_{t_3} = (1 + r_{t_3})(1 + r_{t_3-1}) \cdots \quad (1 + r_{t_3+2})(1 + r_{t_3+1}) A_{t_2}
\]

\[
- (1 + r_{t_3})(1 + r_{t_3-1}) \cdots \quad (1 + r_{t_3+3})(1 + r_{t_3+2}) P^i \prod_{\eta=t_3+1}^{t_3+2} (1 + \pi_\eta)
\]

\[
- (1 + r_{t_3})(1 + r_{t_3-1}) \cdots \quad (1 + r_{t_3+3}) P^i \prod_{\eta=t_3+1}^{t_3+2} (1 + \pi_\eta)
\]

\[
\vdots
\]

\[
- (1 + r_{t_3}) P^i \prod_{\eta=t_3+1}^{t_3} (1 + \pi_\eta) - P^i \prod_{\eta=t_3+1}^{t_3} (1 + \pi_\eta)
\]

As the individual adult saves only for the pension motive, he would use up all the pension assets when he dies, so the year-end balance of pension assets in the death year \(t_3\) is zero, namely, \(A_{t_3}=0\). Thus, we can further get individual account pension annuity \(P^i\), and the pension replacement ratio \(REP\):
The numerator of (3.6) is the total pension assets including the principal $A_{i_3}$ and resultant interests, while the denominator is the length of the retirement period weighted by the return rate and inflation rate$^1$.

From (3.7), the social account replacement ratio $REPS$ is positive to the pension contribution rate $\tau^s$, the retirement age $N_2$, the social account coverage rate of young-age adults $c_{i_3,y}$, negative to the administration costs $AC^s$. The individual account replacement ratio $REPI$ is positive to the contribution rate $\tau^i$, the retirement age $N_2$, the return rate $r_i$, and negative to the administration costs $AC^i$.

### 3.4.2.2 Model Parameter Selection and Data Description

The representative adult starts working at age 20$^2$ in 1991 when China begun its pension reform of adopting the partially funded system, retires at age of 60 (the year 2031), and dies at age 79 (the year 2050) with the life expectancy at age 60 being 19 (WHO, 2010 World Health Statistics).

There are five fund investment options including bank deposit, government bond, domestic stock, industrial investment, and global investment. Accordingly, we build seven investment strategies. Strategy 1 includes bank deposit only, Strategy 2 government bond only, Strategy 3 stock only, Strategy 4 industrial investment only, Strategy 5 global investment only, Strategy 6 all options, and Strategy 7 combination of options.

---

$^1$ If all $r=0$ and $\pi=0$, the individual account pension annuity $P^i$ is just the total pension contributions to the individual account divided by the number of the retirement years, while the replacement ratio $REPS$ is just average yearly contribution rate multiplied by the ratio of working period to the retirement period, that is, $REPS = \frac{A_i}{W^i} \left( N_i - N_1 \right) \left( \frac{N_1}{N_2} \right)$.

$^2$ A Chinese usually goes to school at age 8 and starts working at age 20 after an average 12 years of school studying and working internship or training (NBS, China’s Statistical Yearbook 2009).
Strategy 3 industrial investment only, Strategy 4 domestic stock only, and Strategy 5 global investment only. Strategy 6 includes 50% bank deposit and 50% government bond, the current investment practice of basic pension fund in China. Strategy 7 is a portfolio with a structure of 10:40:20:20:10, i.e. bank deposits 10%, government bonds 40%, industrial investment 20%, domestic stocks 20%, and global investment 10%, the latest portfolio structure of National Social Security Fund (SSF, Annual Report 2009).

Our model has four policy variables including social account coverage rate, administration cost, retirement age, and investment strategy. In the baseline case set as a benchmark in this study, the contribution rates for social account and individual account are 20% and 8%, respectively, the administration costs are 3% of revenues of the social account and 4% of the individual account, the retirement age is 60, the social account coverage rates of young-age adults and old-age adults are 70% and 85% \(^2\), and the investment strategy is strategy 6 (50% bank deposits and 50% government bonds). These parameter values are based on China’s current practices (MOLSS, Statistics Report 2008). We also make other four simulations by changing the values of the four policy variables to see the extent to which these policy variables affect the pension replacement ratio.

Table 3.12 lists the summary of the data on return rates for five kinds of assets, real average wage, and inflation rate until 2008, and the corresponding data sources and ranges. Table 3.12 also includes the mean and the standard deviation of the assumed mixed Strategy 6 and Strategy 7. \(^3\) Additionally, same as in GA model above, we use the population data from UN.

---

\(^1\) Most industrial investments of pension funds in China concentrate on public utility industry for a long-term and stable return. For example, 80% of the industrial investments of SSF in 2008 focus on the public utility including airport, railroad, highway, seaport, and power-generation station (SSF, Annual Report 2009).

\(^2\) The social account coverage rates of young-age adults and old-age adults of China’s urban pension system are 55% and 75% respectively in 2008 (SSF, Annual Report 2009). We assume they increase to 70% and 85% in 2031 as China is expanding its urban pension system coverage.

\(^3\) Based on the portfolio theory, the mean \(R_P\) and variance \(VAR_P\) of a portfolio is:

\[
R_P = \sum_{i=1}^{n} x_i R_i, \quad VAR_P = \sum_{i=1}^{n} \sum_{j=1}^{n} x_i \cdot x_j \cdot COV(R_i, R_j),
\]

where \(x_i\) is the investment ratio in asset \(i\) among a mixed portfolio, \(R_i\) is the return rate of asset \(i\), and \(COV(i,j)\) is the covariance between asset \(i\)’s return and asset \(j\)’s return. From the historical data series of the returns of the five assets, we can get each asset’s mean and variance, and the covariance between each two assets, then we can calculate \(R_P\) and \(VAR_P\) of the mixed Strategy 6 and 7.
Population Database and WHO Life Table$^1$ and age-profiles of wage earnings and pension benefits from the Chinese Urban Household Survey data.

As the data series of Table 3.12 are only available until 2008, data after 2008 need be simulated. Following James (2002), we assume the yearly growth rate for real average wage is 4.5% before 2025 and 3% until 2075, and the yearly inflation rate is 4% before 2025 and 3% until 2075. The underlying rationale is economic and wage growth slow when China gets richer. Then, we can calculate the data of $W_{a,t}$ by using the data of age profile of wage and real yearly average wage. Additionally, following McCarthy and Zheng (1996), we assume the return rates for all seven investment strategies are normally distributed. Thus, these return rates data after 2008 could be stochastically simulated by using the historical mean and standard deviation derived from observations of early periods$^2$.

### 3.4.2.3 Simulation Results

Based on the simulation model and parameters’ values above, we use Matlab 6.5 Program to conduct stochastic simulations. We first use Equation (3.3) to simulate the social account replacement ratio $REPs$. Then, we use Equation (3.6) to simulate individual account replacement ratio $REPi$ and $REP$. As the values of return rates of seven investment strategies are stochastically simulated, in order to make the simulation result as accurate as possible, we make 800 replications for each stochastic simulation, and then calculate the mean and the standard deviation of 800 replication results.

First, we present simulation result for the baseline case: under the current pension policy, the mean of the pension replacement ratio $REP$ is 45.6% ($REPs$ and $REPi$ are 30.4% and 15.2% respectively) with a standard deviation of 2.2%, while the promised replacement ratio by China’s

---


$^2$ As we think China’s stock market will become more developed and stable in the future, the mean and the standard deviation of domestic stock return are assumed to decrease to 8% and 17%, and the mean and the standard deviation of industrial investment to decrease to 7.5% and 14%, a little higher than those of global investment return.
government is 59% (REP and REP\textsuperscript{i} are 35% and 24% respectively) \textsuperscript{1}. Compared with those by China’s government, our result is 30% lower. In terms of REP\textsuperscript{s}, this paper has an older population structure in retirement year 2030 (our estimates show the working population ratio is 63.1% and the old population ratio is 16.7\%, while the government estimates are 66.5\% and 16.2\% respectively). That is, our estimate has a higher representation of the number of retirees relative to the number of taxpayers. So, the simulation model (Equation 3.3) produces a lower REP\textsuperscript{s}. In terms of REP\textsuperscript{i}, our estimates of the return rates of the assets is stochastically simulated by using the historical mean and standard deviation derived from the historical return data, while the government’s estimates assume constant return rates\textsuperscript{2}. Our model (Equation 3.6) simulates much lower return rates, thus produces lower REP\textsuperscript{i}.

Second, we simulate the effects of changes in four policy variables to investigate how to explain the low replacement ratio of the baseline case, thus providing empirical evidence to support some alternative parametric pension reforms. Table 3.13-Table 3.15 list the simulated effects on the replacement ratio of changes in four policy variables including coverage rate, retirement age, administration cost, and pension fund investment strategy.

**Effect of Change in Coverage Rate.** Keeping all other variables same as those in the baseline case, we make simulations by changing the social account coverage rate of young-age adults of 70\% at baseline case to a lower level of 65\% and a higher level of 80\%.

Table 3.13 shows with a higher coverage rate of young-age adults, the corresponding replacement ratios rise significantly. For example, with coverage rate of young-age adults rising from 70\% to 80\%\textsuperscript{3}, the social account replacement ratio REP\textsuperscript{s} increases to 37.2\% and individual account replacement ratio REP\textsuperscript{i} rises to 16.2\%, then the replacement ratio REP increases from

\textsuperscript{1}The promised pension replacement ratio by China’s government is 59\%, among which, the expected replacement ratios from the social account REP\textsuperscript{s} and individual account REP\textsuperscript{i} are 35\% and 24\% respectively (Salditt et al. 2008).

\textsuperscript{2}As shown in Table 3.12, our estimates of the mean return rates of bank deposit and government bond are 1.1\% and 2\%, while the government’s estimates of return rates of bank deposit and government bond are 2.5\% and 4\% respectively.

\textsuperscript{3}The effect of changes in coverage rate actually includes the direct effect of coverage rate change and the indirect effect on changing administration costs of social account and individual account due to the effect of economies of scale as the pension system expands. Please see the details in Note c of Table 3.12 in the Appendix.
45.6% to 52.9%, up 16 percent. The robust results show low coverage rate is one important factor causing the low replacement ratio of the baseline case.

**Effect of Change in Retirement Age.** With a higher retirement age of 65 from 60 at baseline case, both \( \text{REP}^i \) and \( \text{REP}^j \) rise to 35.4% and 19.5% respectively, then the replacement ratio \( \text{REP} \) rises to 54.9%, up 20 percent, while with a lower retirement age of 55, the replacement ratio decreases to 37.4%, down 17 percent. Theoretically, due to prolonging working time and shortening retirement time simultaneously, raising retirement age is an effective way to increase pension replacement ratio (Feldstein 1998), proved by our simulation results shown in Table 3.14.

**Effect of Change in Administration Cost.** Regarding the effect of administration cost, we also discuss two cases with administration cost at a higher level of 5% (4%) \(^1\) and a lower level of 3% (2%) respectively, compared with the level of 4% (3%) at the baseline case. The replacement ratio at the first case decreases to 40.8% and at the second case grows to 50.9%, 10 percent lower and 12 percent higher than the one in the baseline case respectively. The empirical results prove the importance of lowering administration cost, consistent with the results in James (2002). For China’s case, currently the practical way to reduce administration cost is to unify the fragmented and decentralized pension system and to implement national-level pooling of social account (Sin 2005).

**Effects of Different Fund Investment Strategies.** Besides the investment strategy of 50% bank deposit and 50% government bond at the baseline case, we build six other investment strategies (Strategy A-G) including bank deposits only, government bonds only, industrial investment only, domestic stock only, global investment only, and a mixed strategy of 10:40:20:20:10, the latest portfolio structure of NSSF. Table 3.15 shows the significant differences in impact of six different investment strategies \(^2\). Except the bank deposits only

---

\(^1\) It means that the administration costs are 5% of revenues of the individual account and 4% of the social account.  
\(^2\) Changing investment strategy only affects \( \text{REP}^i \) rather than \( \text{REP}^j \). Actually, the effect on \( \text{REP}^i \) includes the direct effect of investment strategy change on portfolio return rate and the indirect effect on changing individual account administration costs. When the individual account is actively invested in risk assets like stock, the administration costs tend to rise. Please see the details in Note c of Table 3.14 in the Appendix.
strategy has a lower replacement ratio than the baseline case, other five strategies have higher or much higher replacement ratios. Among them, industrial investment only strategy, domestic stock only strategy, and global investment only strategy have produced the highest replacement ratios, 85%, 93% and 80% larger than the one of the baseline case respectively. Yet, the corresponding risk levels are higher than 6.0%, against the principle of pension fund safety, the most important pension investment principle stipulated by China’s government (State Council of PRC 1997, 2006), so these three strategies may be unpractical in China. The mixed strategy of 10:40:20:20:10 gives a relatively high result of 66.7% (46 percent larger than the baseline case) with a relatively low risk of 3%, thus a much more viable strategy.

The simulation result is accordant with Friedman et al. (1996)’s finding that the low returns caused by investing only in bank deposit and government bond is one of the main reasons for China’s low pension benefits. The results also show diversifying the pension investment by adding a proportion of stock investment, industrial investment, and global investment can improve the investment returns significantly without bring too much risk.

To sum up, from Table 3.16, our simulations find under current pension policy, the replacement ratio is 45.6%, much lower than the promised 59% by China’s government, and the significant impact of four policy options in increasing the replacement ratio, among which, diversifying pension investment is the most effective and viable one.
Table 3.16  Pension Replacement Ratio Comparison under Five Scenarios

<table>
<thead>
<tr>
<th></th>
<th>Current Pension Policy</th>
<th>Higher Coverage Rate</th>
<th>Higher Retirement Age</th>
<th>Lower Administration Cost</th>
<th>Mixed Investment Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage Rate of Young-Age Adults</td>
<td>0.70</td>
<td>0.80</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>Contribution Rate for Social Account</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.15</td>
<td>0.2</td>
</tr>
<tr>
<td>Contribution Rate for Individual Account</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.13</td>
<td>0.08</td>
</tr>
<tr>
<td>Retirement Age</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Administration Cost a</td>
<td>4% (3%)</td>
<td>3.5% (2.6%)</td>
<td>4% (3%)</td>
<td>3% (2%)</td>
<td>4.5% (3%)</td>
</tr>
<tr>
<td>Investment Strategy b</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0:0</td>
<td>10:40:20:20:10</td>
</tr>
<tr>
<td>Replacement Ratio (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (Change %) c</td>
<td>45.6 (0%)</td>
<td>52.9 (16.1%)</td>
<td>54.9 (20.3%)</td>
<td>50.9 (11.6%)</td>
<td>66.7 (46.2%)</td>
</tr>
<tr>
<td>Standard Deviation c</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
<td>2.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note:  

a. The administration costs 4% (3%) stands for 4% of revenues of the individual account and 3% of social account.

b. The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.

c. The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.

It is also worth noting we only calculate the social account replacement ratio REP at the time of retirement, which may change as the representative individual adult ages. Indeed, due to the decreasing social pension as China’s population is increasingly aging, the values of REP and REP go down when he ages. For instance, when he was 70 old, REP and REP would decrease to 26.8% and 38.9% respectively. However, the decreases do not affect the main results.

The Combined Effects of Changes in Policy Variables. The sections above discuss the separate effect of changes in four policy variables. Furthermore, it is necessary to analyze the combined effects of these four variables as they affect each other. Table 3.17 gives the assumed variables values and simulation results of such two cases (Case A and Case B). Case A produces
a replacement ratio of 100.7% (up 143 percent from the baseline Case), the highest one of all simulations while case B gives 30.2% (down 27 percent), the lowest one of all simulations.

It is worthy to note the case with the highest replacement ratio is not always the optimal choice as some policy changes, for instance, a direct increase in retirement age to 65, are politically difficult in practice. However, the results show the combined changes in four policy variables could improve pension benefits of China’s retiree very significantly, providing empirical proof for options of further pension policy modifications.

**The Significance of Applying to Other Cohorts.** Our simulation analysis above is limited to the cohort born in 1971, however, the main results still apply to other cohorts born after 1971. Table 3.18 shows the simulation results of baseline case and alternative reform options for 1991 Cohort. First, the pension replacement ratio REP under current pension policy remains low. Compared with the 1971 Cohort, REP\(^i\) and REP of the 1991 Cohort decrease to 27.7% and 42.9%, while REP\(^i\) is little changed. The negative effect of decreasing system support ratio (the ratio of contributor to recipient) caused by rapid population aging outpaces the positive effects of increasing system coverage rate and decreasing administration costs, causing a lower REP\(^i\) and REP. Second, the effects of four alternative reform options remain robust on increasing REP of the 1991 Cohort. REP increase by 19%, 20%, 10%, and 48% under the cases of higher coverage rate, higher retirement age, lower administration costs, and the mixed investment strategy respectively.

### 3.5 Policy Recommendations for Improving China’s Pension System

Based on critical analysis of challenges facing China’s pension system and empirical results above, in this section, we propose some policy recommendations to improve China’s pension system.

**Increasing Retirement Age.** Our simulation work shows the strong effect of higher retirement age. When the retirement age increases from 60 to 65, the retiree’s pension benefits
rise by about 20 percent. However, as retirement age directly rising to 65 may be politically difficult (Shi 2005), a lower retirement age of 62 may be more realistic.

**Improving Pension System Participation.** On one hand, incentives for system participation need to improve. Increasing returns for pension fund investment and enhancing mobility of pension rights are two important ways to improve participation incentives. On the other hand, the government needs to make much more effort to expand the pension coverage to 150 million migrant workers and to take necessary legal actions against contribution evasion activities of some enterprises (Shi 2006).

**Increasing Return on Pension Fund Investment.** One way is to diversify pension fund investment by adding industrial investment, domestic stock investment, and global investment. Our simulation results find the significant impact of investment diversification on pension benefits. For example, the current NSSF investment portfolio of 10:40:20:20:10 can increase the replacement ratio by 46 percent. Another way is to lower the administration cost. Currently the most practical way to reduce administration cost is to unify the fragmented and decentralized pension system across the country and to implement national-level pooling of PAYG-based social account (Shi 2005).

**3.6 Conclusion**

In the past two decades, China’s urban pension system has undergone quite a few major fundamental reforms and been shifting from a PAYG system to a partially funded multi-pillar system. In addition, a new rural pension system subsidized by the government is making progress.

Despite significant institutional and other progress, China’s pension system is still suffering from some major challenges: high IPD and empty individual account erode public trust in pension system; fragmentation and decentralization hinder national pooling and portability of pension claims; low returns on pension funds and high contribution rate encourage high evasions from private and foreign invested enterprises; and low retirement age and low coverage rate are
against the financial health of the system. Much worse are these problems being aggravated by increasingly rapid aging of the population, which may necessitate further parametric pension reforms.

We develop two kinds of simulation analysis to evaluate the effects of parametric reform options. One is to apply Generational Accounting method to assess the intergenerational fiscal effect of three pension reforms. The other is to use an extended simulation model to simulate the impact of five reform options on the pension replacement ratio. The simulation results indicate under the current pension policy, the fiscal burden facing future generations is at least 35% higher than that facing the newborns in 2000 and the low return of pension investment is the main reason for the low replacement ratio. The results also show the significant impact of these reform options on decreasing the fiscal burden facing future generations and increasing the pension replacement ratio.

In order to accommodate a population of more than 330 million senior citizens by 2050, further parametric pension reforms may be needed including building an unified system across the nation, raising the retirement age, and diversifying the pension fund investment.

Our paper analyzes the evolution, the progress, and the challenges of China’s urban and rural pension systems, evaluates the quantitative impact of further parametric pension reform, and proposes corresponding policy recommendations. However, many other key issues need further exploration, including the interaction between the urban system and the rural system, the old-age security challenge for the farmers losing their land\(^1\), the choice of pension fund management between prudent person rule and quantitative restriction (Davis 2002). Additionally, our simulation model need be further extended to cover transitional costs, bequest saving motive, and regional disparities and sectoral differences.

\(^1\) There is an estimated 20 million rural farmers losing their land due to the rapid urbanization of China (Shi 2006).
APPENDIX 1.A: DETAILS OF CALCULATION OF $k_{t+1}$ AND $k*_{pg}$

(Under the case of PAYG system and endogenous LFP of the elderly)

The agent’s utility maximization problem is:

$$\text{Maximizes } U = \ln c_{y,t} + \frac{q_t}{1+\rho} \left[ \ln c_{o,t+1} + \beta \ln(1-lp_{r_{t+1}}) \right]$$

subject to:

$$c_{y,t} + \frac{c_{o,t+1}}{(1+r_{t+1}^{-1})/q_t} = (1-\tau_{pg})H_w w_t^t + \frac{lp_{r_{t+1}}H_{r_{t+1}}w_{r_{t+1}}}{(1+r_{t+1})/q_t} + \frac{\tau_{pg}H_{r_{t+1}}w_{r_{t+1}}(1+n)}{(1+r_{t+1})} = I_t$$

(1.A.1)

We can set up a Lagrangian expression:

$$L = \ln c_{y,t} + \frac{q_t}{1+\rho} \left[ \ln c_{o,t+1} + \beta \ln(1-lp_{r_{t+1}}) \right] + \lambda (I_t - c_{y,t} - \frac{qc_{o,t+1}}{1+r_{t+1}})$$

where $\lambda$ is a Lagrangian multiplier. From the first order conditions (FOC), we can get:

$$\frac{\partial L}{\partial c_{y,t}} = \frac{1}{c_{y,t}} - \lambda = 0$$

$$\frac{\partial L}{\partial c_{o,t+1}} = \frac{q_t}{1+\rho} \frac{1}{c_{o,t+1}} - (\frac{q_t}{1+r_{t+1}})\lambda = 0$$

$$\frac{\partial L}{\partial lp_{r_{t+1}}} = \frac{-q_t\beta\delta}{1-lp_{r_{t+1}}} + \lambda \left( H_{r_{t+1}}w_{r_{t+1}}q_t \right) = 0$$

$$\frac{\partial L}{\partial \lambda} = (1-\tau_{pg})H_w w_t + \frac{lp_{r_{t+1}}H_{r_{t+1}}w_{r_{t+1}}}{(1+r_{t+1})/q_t} + \frac{H_{r_{t+1}}w_{r_{t+1}}(1+n)}{(1+r_{t+1})} - c_{y,t} - \frac{qc_{o,t+1}}{1+r_{t+1}} = 0$$

From (1.A.2), we can get $c_{y,t}$, $c_{o,t+1}$, $lp_{r_{t+1}}$, $s_{y,t}$:

$$c_{y,t} = \frac{1}{\lambda} \left( \frac{(1+r_{t+1})(1-\tau_{pg})H_w w_t + H_{r_{t+1}}w_{r_{t+1}}[\tau_{pg}(1+n) + q_t]}{(1+r_{t+1})(1+q_t\beta\delta + q_t\delta)} \right)$$

(1.A.3)

$$c_{o,t+1} = \frac{1+r_{t+1}}{1+\rho} \frac{1}{\lambda} \left( \frac{(1+r_{t+1})(1-\tau_{pg})H_w w_t + H_{r_{t+1}}w_{r_{t+1}}[\tau_{pg}(1+n) + q_t]}{(1+q_t\beta\delta + q_t\delta)/\delta} \right)$$

(1.A.4)

$$lp_{r_{t+1}} = \frac{H_{r_{t+1}}w_{r_{t+1}}(1+q_t\delta) - H_w w_t \beta\delta(1+r_{t+1})(1-\tau_{pg}) - \beta\delta H_{r_{t+1}}w_{r_{t+1}}\tau_{pg}(1+n)}{H_{r_{t+1}}w_{r_{t+1}}(1+q_t\beta\delta + q_t\delta)}$$

(1.A.5)
\[ s_{y,t} = \frac{(1+r_{t})(q_{t} \beta \delta + q_{t} \delta)(1-\tau_{pg})H_{t}w_{t} - H_{t+t}w_{t+t}\left[\tau_{pg}(1+n) + q_{t}\right]}{(1+r_{t+t})(1+q_{t} \beta \delta + q_{t} \delta)} \] (1.A.6)

The capital condition for PAYG economy is:

\[ K_{t+1} = s_{y,t}N_{y,t} \] (1.A.7)

\[ \rightarrow k_{t+1} = s_{y,t}\frac{N_{y,t}}{L_{t+1}} = \phi_{t}H_{t}w_{t}N_{y,t} \]

Where \( \phi_{t} \) is the share of saving of wage income for working-age adults:

\[ \phi_{t} = \frac{s_{y,t}}{\omega_{t}H_{t}} = \frac{(1+r_{t})(q_{t} \beta \delta + q_{t} \delta)(1-\tau_{pg})-(1+g)\left(\frac{k_{t+1}}{k_{t}}\right)^{\alpha}}{(1+r_{t+t})(1+q_{t} \beta \delta + q_{t} \delta)} \]

Due to \( H_{t+1} = (1+g)H_{t}, w_{t} = (1-\alpha)k_{t}^{1/\alpha} \), and \( L_{t} = H_{t}(N_{y,t} + N_{o,t}/lp_{t}) \)

\[ \rightarrow k_{t+1} = \frac{\phi_{t}(1-\alpha)k_{t}^{\alpha}}{(1+n+q_{t} \cdot lp_{t})(1+g)} \] (1.A.8)

(1.A.8) is the new equation describing the evolution of capital per unit of effective labor under PAYG economy at the case of endogenous labor force participation.

At steady state, the capital per unit of effective labor at PAYG system \( k_{pg}^{*} \) is:

\[ k_{pg}^{*} = \frac{\phi^{*}(1-\alpha)}{(1+n+q^{*} \cdot lp^{*})(1+g)} \] (1.A.9)

Where, \( \phi^{*} \) is the steady state share of saving of wage income for working-age adults and \( lp^{*} \) is the steady state labor force participation of the elderly.

\[ \phi^{*} = \frac{(1+r^{*})(q^{*} \beta \delta + q^{*} \delta)(1-\tau_{pg})-(1+g)\left[\tau_{pg}(1+n) + q^{*}\right]}{(1+r^{*})(1+q^{*} \beta \delta + q^{*} \delta)} \]

\[ lp^{*} = \frac{(1+q^{*} \delta) - \beta \delta(1+r^{*})(1-\tau_{pg})/(1+g) - \beta \delta \tau_{pg}(1+n)}{(1+q^{*} \beta \delta + q^{*} \delta)} \]
APPENDIX 1.B: DETAILS of CALCULATING STEADY STATE VARIABLES

(Under the case of PAYG system and endogenous LFP of the elderly)

1) Macroeconomic Variables: \( k^* \), \( y^* \), \( (\frac{S}{Y})^* \), \( (\frac{K}{Y})^* \), \( r^* \), and \( w^* \)

From (1.A.9), the steady state capital per unit of effective labor under PAYG system \( k^*_p \) is:

\[
k^*_p = \frac{\phi^* (1-\alpha)}{(1 + n + q'lp^*)(1 + g)}
\]

(1.B.1)

The steady state output per worker \( y^*_p \) is:

\[
y^*_p = H^*k^*_p^{\alpha}
\]

(1.B.2)

The national saving rate \( \frac{S^*_n}{Y^*_n} \) is:

\[
\frac{S^*_n}{Y^*_n} = \frac{Ltf^a}{k^a} (1 - \alpha) \left[ \phi - \frac{\phi^*}{(1+n)(1+g)} \right]
\]

(1.B.3)

Where \( \phi \) is the share of saving of wage income for working-age adults:

\[
\phi = \frac{g_{t+1}^*(1-r_{t+1}^*)(q^*\delta + q^*\delta)(1-r_{t+1}^*) - (1+g)}{(1+r_{t+1})(1+q^*\beta + q^*\delta)}
\]

(1.B.4)

So, the steady state national saving rate \( \frac{S^*_n}{Y^*_n} \) is:

\[
\left( \frac{S^*_n}{Y^*_n} \right)^* = (1-\alpha) \left[ \phi^* - \frac{\phi^*}{(1+n)(1+g)} \right] = (1-\alpha) \phi^* \left[ \frac{ng + n + g}{(1+n)(1+g)} \right]
\]

(1.B.5)

Where \( \phi^* = \frac{\delta q^*(1-r_{t+1}^*) - \tau^*_p (1+g)(1+n)}{(1+\delta q^*)(1+r^p)} \)

(1.B.6)
The steady state ratio of capital to output \( \left( \frac{K}{Y} \right) \) is:

\[
\left( \frac{K}{Y} \right) = k^{1-\alpha}
\]

(1.B.7)

The steady state interest rate \( r^* \), the annual interest rate \( \bar{r}_{pg} \) and \( w^* \) are:

\[
r^* = \alpha k^{\alpha - 1}, \quad \bar{r}_{pg} = \sqrt[1+r^*]{1} - 1
\]

(1.B.8)

\[
w^* = (1-\alpha)k^{\alpha}
\]

(1.B.9)

2) Consumer Welfare Variables: \( c_{y,pg}, c_{o,pg}, U^*, REP^*, I^*, \) and \( IR^* \)

The steady state young-age consumption per unit of labor \( c_{y,pg}^* \) is:

\[
c_{y,pg}^* = \frac{(1+r_{pg}^*)(1-\tau_{pg})H^* w_{pg}^* + H^* w_{pg}^*(1+g) \left[ \tau_{pg} (1+n) + q^* \right]}{(1+q^* \beta + q^* \delta)}
\]

(1.B.10)

The steady state old age consumption per unit of labor \( c_{o,pg}^* \) is:

\[
c_{o,pg}^* = \frac{(1+c_{pg}^*)(1-\tau_{pg})H^* w_{pg}^* + H^* w_{pg}^*(1+g) \left[ \tau_{pg} (1+n) + q^* \right]}{(1+q^* \beta + q^* \delta) / \delta}
\]

(1.B.11)

The steady state lifetime utility \( U^* = \ln c_{y,pg}^* + \frac{q^*}{1+\rho} \left[ \ln c_{o,pg}^* + \beta \ln(1-lp^*) \right] \)

(1.B.12)

The steady state pension replacement ratio \( REP^* \) is:

\[
REP^* = \tau_{pg} (1+g) \left( \frac{1+n}{q} + lp^* \right)
\]

(1.B.13)

The steady state lifetime income \( I^* \) is:

\[
I^* = (1-\tau_{pg})H^* w^* + H^* w^* \left[ \frac{\tau_{pg} (1+n)(1+g)}{q^* (1+r_{pg})} + \frac{lp^*(1+g)}{1+r_{pg}^*} \right]
\]

(1.B.14)

The steady state present value of income redistribution \( IR^* \) is:

\[
IR^* = \frac{\tau_{pg} (1+g)}{1+r_{pg}^*} \left( \frac{1+n}{q^* + lp^*} - \tau_{pg} \right)
\]

(1.B.15)
APPENDIX 1.C: DETAILS OF CALCULATION OF $k_{t+1}$ AND $k^{*}_{pf}$

(Under the case of Partially Funded system and endogenous LFP of the elderly)

The agent’s lifetime utility maximization problem becomes:

$$\text{Maximizes } U = \ln c_{t,t} + \frac{q_{t}}{1 + \rho} \left[ \ln c_{o,t+1} + \beta \ln(1 - lp_{t+1}) \right]$$

s.t. \((1 + \tau_{c})c_{y,t} + \frac{(1+\tau_{c})c_{o,t+1}}{(1+r_{t+1})/q_{t}} = (1-\tau_{pf})H_{t}w_{t} + lp_{t+1}H_{t+1}w_{t+1} + \frac{\tau_{pf}H_{t+1}w_{t+1}(1+n)}{(1+r_{t+1})/q_{t}} = I_{t}\) (1.C.1)

We can set up a Lagrangian expression:

$$L = \ln c_{y,t} + \frac{q_{t}}{1 + \rho} \left[ \ln c_{o,t+1} + \beta \ln(1 - lp_{t+1}) \right] + \lambda \left( \frac{I_{t}}{1 + \tau_{c}} - c_{y,t} - \frac{q_{t}c_{o,t+1}}{1 + r_{t+1}} \right)$$

where $\lambda$ is a Lagrangian multiplier. From the first order conditions (FOCs), we can get:

$$\frac{\partial L}{\partial c_{y,t}} = \frac{1}{c_{y,t}} - \lambda = 0$$

$$\frac{\partial L}{\partial c_{o,t+1}} = \frac{q_{t}}{1 + \rho} - \left( \frac{q_{t}}{1 + r_{t+1}} \right)\lambda = 0$$

$$\frac{\partial L}{\partial lp_{t+1}} = \frac{-q_{t}\beta\delta}{1 - lp_{t+1}} + \lambda \left( \frac{H_{t+1}w_{t+1}q_{t}}{(1+r_{t+1})(1+\tau_{c})} \right) = 0$$

$$\frac{\partial L}{\partial \lambda} = (1-\tau_{pf})H_{t}w_{t} + \frac{lp_{t+1}H_{t+1}w_{t+1}}{(1+r_{t+1})/q_{t}} + \frac{H_{t+1}w_{t+1}(1+n)}{(1+r_{t+1})} - c_{y,t} - \frac{q_{t}c_{o,t+1}}{1 + r_{t+1}} = 0$$

From (1.C.2), we can get we can get $c_{y,t}$, $c_{o,t+1}$, $lp_{t+1}$, $s_{y,t}$:

$$c_{y,t} = \frac{1}{\lambda} = \frac{(1+r_{t+1})(1-\tau_{pf})H_{t}w_{t} + H_{t+1}w_{t+1}\left[ \tau_{pf}(1+n) + q_{t} \right]}{(1+r_{t+1})(1+q_{t}\beta\delta + q_{t}\delta)(1+\tau_{c})}$$

(1.C.3)

$$c_{o,t+1} = \frac{1+r_{t+1}}{1 + \rho} \frac{1}{\lambda} = \frac{(1+r_{t+1})(1-\tau_{pf})H_{t}w_{t} + H_{t+1}w_{t+1}\left[ \tau_{pf}(1+n) + q_{t} \right]}{(1+q_{t}\beta\delta + q_{t}\delta)(1+\tau_{c})/\delta}$$

(1.C.4)

$$lp_{t+1} = \frac{H_{t+1}w_{t+1}(1+q_{t}\delta) - H_{t}w_{t}\beta\delta(1+r_{t+1})(1-\tau_{pf}) - \beta\delta H_{t+1}w_{t+1}\tau_{pf}(1+n)}{H_{t+1}w_{t+1}(1+q_{t}\beta\delta + q_{t}\delta)}$$

(1.C.5)
Under Partially Funded economy, the real saving of the agent $s_{y,t}^\prime$ is the sum of pension savings and the individual account saving:

$$s_{y,t}^\prime = s_{y,t} + \tau_e (1 - \tau_{pf}) H_t w_t (1 - \tau_{pf}) - c_{y,t}^i - d_t \quad (1.7)$$

The new capital condition for the economy with transitional costs is:

$$K_{t+1} = s_{y,t}^\prime N_{y,t} = \phi_t H_t w_t N_{y,t} - D_{t+1} \quad (1.8)$$

The stock of government debts $D_t$ keeps constant since reform period $t$, i.e.

$$D_t = D_{t+1} = D_{t+2} = \cdots = D_{t+T} = TC_i = (\tau_{pg} - \tau_{pf}) H_t w_t N_{y,t}$$

The capital per unit of effective labor under Partially Funded system $k_{t+1}$ is:

$$k_{t+1} = \frac{\phi_t H_t w_t N_{y,t}}{L_{t+1}} - \frac{(\tau_{pg} - \tau_{pf}) H_t w_t N_{y,t}}{L_{t+1}} = \frac{\phi_t (1 - \alpha)(1 - \tau_e) k_{t+1}^Q}{(1 + n + q^* l p^*)(1 + g)} - \frac{(\tau_{pg} - \tau_{pf}) w_t}{(1 + n + q^* l p_{t+1}^*)(1 + g)} \quad (1.9)$$

So, the steady state capital per unit of effective labor under Partially Funded system $k_{pf}^*$ is:

$$k_{pf}^{**} = \frac{\phi \ast (1 - \alpha)}{(1 + n + q^* l p^*)(1 + g)} - \frac{(\tau_{pg} - \tau_{pf}) (1 - \alpha) k_{pf}^{**}}{(1 + n + q^* l p^*)(1 + g)^2}$$

Where:

$$\phi \ast = \frac{(1 + r^\ast) (q^* \beta \delta + q^* \delta)(1 - \tau_{pf}) - (1 + g) \left[ \tau_{pg} (1 + n + q^*) \right]}{(1 + q^* \beta \delta + q^* \delta)}$$

$$l p^\ast = \frac{(1 + q^* \delta) - \beta \delta (1 + r^\ast)(1 - \tau_{pf})/(1 + g) - \beta \delta \tau_{pf} (1 + n)}{(1 + q^* \beta \delta + q^* \delta)}$$

$$r^\ast = \alpha k_{pf}^{**} - 1$$
APPENDIX 1.D: DETAILS of CALCULATION of STEADY STATE VARIABLES

(Under the case of Partial Funded system and endogenous LFP of the elderly)

3) Macroeconomic Variables: $k^*_{pf}$, $y^*_{pf}$, $(\frac{S}{Y})^*_{pf}$, $(\frac{K}{Y})^*_{pf}$, $r^*_{pf}$, and $w^*_{pf}$

The steady state capital per unit of effective labor under Partial Funded system $k^*_{pf}$ is:

$$k^*_{pf} = \frac{\phi^* (1 - \alpha)}{(1 + n + q^* lp^*) (1 + g)} - \frac{(\tau_{pg} - \tau_{pf})(1 - \alpha)k^*_{pf}}{(1 + n + q^* lp^*)^2 (1 + g)^2 k^*_{pf}} \tag{1.D.1}$$

The steady state output per worker $y^*_{pf}$ is:

$$y^*_{pf} = H^* k^*_{pf} \alpha \tag{1.D.2}$$

The national saving rate $\frac{S}{Y}$ is:

$$\frac{S}{Y} = \frac{s_{t}^'* N_{t-1} - s_{t}^'* N_{t-1}}{L_t k^*_{t}} \tag{1.D.3}$$

$$= \frac{(1 - \alpha) \left[ \phi_t - \frac{\phi_{t-1} \left( k_t \over k_{t-1} \right)^{\alpha}}{(1 + n) (1 + g)} \right]}{1 + \frac{q_{t-1}}{1 + n} lp_t}$$

Where $\phi_t$ is the share of saving of wage income for working-age adults:

$$\phi_t = \frac{s_{t}^'*}{w_t H_t} \frac{(1 + r_{t}) (q_{t} \beta^* + q_{t} \delta) (1 - \tau_{pf}) - (1 + g) \left( k_{t-1} \over k_t \right)^{\alpha} \tau_{pf} (1 + n) + q_{t}}{(1 + r_{t})(1 + q_{t} \beta^* + q_{t} \delta)} \tag{1.D.4}$$

So, the steady state national saving rate $(\frac{S}{Y})^*_{pf}$ is:

$$\left( \frac{S}{Y} \right)^*_{pf} = \frac{(1 - \alpha) \phi^* \left[ 1 - \frac{1}{(1 + n)(1 + g)} \right]}{1 + \frac{q^*}{1 + n} lp^*} \tag{1.D.5}$$
The steady state ratio of capital to output \( \left( \frac{K}{Y} \right)_t^* \) is:

\[
\left( \frac{K}{Y} \right)_t^* = k_t^* 1 - \alpha
\]  

(1.D.7)

The steady state interest rate \( r_t^* \), the annual interest rate \( r_t \) and wage rate \( w_t^* \) are:

\[
r_t^* = \alpha k_t^* 1 - \alpha
\]  

(1.D.8)

\[
\bar{r} = \frac{\sqrt{3 \alpha}}{1 + \bar{r}} - 1
\]

\[
w_t^* = (1 - \alpha) k_t^* 1 - \alpha
\]  

(1.D.9)

4) Consumer Welfare Variables: \( c_{y, pf}^* \), \( c_{o, pf}^* \), \( U_{pf}^* \), \( REP_{pf}^* \), \( I_{pf}^* \), and \( IR_{pf}^* \)

The steady state young-age consumption per unit of labor \( c_{y, pf}^* \) is:

\[
c_{y, pf}^* = \frac{(1 + r^*)(1 - \tau^*_{pf}) H * w^* + H * w^* (1 + g) \left[ \tau_{pf} (1 + n) + q^* \right]}{(1 + r^*)(1 + q^* \beta \delta + q^* \delta)(1 + \tau^*)}
\]  

(1.D.10)

The steady state old age consumption per unit of labor \( c_{o, pf}^* \) is:

\[
c_{o, pf}^* = \frac{(1 + r^*)(1 - \tau^*_{pf}) H * w^* + H * w^* (1 + g) \left[ \tau_{pf} (1 + n) + q^* \right]}{(1 + q^* \beta \delta + q^* \delta)(1 + \tau^*)}
\]  

(1.D.11)

The steady state lifetime utility \( U_{pf}^* = \ln c_{y, pf}^* + \frac{q^*}{1 + \rho} \ln c_{o, pf}^* \).

The steady state pension replacement ratio \( REP_{pf}^* \) is:

\[
REP_{pf}^* = \tau_{pf} (1 + g) \left( \frac{1 + n}{q} + lp^* \right) + \left( \frac{1 + r^*}{q} \right) \tau_{i} (1 - \tau_{pf})
\]  

(1.D.12)
The steady state lifetime income $I_{pf}^*$ is:

$$I_{pf}^* = (1 - \tau_{pf})H^* w^* + H^* w^* \left[ \tau_{pf} \frac{(1+n)(1+g)}{q^*(1+r^*)} + \frac{lp^*(1+g)}{1+r^*} \right]$$  (1.D.13)

The steady state present value of income redistribution $IR_{pf}^*$ is:

$$IR_{pf}^* = \frac{\tau_c(1-\tau_{pf})}{q^*} + \frac{\tau_{pf}(1+g)}{1+r^*} - \frac{n}{q^*} + \frac{l_p^*}{q^*} - \tau_c(1-\tau_{pf}) - \tau_{pf}$$  (1.D.14)

5) Transitional Variables: $tc_t$, $\frac{TC_t}{Y_t}$, and $\tau_c$

$$tc_t = \frac{TC_t}{L_t} = (\tau_{pg} - \tau_{pf})w_{pg}^*$$  (1.D.15)

$$\frac{TC_t}{Y_t} = \frac{(\tau_{pg} - \tau_{pf})H_t w_t N_{t,j}}{Y_{pg}^*} = \frac{(\tau_{pg} - \tau_{pf})w_{pg}^*}{Y_{pg}^*}$$  (1.D.16)

The steady state special consumption tax rate $\tau_c^*$ is:

$$\tau_c^* = \frac{(\tau_{pg} - \tau_{pf})H^* w_{pg}^*}{c_{y}^* + c_{q}^* q^*/(1+n)}$$  (1.D.17)
APPENDIX 1.E: DETAILS OF CALCULATION OF PARAMETER VALUE SELECTION

(Under the case of Endogenous LFP of the elderly)

In reality, China begun the pension reform from PAYG to partial funding since the middle 1990s, yet in this paper, for simplicity, we assume the pension reform begun since 2000 and PAYG economy reached steady state in 2000. Thereof, since the People’s Republic of China founded in 1949, China’s pension system history includes three stages. From 1950 to 2000, the pension system in China is PAYG system; the transition period from PAYG to Partially Funded system is from 2000 to 2030; after 2030, the pension system will be Partially Funded system.

We divide the nine model parameters $q^*$, $\alpha$, $\tau_{pg}$, $\tau_{pf}$, $\delta$, $n$, $g$, $H^\beta$, $\beta$ into three categories.

4) Population Factors: $n$ and $q^*$

$n$ is the working-age population growth rate for a period lasting 30 years, which we assume a constant in our model. In the next 50 years, China will be in the rapid aging process. According to population data from UN\(^1\), the ratio of working population aged 15-64 in China is estimated to be 72% in 2010, 69.8% in 2020, 66.5% in 2030, 62.2% in 2040, and 61% in 2050. Given the great change in China’s population structure, in order to calculate $n$ as exactly as possible, we separately calculate the working-age population growth rates from 1990 to 2020 and from 2020 to 2050 by using UN population data, then calculate the average of the two periods’ working-age population growth rates, which is $n$. From 1990 to 2020, the working-age population increases from 767.981 million to 991.903 million with an average rate 0.292. From 2020 to 2050, the working-age population decreases from 991.903 million to 859.778 million with a negative average growth rate -0.133. Thus, $n=0.08$.

q* is the steady state adult survival rate. We define adult survival rate q_t as the probability of living at the working-age period (from 25 to 54 years old) and survival to the old age period (from 55 to 84 years old), that is, \( q_t = \frac{\sum_{a=55}^{85} N_{a,t+1}}{\sum_{a=25}^{54} N_{a,t}} \), where \( N_{a,t} \) is the population aged a at period t.

As UN population dataset on China only covers from 1950 to 2050, we can only calculate three periods adult survival rates: \( q_1, q_2, q_3 \). They are 0.605, 0.746, and 0.759 respectively. The increase in survival rate is high from 1960 to 2020 and becomes much lower from 2020-2050. Thereafter, it is expected the growth will become even flatter.

\( q^* \) is the steady state adult survival rate. It may take several periods or more for the economy after pension reform to reach the steady state. As there is no sufficient data to calculate \( q^* \), we assume \( q^* = 0.8 \) based on the trend of \( q_t \).

5) Economic and Technological Factors: \( \alpha, g, \) and \( H^f \)

\( \alpha \) is output elasticity with respect to capital. It is difficult to estimate this parameter due to both rapid change of China’s economic structure and insufficient and inaccurate data. Economists use different methods and different data sources, and thus get different estimates for \( \alpha \). For example, a study by OECD (2005)\(^2\) calculates \( \alpha = 0.53 \) during 1978-2003. Cai and Wang (2002) uses FGLS regression method to get an estimated value 0.45 for \( \alpha \) using China’s time-series data during 1978-1998. Here following Cai and Wang (2002), we assume \( \alpha = 0.4 \).

\( g \) is technological improvement growth during a period. We use Total Factor Productivity (TFP) as an index of technological improvement, thus use the growth of TFP as a proxy for \( g \). Same as the case of \( \alpha \), different research has different estimates for \( g \). Based on a country case

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\(^1\) period 1 means 1960-1990, period 2 means 1990-2020, period 3 means 2020-2050
study of China by UNIDO (2005)\(^1\) that estimates the annual growth rate of China’s TFP after China started its reform and opening-up policy (1979-2000) is 1%, we assume annual growth rate of technological improvement equal to 1%, thus technological improvement growth during a period (30 years) \(g\) is 0.348.

\(\bar{H}\) is the steady state stock of human capital. \(\bar{H}\) can affects values for welfare and income variables such as \(c^*_y, c^*_o, U^*, I^*\). Here we assume \(\bar{H}\) is 100 with an indirect reason that the values for the affected variables are positive.

6) Other Parameters: \(\tau_{pf}, \tau_i, \tau_{pg}, \delta, \rho\)

\(\tau_{pf}\) is Partially Funded system social security contribution rate. \(\tau_i\) is Partially Funded system individual account contribution rate. According to the regulations of China’s new partially funded pension system, \(\tau_{pf}=0.2\) and \(\tau_i=0.08\). \(\tau_{pg}\) is PAYG system contribution rate. Under China’s traditional PAYG system, there is no unified regulation on it. For simplicity, we can assume the contribution rates under two pension systems are same, that is, \(\tau_{pg}=\tau_i(1-\tau_{pf})+\tau_{pf}=0.264\).

\(\delta\) is the discount rate and \(\rho\) is the pure rate of time preference during a period. We set the pure rate of time preference per year equal to 1.5%, the same level used in the original Auerbach-Kotlikoff Model. Thus, \(\rho=(1+0.015)^{30}-1=0.56\) and \(\delta=0.64\).

\(\beta\) is agent’s preference for leisure. There is no special reason for the value of \(\beta\), yet a high value for \(\beta\) can lead to \(lp\leq0\). That is, there is no optimal interior solution for our Model. Thus, we set a medium value of 0.6 for \(\beta\).

APPENDIX 1.F: DETAILS of CALCULATION of $k^*$ and OTHER VARIABLES
(Under the case of PAYG system and exogenous LFP of the elderly)

The agent’s utility maximization problem is:

\[
\text{Maximizes } U = U(c_{y,t}, c_{o,t+1}) = \ln c_{y,t} + \frac{q_t}{1 + \rho} \ln c_{o,t+1}
\]

s.t. \[ c_{y,t} + \frac{c_{o,t+1}}{1 + r_{t+1}} = (1 - \tau_{pg} H_t w_t^c + \frac{\tau_{pg} H_t w_t^c (1 + n)}{1 + r_{t+1}}) I_t \] (1.F.1)

We can set up a Lagrangian expression:

\[
L = \ln c_{y,t} + \frac{q_t}{1 + \rho} \ln c_{o,t+1} + \lambda (I_t - c_{y,t} - \frac{q_c c_{o,t+1}}{1 + r_{t+1}})
\]

where $\lambda$ is a Lagrangian multiplier. From the first order conditions (FOC), we can get:

\[
\begin{align*}
\frac{\partial L}{\partial c_{y,t}} &= \frac{1}{c_{y,t}} - \lambda = 0 \\
\frac{\partial L}{\partial c_{o,t+1}} &= \frac{q_t}{1 + \rho c_{o,t+1}} - \left(\frac{q_t}{1 + r_{t+1}}\right) \lambda = 0 \\
\frac{\partial L}{\partial \lambda} &= (1 - \tau_{pg} H_t w_t^c + \frac{\tau_{pg} H_t w_t^c (1 + n)}{1 + r_{t+1}}) - c_{y,t} - \frac{q_t c_{o,t+1}}{1 + r_{t+1}} = 0
\end{align*}
\]

From (1.F.3), we can get the agent’s consumption during working age $c_{y,t}$ and consumption during old age $c_{o,t+1}$:

\[
\begin{align*}
c_{y,t} &= \frac{1 + \rho}{\lambda} \left[ (1 - \tau_{pg} H_t w_t^c + \frac{\tau_{pg} H_t w_t^c (1 + n)}{1 + r_{t+1}}) \right] \\
c_{o,t+1} &= \frac{1 + r_{t+1}}{1 + \rho + q_t} \left[ (1 - \tau_{pg} H_t w_t^c + \frac{\tau_{pg} H_t w_t^c (1 + n)}{1 + r_{t+1}}) \right]
\end{align*}
\]

(1.F.4)

(1.F.5)

Saving of working-age $s_{y,t}$ is:
\[
S_{o,t} = \frac{(1 + r_{st}) - (1 + \rho)r_{pg}w_{st}((1 + n)(1 + g))}{1 + r_{st}(1 + \rho + q)}
\] 

(1.F.6)

During the working period, the agent saves and accumulates assets. After retirement, he has no other income but the capital income from the accumulated assets to smooth his consumption. Because there is no bequest motive, he will deplete all his assets at the end of the old age period. Thus, the elderly saving \( S_{o,t} \) is:

\[
S_{o,t} = \frac{(1 + r_{st}) - (1 + r_{st})s_{y,t-1} - c_{o,t} = \frac{(1 + r_{st}) - (1 + r_{st})s_{y,t-1}}{1 + r_{st}} - \frac{1 + r_{st}1}{q} s_{y,t-1} = -s_{y,t-1}}{1 + r_{st}(1 + \rho + q)}
\] 

(1.F.7)

The capital condition for the economy is:

\[
K_{t+1} = s_{y,t}N_{y,t}
\] 

(1.F.8)

From (1.F.8), the capital per unit of effective labor \( k_{t+1} \) is:

\[
k_{t+1} = \frac{N_{y,t}}{L_{t+1}} = \frac{s_{y,t}}{H_{t+1}(1 + n)}
\] 

(1.F.9)

\[
q_{t}(1 - \alpha)k_{t}^{\alpha}(1 - \tau_{pg}) - \frac{(1 + \rho)\tau_{pg}(1 - \alpha)k_{t+1}^{\alpha}(1 + n)(1 + g)}{1 + \alpha k_{t}^{\alpha} - 1}
\]

\[
= \frac{(1 + \rho + q_{t})(1 + n)(1 + g)}{(1 + \rho + q_{t})(1 + n)(1 + g)}
\]

(1.F.9) is the equation describing the evolution of capital per unit of effective labor from period \( t \) to period \( t+1 \) under Partially Funded economy.

From \( r_{t} = \alpha k_{t}^{\alpha} - 1 \), \( w_{t} = (1 - \alpha)k_{t}^{\alpha} \)

\[
q_{t}(1 - \alpha)k_{t}^{\alpha}(1 - \tau_{pg}) - \frac{(1 + \rho)\tau_{pg}(1 - \alpha)k_{t+1}^{\alpha}(1 + n)(1 + g)}{1 + \alpha k_{t}^{\alpha} - 1}
\]

\[
\rightarrow k_{t+1} = \frac{(1 + \rho + q_{t})(1 + n)(1 + g)}{(1 + \rho + q_{t})(1 + n)(1 + g)}
\] 

(1.F.10)

At steady state, the capital per unit of effective labor at PAYG system \( k_{pg}^{*} \) is

\[
k_{pg}^{*} = \frac{q^{*}(1 - \alpha)(1 - \tau_{pg})(1 + \alpha k_{pg}^{* - 1}) - (1 + \rho)\tau_{pg}(1 - \alpha)(1 + n)(1 + g)}{(1 + \rho + q^{*})(1 + n)(1 + g)(1 + \alpha k_{pg}^{* - 1})}
\] 

(1.F.11)
We continue to get algebraic expression for other economic variables at steady state.

1) Macroeconomic Variables: \( \frac{K^*}{Y^*}, \frac{Y^*}{Y^*}, \frac{(S^*)}{Y^*}, \frac{(K^*)}{Y^*}, r^*, \) and \( w^* \)

The steady state output per worker \( \frac{Y^*}{p_y} \) is:

\[
y^* = H \cdot \frac{k^*}{p_k} \alpha
\]

(1.F.12)

The total savings in the economy \( S_t \) are the sum of the working population saving \( S_{y,t} \) and retired population saving \( S_{o,t} \).

\[
S_t = S_{y,t} + S_{o,t} = s_{y,t}N_{y,t} - s_{y,t-1}N_{y,t-1}
\]

The national saving rate \( \frac{S_t}{Y_t} \) is:

\[
\frac{S_t}{Y_t} = s_{y,t}N_{y,t} - s_{y,t-1}N_{y,t-1} \left[ \frac{\phi_t \left( \frac{k_t}{k_{t-1}} \right)^{\alpha}}{(1 + n)(1 + g)} \right]
\]

(1.F.13)

Where \( \phi_t \) is the share of saving of wage income for working-age adults:

\[
\phi_t = \frac{s_{y,t}}{w_t} = (1 - \tau_{pg}) \frac{q_t}{1 + \rho + q_t} - \frac{1 + \rho}{1 + \rho + q_t} \frac{\tau_{pg}(1 + g)w_{t+1}(1 + n)}{(1 + r_{t+1})w_t}
\]

(1.F.14)

So, the steady state national saving rate \( \frac{(S^*)}{Y^*} \) is:

\[
\frac{(S^*)}{Y^*} = (1 - \alpha) \left[ \phi^* - \frac{\phi^*}{(1 + n)(1 + g)} \right]
\]

(1.F.15)

\[
\phi^* = (1 - \tau_{pg}) \frac{q^*}{1 + \rho + q^*} - \frac{1 + \rho}{1 + \rho + q^*} \frac{\tau_{pg}(1 + g)(1 + n)}{(1 + r^*)}
\]

(1.F.16)

The steady state ratio of capital to output \( \frac{(K^*)}{Y^*} \) is:
\[
\left( \frac{K}{Y} \right)_{\ast} = \frac{k_{\ast}}{y} = k_{\ast}^{1-u}
\]

(1.F.17)

From \( r_t = \alpha k_t^{\alpha - 1} \), the steady state interest rate \( r_{pg}^{\ast} \) is:

\[
r_{pg}^{\ast} = \alpha k_{pg}^{\alpha - 1}
\]

(1.F.18)

In addition, \( r_{pg}^{\ast} \) is the interest rate for a period, which we assume lasts 30 years, so the annual interest rate \( \overline{r}_{pg} = \sqrt[30]{1 + r_{pg}^{\ast}} - 1 \)

From \( w_t = (1 - \alpha) k_t^{\alpha} \), the steady state wage rate \( w_{pg}^{\ast} \) is:

\[
w_{pg}^{\ast} = (1 - \alpha) k_{pg}^{\alpha - u}
\]

(1.F.19)

2) Consumer Welfare Variables: \( c_{y,pg}^{\ast} \), \( c_{o,pg}^{\ast} \), \( U_{pg}^{\ast} \) \( R_{pg}^{\ast} \), \( I_{pg}^{\ast} \), and \( IR_{pg}^{\ast} \)

From \( c_{y,t} = \frac{1 + \rho}{1 + \rho + q_t} \left[ (1 - \tau_{pg}) H_t w_t + \frac{\tau_{pg} H_{t+1} w_{t+1} (1+n)}{1 + r_{pg}} \right] \), so the steady state young-age consumption per unit of labor \( c_{y,pg}^{\ast} \) is:

\[
c_{y,pg}^{\ast} = \frac{(1 + \rho) H^{\ast} w_{pg}^{\ast}}{1 + \rho + q^{\ast}} \left[ (1 - \tau_{pg}) + \frac{\tau_{pg} (1+n)(1+g)}{1 + r_{pg}} \right]
\]

(1.F.20)

From \( c_{o,t+1} = \frac{1 + r_{pg}}{1 + \rho + q_t} \left[ (1 - \tau_{pg}) H_{t+1} w_{t+1} + \frac{\tau_{pg} H_{t+2} w_{t+2} (1+n)}{1 + r_{pg}} \right] \), so the steady state old age consumption per unit of labor \( c_{o,pg}^{\ast} \) is:

\[
c_{o,pg}^{\ast} = \frac{(1 + r_{pg}) H^{\ast} w_{pg}^{\ast}}{1 + \rho + q^{\ast}} \left[ (1 - \tau_{pg}) + \frac{\tau_{pg} (1+n)(1+g)}{1 + r_{pg}} \right]
\]

(1.F.21)

From \( U = \ln c_{pg}^{\ast} + \frac{q}{1 + \rho} \ln c_{o,pg}^{\ast} \), the steady state lifetime utility is \( U_{pg}^{\ast} = \ln c_{y,pg}^{\ast} + \frac{q^{\ast}}{1 + \rho} \ln c_{o,pg}^{\ast} \).
The pension replacement ratio $\text{REP}_{pg}$ is the ratio of the pension received after retirement to the wage income before retirement, often considered as the index of pension benefits level.

$$\text{REP}_{pg} = \frac{\tau_{pg} H_{t+1} w_{t+1}(1 + n)}{H_{t} w_{t} q_{t}} = \frac{\tau_{pg}(1 + g)(1 + n)w_{t+1}}{w_{t} q_{t}},$$

so the steady state pension replacement ratio $\text{REP}_{pg}^*$ is:

$$\text{REP}_{pg}^* = \frac{\tau_{pg}(1 + g)(1 + n)}{q^{*}},$$  \hspace{1cm} (1.F.22)

The agent’s lifetime income $I_{pg}$ is the present value of the total income throughout his whole life. In our model, $I_{pg}$ is equal to the sum of working-age wage income and the present value of old age pension, that is $I_{pg} = (1 - 
\tau_{pg}) H_{t} w_{t} + \frac{(1 + n) \tau_{pg} H_{t+1} w_{t+1}}{q_{t}(1 + r_{n+1})}$. The steady state lifetime income $I_{pg}^*$ is:

$$I_{pg}^* = (1 - \tau_{pg}) H * w * + H * w * \frac{\tau_{pg}(1 + n)(1 + g)}{q^{*}(1 + r^{*})},$$  \hspace{1cm} (1.F.23)

The present value of income redistribution $\text{IR}_{pg}$ is defined as the ratio of the present value of agent’s net pension income during the lifetime to the wage income during working-age, a variable measuring the intergenerational or intragenerational income redistribution effect of PAYG system. By definition, $\text{IR}_{pg} = \frac{(1 + n) \tau_{pg} H_{t+1} w_{t+1} - \tau_{pg} H_{t} w_{t}}{q_{t}(1 + r_{n+1})}$. If $\text{IR}_{pg} > 0$, it means the current generation gets the intergenerational transfers from the next generation; if $\text{IR}_{pg} < 0$, the current generation gives the intergenerational transfers to the next generation. The more $\text{IR}_{pg}$ is, the bigger the extent of intergenerational transfers is.

The steady state present value of income redistribution $\text{IR}_{pg}^*$ is:

$$\text{IR}_{pg}^* = \frac{\tau_{pg} \cdot ((1 + n)(1 + g) - q^{*}(1 + r^{*}))}{q^{*}(1 + r^{*})},$$  \hspace{1cm} (1.F.24)

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APPENDIX 1.G: DETAILS of CALCULATION of $k_{pf}$ and OTHER VARIABLES

(Under the case of Partial-Funded system and exogenous LFP of the elderly)

The agent’s utility maximization problem is:

$$
\max_{c_{y,t}, c_{o,t+1}} U = U(c_{y,t}, c_{o,t+1}) = \ln c_{y,t} + \frac{q_t}{1 + \rho} \ln c_{o,t+1} \\
\text{s.t.} \quad (1 + \tau_c) c_{y,t} + \frac{(1 + \tau_c) q_t c_{o,t+1}}{1 + r_{t+1}} = (1 - \tau_{pf}) H_t w_t + \frac{\tau_{pf} H_{t+1} w_{t+1} (1 + n)}{1 + r_{t+1}} = I
$$

(1.G.1)

We can set up a Lagrangian expression:

$$
L = \ln c_{y,t} + \frac{q_t}{1 + \rho} \ln c_{o,t+1} + \lambda \left( \frac{I_t}{1 + \tau_c} - c_{y,t} - \frac{q_t c_{o,t+1}}{1 + r_{t+1}} \right)
$$

where $\lambda$ is a Lagrangian multiplier. From the first order conditions (FOC), we can get:

$$
\frac{\partial L}{\partial c_{y,t}} = \frac{1}{c_{y,t}} - \lambda = 0 \\
\frac{\partial L}{\partial c_{o,t+1}} = \frac{q_t}{1 + \rho} \frac{1}{c_{o,t+1}} - \left( \frac{q_t}{1 + r_{t+1}} \right) \lambda = 0 \\
\frac{\partial L}{\partial \lambda} = (1 - \tau_{pf}) H_t w_t + \frac{\tau_{pf} H_{t+1} w_{t+1} (1 + n)}{1 + r_{t+1}} - \frac{q_t c_{o,t+1}}{1 + r_{t+1}} = 0
$$

From (1.G.2), we can get the agent’s consumption $c_{y,t}$ and $c_{o,t+1}$:

$$
c_{y,t} = \frac{H_t w_t (1 - \tau_{pf}) + \tau_{pf} H_{t+1} w_{t+1} (1 + n)}{(1 + \delta q_t)(1 + \tau_c)}
$$

(1.G.2)

$$
c_{o,t+1} = \frac{1 + r_{t+1}}{1 + \rho} \frac{1}{\lambda} = \delta (1 + r_{t+1}) c_{y,t}
$$

(1.G.3)

The agent’s saving of working-age $s_{y,t}$ is:

$$
s_{y,t} = (1 - \tau_c) (1 - \tau_{pf}) H_t w_t - c_{y,t} \\
= \frac{(1 - \tau_{pf}) H_t w_t (1 + r_{t+1}) \left[ (\delta q_t - (1 + \delta q_t) \tau_c) - \tau_{pf} H_{t+1} w_{t+1} (1 + n) \right]}{(1 + \delta q_t)(1 + r_{t+1})}
$$

(1.G.4)
Under Partially Funded economy, not only the agent’s pension saving but also the individual account saving is accumulated as capital through the financial system. So, the real saving of the agent $s'_{y,t}$ is the sum of pension savings and the individual account saving:

$$s'_{y,t} = s_{y,t} + \tau_l(1 - \tau_{pf})H_tw_t = \frac{\delta q_t(1 - \tau_{pf})H_tw_t(1 + r_{t+1}) - \tau_{pf}H_{t+1}w_{t+1}(1 + n)}{(1 + \delta q_t)(1 + r_{t+1})} \tag{1.G.5}$$

As the government has debts caused by issuing special treasury bonds, the new capital condition for the economy is:

$$K_{t+1} = s'_{y,t}N_{y,t} - D_{t+1} \tag{1.G.6}$$

$$k_{t+1} = \frac{s'_{y,t}}{H_tw_t(1 + n)} - \frac{(\tau_{pg} - \tau_{pf})H_tw_tN_{y,t}}{L_{y,t}} \tag{1.G.7}$$

$$= \frac{\delta q_t(1 - \tau_{pf})(1 - \alpha)k_{t+1}^\alpha}{(1 + \delta q_t)(1 + n)(1 + g)} - \frac{\tau_{pf}(1 - \alpha)k_{t+1}^\alpha}{(1 + \alpha k_{t+1}^\alpha - 1)} - \frac{(\tau_{pg} - \tau_{pf})w_t}{(1 + n)(1 + g)}$$

The steady state capital per unit of effective labor $k_{pf}^*$ is:

$$k_{pf}^{* - \alpha} = \frac{(1 - \alpha)}{(1 + \delta q_t)} \left[ \frac{\delta q^*_t (1 - \tau_{pf})}{(1 + n)(1 + g)} - \frac{\tau_{pf}^* (1 - \tau^*_p)}{1 + \alpha k_{pf}^{* - \alpha} - 1} \right] - \frac{(1 - \alpha)(\tau_{pg}^* - \tau_{pf}^*)k_{pf}^{* - \alpha}}{(1 + n)(1 + g)k_{pf}^{* - \alpha}} \tag{1.G.8}$$

We continue to derive algebraic expression for other economic variables at steady state

6) Macroeconomic Variables: $k_{pf}^*$, $y_{pg}^*$, $\left(\frac{S}{Y_{pf}}\right)_t^*$, $\left(\frac{K}{Y_{pf}}\right)_t^*$, $r_{pf}^*$, and $w_{pf}^*$

From (1.53), the steady state capital per unit of effective labor $k_{pf}^*$ is:

$$k_{pf}^{* - \alpha} = \frac{(1 - \alpha)}{(1 + \delta q_t)} \left[ \frac{\delta q^*_t (1 - \tau_{pf})(1 - \tau^*_p)}{(1 + n)(1 + g)} - \frac{\tau_{pf}^* (1 - \tau^*_p)}{1 + \alpha (1 - \tau^*_p)k_{pf}^{* - \alpha} - 1} \right] - \frac{(1 - \alpha)(\tau_{pg}^* - \tau_{pf}^*)k_{pf}^{* - \alpha}}{(1 + n)(1 + g)k_{pf}^{* - \alpha}} \tag{1.G.9}$$

The steady state output per worker $y_{pg}^*$ is:

$$y_{pg}^* = H^* k_{pf}^* \alpha \tag{1.G.10}$$
The national saving rate $\frac{S_t}{Y_t}$ is:

$$S_t = \frac{s_{t,t}N_{y,t} - s_{t,t-1}N_{y,t-1}}{L_t k_t^\alpha} = (1 - \alpha) \left[ \phi_t - \frac{\phi_{t-1} \left( \frac{k_t}{k_{t-1}} \right)^{\alpha}}{(1 + n)(1 + g)} \right]$$  \hspace{1cm} (1.G.11)

Where $\phi_t$ is the share of saving of wage income for working-age adults:

$$\phi_t = \frac{s_{t,t}N_{y,t}}{\omega_t H_t} = \frac{\delta q_t (1 - r_{pf})}{1 + \delta q_t} - \frac{r_{pf} w_{t,i} (1 + n)(1 + g)}{(1 + \delta q_t)(1 + r_{t,i})w_t}$$  \hspace{1cm} (1.G.12)

So, the steady state national saving rate $(\frac{S}{Y})^*$ is:

$$\left( \frac{S}{Y} \right)^* = (1 - \alpha) \left[ \phi^* - \frac{\phi^*}{(1 + n)(1 + g)} \right] = (1 - \alpha) \phi^* \left[ \frac{ng + n + g}{(1 + n)(1 + g)} \right]$$  \hspace{1cm} (1.G.13)

$$\phi^* = \frac{\delta q^* (1 - r_{pf})}{1 + \delta q^*} - \frac{r_{pf} (1 + g)(1 + n)}{(1 + \delta q^*)(1 + r^*)}$$  \hspace{1cm} (1.G.14)

The steady state ratio of capital to output $(\frac{K}{Y})^*$ is:

$$\left( \frac{K}{Y} \right)^* = k^* \left[ 1 - \alpha \right]$$  \hspace{1cm} (1.G.15)

The steady state interest rate $r_{pf}^*$ and the annual interest rate $\bar{r}_{pf}$ is:

$$r_{pf}^* = \alpha k_{pf}^* \alpha - 1$$  \hspace{1cm} (1.G.16)

$$\bar{r}_{pf} = \frac{\delta}{\sqrt{1 + r_{pf}}} - 1$$

The steady state wage rate $w_{pf}^*$ is:

$$w_{pf}^* = (1 - \alpha)(1 - r^*) k_{pf}^*$$  \hspace{1cm} (1.G.17)

7) Consumer Welfare Variables: $c_{y,pf}^*$, $c_{o,pf}^*$, $U^*, RE^B_{pf}$, $I_{pf}^*$, and $IR_{pf}^*$
The steady state young-age consumption per unit of labor $c_{y,pf}^*$ is:

$$c_{y,pf}^* = \frac{H^* w_{pf}^*}{1 + \delta q^*} \left[ (1 - \tau_{pf}^*) + \frac{\tau_{pf}^* (1 + g)(1 + n)}{1 + r_{pf}^*} \right]$$

(1.G.18)

The steady state old age consumption per unit of labor $c_{o,pf}^*$ is:

$$c_{o,pf}^* = \frac{\delta(1 + r_{pf}^*)H^* w_{pf}^*}{1 + \delta q^*} \left[ (1 - \tau_{pf}^*) + \frac{\tau_{pf}^* (1 + n)(1 + g)}{1 + r_{pf}^*} \right]$$

(1.G.19)

The steady state lifetime utility $U_{pf}^* = \ln c_{y,pf}^* + \frac{q^*}{1 + \rho} \ln c_{o,pf}^*$. 

The steady state pension replacement ratio $REP_{pf}^*$ is:

$$REP_{pf}^* = \frac{1 + r_{pf}^*}{q^*} \tau_i (1 - \tau_{pf}^*) + \frac{\tau_{pf}^* (1 + g)(1 + n)}{q^*}$$

(1.G.20)

The steady state lifetime income $I_{pf}^*$ is:

$$I_{pf}^* = H^* w_{pf}^* \left[ (1 - \tau_{pf}^*) (1 - \tau_i) + \frac{\tau_i (1 - \tau_{pf}^*)}{q^*} \tau_{pf}^* (1 + g)(1 + n) \right]$$

(1.G.21)

The present value of income redistribution $IR_{pf}$ is the ratio of the present value of agent’s net pension income during the lifetime to the wage income during working-age.

$$IR_{pf} = \frac{\tau_i (1 - \tau_{pf}^*) (1 + r_{s+1}) H_i w_i + \tau_{pf}^* H_{s+1} w_{s+1} (1 + n)}{q_i (1 + r_{s+1})} - \frac{\tau_i (1 - \tau_{pf}^*) H_i w_i - \tau_{pf}^* H_i w_i}{H_i w_i}$$

The steady state present value of income redistribution $IR_{pf}^*$ is:

$$IR_{pf}^* = \frac{\tau_i (1 - \tau_{pf}^*) (1 + r_{pf}^*) + \tau_{pf}^* (1 + n)(1 + g)}{q^* (1 + r_{pf}^*)} - \tau_i (1 - \tau_{pf}^*) - \tau_{pf}^*$$

(1.G.22)

8) Transitional Variables: $tc_y$, $TC_i$, and $\tau_c$
From APPENDIX D, we can get transitional variables:

\[ tc_i = \frac{TC_i}{L_i} = (\tau_{pg} - \tau_{pf})w_{pg}^* \]  \hspace{1cm} (1.G.23)

\[ \frac{TC_i}{Y_i} = \frac{(\tau_{pg} - \tau_{pf})H_iw_iN_{y,i}}{y_{pg}^*} = \frac{(\tau_{pg} - \tau_{pf})w_{pg}^*}{y_{pg}^*} \]  \hspace{1cm} (1.G.24)

The special consumption tax rate \( \tau_c \) is:

\[ \tau_c = \frac{TC_c}{c_{y,i}N_{y,i} + c_{o,i}N_{o,i}} = \frac{tc_iH_i}{c_{y,i} + c_{o,i}/(1+n)} \]  \hspace{1cm} (1.G.25)
APPENDIX 2.A: DETAILS OF CALCULATION OF $k_{t+1}$ AND $k^*_{pf}$

(Under the case of PF system, endogenous LFP of the elderly, heterogeneous agent)

The agent $i'$ ($i=1, 2$) lifetime utility maximization problem is:

$$\text{Maximizes } U' = U(c'_{y,t}, c'_{a,t+1}, l_{p,t}) = \ln c'_{y,t} + \frac{q_i}{1+\rho} \left[ \ln c'_{a,t+1} + \beta \ln(1-l_{p,t}) \right]$$

s.t. $$(1+\tau_{st})c'_{y,t} + \frac{q_i(1+\tau_{st})c'_{a,t+1}}{1+r_{st}} = H'_i w_i (1-\tau_{pf}) + \tau_{pf} H'_i w_i + \frac{(1+n)a}{1+r_{st}} - \frac{(1-\tau_{pf})H'_i w_{i+1}l_{p,t}}{(1+r_{st})/q_i} = I'_i$$

We can set up a Lagrangian expression:

$$L = \ln c'_{y,t} + \frac{q_i}{1+\rho} \left[ \ln c'_{a,t+1} + \beta \ln(1-l_{p,t}) \right] + \lambda_i \left( \frac{I'_i}{1+\tau_c} - c'_{y,t} - \frac{q_i c'_{a,t+1}}{1+r_{st}} \right)$$

where $\lambda_i$ is a Lagrangian multiplier. From the first order conditions (FOCs), we can get:

$$\frac{\partial L}{\partial c'_{y,t}} = \frac{1}{c'_{y,t}} - \lambda_i = 0$$
$$\frac{\partial L}{\partial c'_{a,t+1}} = \frac{1}{1+\rho} c'_{a,t+1} - \left( \frac{q_i}{1+r_{st}} \right) \lambda_i = 0$$
$$\frac{\partial L}{\partial l_{p,t}} = \frac{q_i\beta\delta}{1-l_{p,t}} + \lambda_i \frac{H'_i w_i q_i(1-\tau_{pf})}{(1+r_{st})(1+\tau_c)} = 0$$
$$\frac{\partial L}{\partial \lambda_i} = \left( (1-\tau_{pf})H'_i w_i + \frac{l_{p,t} H'_i w_{i+1}}{1+\rho} + \frac{H'_i w_i (1+n)}{(1+r_{st})/q_i} - (1+\tau_c)c'_{y,t} - \frac{q_i(1+\tau_c)c_{a,t+1}}{1+r_{st}} \right) = 0$$

From (2.A.2), we get $c'_{y,t}$, $c'_{a,t+1}$, $l_{p,t}$, $s_{y,t}$:

$$c'_{y,t} = \frac{1}{\lambda} \left( (1+r_{st})(1-\tau_{pf})H'_i w_i + H'_i w_{i+1} q_i (1-\tau_{pf}) + H'_i w_{i+1} \tau_{pf} (1+n)a \right)$$

$$c'_{a,t+1} = \frac{1+\tau_{st}}{1+\rho} \frac{1}{\lambda} \left( (1+r_{st})(1-\tau_{pf})H'_i w_i + H'_i w_{i+1} q_i (1-\tau_{pf}) + H'_i w_{i+1} \tau_{pf} (1+n)a \right)$$

$$l_{p,t} = \frac{\beta\delta (1+r_{st}) c'_{y,t}}{H'_i w_{i+1} (1-\tau_{pf})}$$

$$s_{y,t} = H'_i w_i (1-\tau_{pf}) - c'_{y,t} - d_t$$
Under Partially Funded economy, the real saving of the agent $s_{y,t}^i$ is the sum of pension savings and the individual account saving:

$$s_{y,t}^i = s_{y,t}^i + \tau_t (1 - \tau_{pf}) H_t w_t^i (1 - \tau_{pf}) - c_{y,t}^i - d_t$$  \hspace{1cm} (2.A.7)$$

The new capital condition for the economy with transitional costs is:

$$K_{t+1} = s_{y,t}^i N_{y,t} + s_{2,y,t}^i N_{y,t} = \phi_1 H_t^1 w_t^i N_{y,t} + \phi_2 H_t^2 w_t^i N_{y,t} - D_{t+1}$$  \hspace{1cm} (2.A.8)$$

The stock of government debts $D_t$ keeps constant since reform period $t$, i.e.

$$D_t = D_{t+1} = D_{t+2} = \cdots = D_{t+1} = D_{pf} = TC_t = D_t = (\tau_{pg} - \tau_{pf}) w^*_{pg} (H_{pg}^1 N_{pg}^1 + H_{pg}^2 N_{pg}^2)$$

The capital per unit of effective labor under Partially Funded system $k_{t+1}$ is

$$k_{t+1} = \frac{\phi_1^* H_t^1 w_t^i N_{y,t}^1 + \phi_2^* H_t^2 w_t^i N_{y,t}^2 - D_{t+1}}{L_{t+1}} = \frac{\phi_1^* \gamma \eta w_t^i + \phi_2^* \gamma \eta (1 - \gamma) (1 - \eta) w^*_{pf} a}{(1 + n)(1 + g)} - \frac{(\tau_{pg} - \tau_{pf}) w^*_{pf} a}{(1 + g)^{(1 + n)} (1 + g)}$$  \hspace{1cm} (2.A.9)$$

So, the steady state capital per unit of effective labor under Partially Funded system $k_{pf}^*$

$$k_{pf}^* = \frac{\phi_1^* \gamma \eta w_{pf}^* + \phi_2^* (1 - \gamma) (1 - \eta) w_{pf}^*}{(1 + n)(1 + g)} - \frac{(\tau_{pg} - \tau_{pf}) w_{pf}^* a}{(1 + g)^{(1 + n)} (1 + g)}$$

Where:

$$\phi_1^* = \frac{(1 + r^*)(q^* \beta \delta + q^* \delta)(1 - \tau_{pf}) - (1 + g)[\tau_{pf}(1 + n)a / \gamma + q^*(1 - \tau_{pf})]}{(1 + r^*)(1 + q^* \beta \delta + q^* \delta)}$$

$$\phi_2^* = \frac{(1 + r^*)(q^* \beta \delta + q^* \delta)(1 - \tau_{pf}) - (1 + g)[\tau_{pf}(1 + n)a / (1 - \gamma) + q^*(1 - \tau_{pf})]}{(1 + r^*)(1 + q^* \beta \delta + q^* \delta)}$$

$$b^* = (1 + \frac{q^* lp_{1,r}^*}{1 + n}) \gamma \eta + (1 + \frac{q^* lp_{2,r}^*}{1 + n})(1 - \gamma)(1 - \eta)$$

$$lp_{1,r}^* = 1 - \frac{\beta \delta (1 + r^*)}{(1 + g)(1 + q^* \beta \delta + q^* \delta)} - \frac{\beta \delta [\gamma q^* (1 - \tau_{pf}) + \tau_{pf}(1 + n)a]}{\gamma (1 - \tau_{pf})(1 + q^* \beta \delta + q^* \delta)}$$

$$lp_{2,r}^* = 1 - \frac{\beta \delta (1 + r^*)}{(1 + g)(1 + q^* \beta \delta + q^* \delta)} - \frac{\beta \delta [(1 - \gamma) q^* (1 - \tau_{pf}) + \tau_{pf}(1 + n)a]}{(1 - \gamma)(1 - \tau_{pf})(1 + q^* \beta \delta + q^* \delta)}$$

$$r^* = \alpha k_{pf}^* a - 1, w_{pf}^* = (1 - \alpha) k_{pf}^* a$$
APPENDIX 2.B: DETAILS of CALCULATION of STEADY STATE VARIABLES

(Under the case of PF system, endogenous LFP of the elderly, heterogeneous agent)

1) Macroeconomic Variables: $k_{pf}^*$, $y_{pf}^*$, $(\frac{S}{Y})_{pf}^*$, $(\frac{K}{Y})_{pf}^*$, $r_{pf}^*$, and $w_{pf}^*$

The steady state capital per unit of effective labor under Partial Funded system $k_{pf}^*$ is:

$$k_{pf}^{* - \alpha} = \frac{\phi_1^1 \gamma \eta k_{pf}^* + \phi_2^2 (1 - \gamma)(1 - \eta) w_{pf}^*}{b^*(1 + n)(1 + g)} - \frac{(\tau_{pg} - \tau_{pf}) w_{pg}^*}{(1 + g)^2} \frac{\alpha}{(1 + n)^2 b^*}$$ (2.B.1)

The steady state output per unit of labor $y_{pf}^*$ is:

$$y_{pf}^* = k_{pf}^* \alpha$$ (2.B.2)

The national saving rate $\frac{S}{Y}$ is:

$$\frac{S}{Y} = \frac{\phi_1^1 N_{pf} - \phi_1^1 N_{pf-1}}{L} \frac{\alpha}{H h k_t^\alpha}$$ (2.B.3)

So, the steady state national saving rate $\frac{(S_{pf}^*)}{(Y_{pf}^*)}$ is:

$$\left(\frac{S}{Y}\right)_{pf}^* = \frac{\gamma \eta \phi_1^1 \left[1 - \frac{1}{(1 + n)(1 + g)}\right] + (1 - \gamma)(1 - \eta) \phi_2^2 \left[1 - \frac{1}{(1 + n)(1 + g)}\right]}{b^*/(1 - \alpha)}$$ (2.B.4)

Where $\phi_1^1$ is the share of saving of wage income for working-age adult:

$$\phi_1^1 = \frac{(1 + r^*) (q * \beta \delta + q * \delta)(1 - \tau_{pf}) - (1 + g) \tau_{pf} (1 + n) \alpha / \gamma + q * (1 - \tau_{pf})}{(1 + r^*) (1 + q * \beta \delta + q * \delta)}$$ (2.B.5)

$$\phi_2^2 = \frac{(1 + r^*) (q * \beta \delta + q * \delta)(1 - \tau_{pf}) - (1 + g) \tau_{pf} (1 + n) \alpha / (1 - \gamma) + q * (1 - \tau_{pf})}{(1 + r^*) (1 + q * \beta \delta + q * \delta)}$$ (2.B.6)
The steady state ratio of capital to output \( (\frac{K}{Y})^* \) is:

\[
(\frac{K}{Y})^* = k^*(1 - \alpha)
\]

(2.B.7)

The steady state interest rate \( r^* \), the annual interest rate \( \bar{r} \) and wage rate \( w^* \) are:

\[
r^* = \alpha k^* \alpha - 1
\]

(2.B.8)

\[
\bar{r} = \sqrt{\frac{1}{1 + r^*}} - 1
\]

\[
w^* = (1 - \alpha)k^* \alpha
\]

(2.B.9)

2) Consumer Welfare Variables: \( c^*_y, c^*_o, U^*_t, RE^*_t, I^*_t, \) and \( IR^*_t \)

The steady state young age consumption per unit of labor \( c^*_y \) is:

\[
c^*_y = \frac{\gamma H^* w^*_t (1 + r^*_t) (1 - \tau^*_t) + H^* w^*_t \left[ \tau^*_t (1 + n) a + \gamma q^* (1 - \tau^*_t) \right]}{(1 + q^* \beta \delta + q^* \delta)}
\]

(2.B.10)

The steady state old age consumption per unit of labor \( c^*_o \) is:

\[
c^*_o = \frac{(1 - \gamma) H^* w^*_t (1 + r^*_t) (1 - \tau^*_t) + H^* w^*_t \left[ \tau^*_t (1 + n) a + (1 - \gamma) q^* (1 - \tau^*_t) \right]}{(1 + r^*_t) (1 + q^* \beta \delta + q^* \delta)}
\]

(2.B.11)

The steady state lifetime utility is:

\[
U^*_t = \ln c^*_t + \frac{q}{1 + \rho} \left[ \ln c^*_t + \beta \ln (1 - lp^*) \right] \quad (i=1,2)
\]

The pension replacement ratios of type 1 agent and type 2 agent are:

\[
RE^*_t = \frac{\tau^*_t H^*_t w_t (1 + n) a + \tau^*_t (1 - \tau^*_t) H^*_t w_t (1 + r^*_t) / q^*}{H^*_t w_t}
\]

\[
RE^*_t = \frac{\tau^*_t H^*_t w_t (1 + n) a + \tau^*_t (1 - \tau^*_t) H^*_t w_t (1 + r^*_t) / q^*}{H^*_t w_t}
\]

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The pension replacement ratios of type 1 agent and type 2 agent are same, which reflects one feature of China’s PAYG system that the retiree’s pension benefit is in proportion to his wage income before retirement. The steady state pension replacement ratio $REP_{pf}^*$ is:

$$REP_{pf}^* = \tau_{pf} (1 + n)(1 + g) a / \gamma + \tau^* (1 - \tau_{pf} )(1 + r^*) / q^*$$

(2.B.12)

The steady state lifetime income $I_{pf}^*$ is:

$$I_{pf}^* = H w^* \left[ (1 - \tau_{pf} ) \gamma + \frac{\tau_{pf} (1 + n)(1 + g)}{q^* (1 + r_{pf}^*)} + \frac{lp^* \gamma (1 + g)(1 - \tau_{pf} )}{(1 + r_{pf}^*)} \right]$$

(2.B.13)

The steady state present value of income redistribution $IR_{pg}^{i*}$ is:

$$IR_{pf}^{i*} = \frac{\tau_{pf} (1 + g)(1 + n)a}{(1 + r_{pf}^*)q^* \gamma} - \tau_{pf} + \tau^* (1 - \tau_{pf} ) \left( \frac{1}{q^*} - 1 \right)$$

(2.B.14)

3) Transitional Variables: $tc_i$, $\frac{TC_L}{Y_i}$, and $c^*$

$$tc_i = \frac{TC_L}{Y_i} = (\tau_{pg} - \tau_{pf} ) w_{pg}^* a / b_{pg}^*$$

(2.B.15)

$$\frac{TC_L}{Y_i} = (\tau_{pg} - \tau_{pf} ) w_{pg}^* \left( H_{pg}^{x_s} N_{pg}^{x_s} + H_{pg}^{x_s} N_{pg}^{x_s} \right) = \frac{\tau_{pg} - \tau_{pf} ) w_{pg}^* a}{Y_{pg}^* b_{pg}^*}$$

(2.B.16)

The steady state special consumption tax rate is:

$$\tau^* = \frac{(\tau_{pg} - \tau_{pf} ) H_{pg}^{x_s} r a}{c_{y_s}^*(1 + n)^{y_s} + c_{q}^*(1 + n)^{y_{q_s}}}$$

(2.B.17)
Source: Figure 3.1 and Figure 3.2: United Nations (2009), World Population Prospects: The 2008 Revision Population Database (medium variant case)

Figure 3.3: United Nations (2009), World Population Prospects: The 2008 Revision Population Database (medium variant case); IMF (2009), World Economic Outlook
Figure 3.4  Urban Pension Coverage (1995-2008)

Source: China’s Statistical Yearbook (2009)

Figure 3.5  Basic Pension Revenue/Expenditure/Balance (1995-2008)

Source: China’s Statistical Yearbook (2009)
### Table 3.1 Basics of China’s New Partially Funded Three-Pillar Pension System

<table>
<thead>
<tr>
<th>Three Pillars</th>
<th>Quality</th>
<th>Contributions</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pillar I: Basic Pension Plan</strong></td>
<td>IA: Social Pooling Account</td>
<td>Basic, PAYG, Public-Managed, and Mandatory</td>
<td>From Employer: 20% of employee’s wage, at least 15-year contribution</td>
</tr>
<tr>
<td>IB: Individual Account</td>
<td>Basic, Funded, Public-Managed, and Mandatory</td>
<td>From Employee: 8% of employee’s wage, at least 15-year contribution</td>
<td>Individual Account Assets Divided by Distributing Months&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Pillar II: Supplementary Pension Plan</strong></td>
<td>Enterprise Annuity Plan</td>
<td>Funded, Complementary, and Voluntary</td>
<td>Contributions from Employer and Employee</td>
</tr>
<tr>
<td><strong>Pillar III: Supplementary Pension Plan</strong></td>
<td>Individual Saving Plan</td>
<td>Funded, Complementary, and Voluntary</td>
<td>Contributions from Employee</td>
</tr>
</tbody>
</table>


### Table 3.2 Contribution Rates for Social Security Programs in China in 2004 (% of Payroll)

<table>
<thead>
<tr>
<th></th>
<th>Pension</th>
<th>Unemployment Insurance</th>
<th>Medical Insurance</th>
<th>Work Injury Insurance</th>
<th>Maternity Insurance</th>
<th>Housing Provident Fund</th>
<th>Total</th>
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<tr>
<td>Employer</td>
<td>20</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>Employee</td>
<td>8</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Both</td>
<td>28</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>14</td>
<td>56</td>
</tr>
</tbody>
</table>

Source: MOLSS Statistics (2008)

### Table 3.3 Comparison of Contribution Rates for Pension Program in 2004 (% of Payroll)

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>USA</th>
<th>Japan</th>
<th>Korea</th>
<th>Chile</th>
<th>Mexico</th>
<th>Indonesia</th>
<th>China</th>
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</thead>
<tbody>
<tr>
<td>Employer</td>
<td>9.8</td>
<td>6.2</td>
<td>6.8</td>
<td>4.5</td>
<td>0</td>
<td>3.2</td>
<td>3.7</td>
<td>20</td>
</tr>
<tr>
<td>Employee</td>
<td>9.8</td>
<td>6.2</td>
<td>6.8</td>
<td>4.5</td>
<td>10.0</td>
<td>1.1</td>
<td>2.0</td>
<td>8</td>
</tr>
<tr>
<td>Both</td>
<td>19.6</td>
<td>12.4</td>
<td>13.6</td>
<td>9.0</td>
<td>10.0</td>
<td>4.3</td>
<td>5.7</td>
<td>28</td>
</tr>
</tbody>
</table>

Source: Social Security Administration (2004). Contributions are used to cover old age, disability and survivors.

<sup>1</sup> Distributing months depend on the life expectancy, retirement age, and interest rate, currently is 139 months (MOLSS, 2008).
APPENDIX BOX 3.1: LITERATURE ON CHINA’s IPD AND FISCAL HEALTH

As the fiscal health of social security system plays a key role in a country’s fiscal health (James 2003), the fiscal sustainability of China’s social security system is of much interest to many researchers. Three benchmarks to measure the fiscal soundness of the social security system are implicit pension debt (IPD), the financing gap, and the required contribution rate (Sin 2005).

Implicit pension debt (IPD) is measured as the sum of the present value of pension benefits that have to be paid to current retirees and all pension rights that current workers have already earned if the current PAYG pension system is terminated today (Holzmann et al. 2004). Current literature gives some estimates on the size of China’s IPD ranging from 70%-140% of GDP (Table 3). Based on data extrapolated from hypothetical scenarios of dependency ratios and a relatively high real discount rate (around 5%), World Bank (1997) estimated China’s IPD ranging from 46% to 69% of GDP in 1994. Dorfman and Sin (2000) measured the IPD around 95% of the 1998 GDP by using the World Bank’s Pension Reform Options Simulation Toolkit (PROST). Based on an actuarial model, a research by China’s State Council Office for Restructuring the Economic Systems calculated China’s IPD at 80%-110% of GDP in 2000 (Song et al. 2001).

Wang et al. (2001) used a computable general equilibrium (CGE) model that differentiates between three types of enterprise and 22 groups in the labor force to calculate China’s IPD around 71% of GDP in 2000. By using the same PROST software, yet an assumed lower interest rate, Sin (2005) provided a detailed estimate of IPD at 141% of 2001 GDP (about US$ 1.6 trillion), of which 111% of GDP belongs to social account debt and the rest 30% to individual account debt.

The financing gap is measured as the sum of the present values of yearly pension balances, i.e., revenues less expenditures, of the pension system during the projection period. The
required contribution rate is a set rate such that the fiscal balance of the pension system can be maintained. Sin (2005) calculated the financing gap around 95% of the GDP in 2001 and the total contributions would have to be increased from the current 28% to 37% of the wage bill in China.

**Current Fiscal Situation in China.** China’s ratio of public debt to GDP that excludes local governments’ liabilities is 22% in 2009, much lower than the world average of 59%, the U.S. of 94%, and Japan of 227% (IMF, 2009). However, according to a research by Professor Victor Shih from Northwestern University, if the surging hidden debts by local governments and other large state-owned entities are counted, the estimated total public debt may reach 40 trillion Yuan (US$5.8 trillion), 96% of GDP in 2010 (Bloomberg News Online, 03/02/2010).

To sum up, due to different calculation models and different assumptions about economic and demographic factors, the estimates of China’s IPD are divergent, yet the literature shows China has high IPD, more than 70% of GDP. Furthermore, as the current pension system only cover 55% urban employment (21% of total employment), with the coverage expansion of the system and rapid population aging, China’s IPD may become larger and larger. If the increasing IPD included in China’s public debts, China’s fiscal health would deteriorate substantially (Salditt et al. 2008). Additionally, due to huge hidden local governments’ liabilities, China’s current fiscal health is much more serious than it seems.

<table>
<thead>
<tr>
<th>Authors or Research</th>
<th>IPD Estimates</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Bank (1997)</td>
<td>46%-69% of GDP in 1994</td>
<td>Pension Reform Options Simulation Toolkit (PROST)</td>
</tr>
<tr>
<td>Dorfman and Sin (2000)</td>
<td>94% of GDP in 1998</td>
<td>PROST</td>
</tr>
<tr>
<td>Song et al. (2001)</td>
<td>80%-110% of GDP in 2000</td>
<td>An Actuarial Model</td>
</tr>
<tr>
<td>Wang et al. (2001)</td>
<td>71% of GDP in 2000</td>
<td>A Computable General Equilibrium (CGE) Model</td>
</tr>
<tr>
<td>Sin (2005)</td>
<td>141% of GDP in 2001</td>
<td>PROST</td>
</tr>
</tbody>
</table>
Appendix BOX 3.2: MODEL ASSUMPTION, DATA DESCRIPTION, and GA CALCULATIONS ON GENERATIONAL ACCOUNTING MODEL

To calculate generational accounts, we require projections of population, the discount rate, the growth rate, and the age-specific taxes and transfers, government expenditures, initial government wealth that are directly related to the social security system including pension, health insurance, unemployment, work injury, maternity insurance, and education.

Population projections by age are available from UN Population Database\(^1\) that covers the period from 1950 to 2050. After 2050, based on the UN 2050 projection levels, we extrapolate the population projection using the assumed fertility rates and mortality rates by following Du et al. (2005).\(^2\) Figure 6 shows population structure forecast in China (2000-2100).

There are two assumed values for the real productivity growth rate \(g\): 2.5\% and 4\% and three values for the discount rate \(r\): 4\%, 6\% and 8\%. Labor productivity grew on average by 5\% during 1978-2000 (Wang et al. 2001). As future technological progress may slow due to population aging (Wattenberg 1987), we choose a slower growth rate of 2.5\% or 4\%. The discount rate is crucial to measuring the pension system (Elliott 2010). There is a divide between economists and actuaries on choosing the discount rate. Economists generally prefer using risk-free such as Treasury bond rates or low-risk interest rate such as municipal bond rates as the discount rate, while actuaries prefer using the market interest rate in the presence of the uncertainty\(^3\). In this paper, we make different assumptions on the discount rate in order to accommodate the alternative views above. The first is to apply risk-free treasury rate (\(r=4\%\)) or low-risk bond rate (\(r=6\%\)) to the projected flows. The second is to use a risk-adjusted market rate (\(r=8\%\)) in the calculation. We choose the case of \(g=4\%, r=6\%\) as our baseline case since it is more appropriate to use the low-risk interest rate (\(r=6\%\)) as the discount rate based on the

---

\(^1\) UN Population Division, World Population Prospects: The 2008 Revision Population Database, Medium Variant Case
\(^2\) We use the cohort-component population projection method by following Du et al. (2005). We assume the total fertility rate is 1.8 between 2050-2075, and 1.85 until 2100 due to the possible easing of “one child policy”. The life expectancy at birth for male and female are 77.4 years and 81.3 years between 2050-2075, and 80 years and 83.8 years until 2100.
\(^3\) Please see Elliott (2010) for more details on the choice of the discount rate.
assumed real growth rate \( g = 4\% \). We also analyze the effects of different combinations of discount rate and growth rate on generational accounts through sensitivity analysis.

We use the Chinese Urban Household Survey (UHS) \(^1\) conducted by China’s National Bureau of Statistics in 2000 to derive the age-profile of wage earning (Figure 7) and age-profiles of all types of tax payments and transfer receipts including pension, health insurance, unemployment insurance, work injury insurance, and maternity insurance (Figure 8-10). Following Auerbach et al. (1991), we first use UHS data to calculate the average 2000 values of each type of tax and transfer by age group from 0 to 90, and then get the age-tax profiles and age-transfer profiles relative to a base age group. Furthermore, these relative age profiles are used to distribute the amount of the corresponding tax or transfer among age groups by benchmarking against the aggregate amounts reported in China’s Statistical Yearbook until 2008\(^2\). For future years when the aggregate data are unavailable, the age-specific average values for each tax and transfer are assumed to rise at the rate of productivity growth.

Government educational expenditure is regarded as a transfer to younger generations. Estimates of public expenditure on preschool, elementary, middle, and higher education in 2000 are calculated from China’s Statistical Yearbook (2001). These four kinds of expenses are then distributed equally among the age groups of the appropriate educational category (Figure 11).

In the base year 2000, the accumulated social security-related government wealth was 133 billion Yuan, where pension asset was 95 billion, health insurance asset was 20 billion, and other social security assets were 18 billion (NBS, China’s Statistical Yearbook 2009). It is well known that China government has huge state-owned assets. In 2000, the total state-owned asset balance reached around 10 trillion Yuan, 101% of 2000 GDP (Xinhua Online, 06/19/2002).

\(^1\) The UHS provides detailed household-level information on income, consumption, asset, transfers, and expenditures. It also provides demographic and employment information about household members, living conditions, and a number of other household characteristics. The UHS in 2000 covers 24,650 urban households.

\(^2\) For example, in 2000, the aggregate revenue/expenditure for pension were 227.8 / 211.5 billion, for health insurance were 17 / 12.4 billion, for unemployment insurance were 16 / 12.3 billion respectively (NBS, China’s Statistical Yearbook 2001).
We also get social security-related government expenditure that excludes educational expenditure from China’s Statistical Yearbook until 2008. For instance, in 2000, the total social security-related government expenditure was 438.4 billion Yuan. For future years when the data is unavailable, the government expenditure increase at the rate of productivity growth.

Source: Figure 6: United Nations (2009), World Population Prospects: The 2008 Revision Population Database (medium variant) (2000-2050); Author’s Forecast (2051-2100). Figure 7-Figure 12: UHS (2000); China’s Statistical Yearbook (2001); Author’s calculation.
Table 3.4  Generational Accounts of Existing and Future Generations \(^{a}\)
Under Current Pension Policy, Per Capita, in 2000
(RMB $1,000$Yuan)

<table>
<thead>
<tr>
<th>Generation’s Age in 2000</th>
<th>(g=2.5%)</th>
<th>(r=4%)</th>
<th>(r=6%)</th>
<th>(r=8%)</th>
<th>(g=4%)</th>
<th>(r=4%)</th>
<th>(r=6%)</th>
<th>(r=8%)</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>83.99</td>
<td>49.05</td>
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<td>37.78</td>
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\(^{a}\) Source: Author’s calculations
\(^b\) The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.

Table 3.5  Comparison of Several Scenarios under Current Pension Policy

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\(^{a}\) The account ratio is the generational account ratio between the future generations and the newborn generation in 2000. \(^{b}\) The two hypothetical scenarios that are impractical in reality are only used for the aim of comparison here.
Table 3.6  Generational Accounts of Existing and Future Generations *
Higher Contribution Rate by 2.2 Percent Point, Per Capita, in 2000
(RMB 1,000 Yuan)

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a. Source: Author’s calculations
b. The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.
Table 3.7  Generational Accounts of Existing and Future Generations <sup>a</sup>
Higher Retirement Age to 65, Per Capita, in 2000
(RMB 1,000Yuan)

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<sup>a</sup> Source: Author’s calculations
<sup>b</sup> The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.
### Table 3.8 Generational Accounts of Existing and Future Generations

**Lower Pension Benefit by 11%, Per Capita, in 2000**
(RMB 1,000 Yuan)

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a. Source: Author’s calculations

b. The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.
Table 3.9  Generational Accounts of Existing and Future Generations *  
Subsidizing with Interests of State-Owned Assets, Per Capita, in 2000  
(RMB 1,000Yuan)

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a. Source: Author’s calculations  
b. The account ratio is the generational account ratio between the future generations and the newborn generation in 2000.
Table 3.10 Generational Accounts Comparison of Five Scenarios under the Baseline Case

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<th>Higher Retirement Age to 65</th>
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<td>76.74</td>
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<td>1.03</td>
<td>1.01</td>
<td>1.03</td>
<td>1.08</td>
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</table>

Note:  
a. All scenarios are under the baseline case (g=4% and r=6%)  
b. The account ratio is the generational account ratio between the future generations and the newborn generation in 2000
Table 3.11  Additional Tax Burden Imposed under Four Pension Reform Options  
(Baseline Case: g=4% and r=6%)

<table>
<thead>
<tr>
<th>Generation's Age in 2000</th>
<th>Higher Tax by 2.2 Percent Point</th>
<th>Higher Retirement Age to 65</th>
<th>Lower Pension Benefit by 11%</th>
<th>Subsidizing with State-Owned Asset Interests</th>
</tr>
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<tr>
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<td>4.7</td>
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<tr>
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<td>4.4</td>
<td>4.1</td>
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<td>70</td>
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<td>0.2</td>
<td>4.1</td>
<td>0.0</td>
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<tr>
<td>75</td>
<td>0.0</td>
<td>0.3</td>
<td>3.6</td>
<td>0.0</td>
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<td>80</td>
<td>0.0</td>
<td>0.1</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>85</td>
<td>0.0</td>
<td>0.1</td>
<td>2.2</td>
<td>0.0</td>
</tr>
<tr>
<td>90</td>
<td>-0.2</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
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<tr>
<td>Future Generations</td>
<td>-26.2</td>
<td>-29.1</td>
<td>-27.5</td>
<td>-28.4</td>
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</tbody>
</table>

Source: Author’s calculations
### Table 3.12 Variables Data Summary

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observation</th>
<th>Mean (^a)</th>
<th>STDEV (^a)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly Average Wage (Yuan)</td>
<td>1980-2008</td>
<td>5.56</td>
<td>3.99</td>
<td>NBS (2009) (^g)</td>
</tr>
<tr>
<td>Yearly Inflation Rate (^b) (%)</td>
<td>1980-2008</td>
<td>4.02</td>
<td>3.53</td>
<td>IMF (2009)</td>
</tr>
<tr>
<td>Bank Deposit Return (^b) (%)</td>
<td>1980-2008</td>
<td>1.05</td>
<td>2.25</td>
<td>IMF (2009)</td>
</tr>
<tr>
<td>Government Bond Return (^b) (%)</td>
<td>1990-2008</td>
<td>2.01</td>
<td>2.98</td>
<td>NBS (2009)</td>
</tr>
<tr>
<td>Industrial Investment Return (^c) (%)</td>
<td>1980-2008</td>
<td>8.03</td>
<td>14.15</td>
<td>SSE</td>
</tr>
<tr>
<td>Domestic Stock Return (^d) (%)</td>
<td>1993-2008</td>
<td>8.95</td>
<td>28.75</td>
<td>SSE and SZE</td>
</tr>
<tr>
<td>Global Investment Return (^e) (%)</td>
<td>1980-2008</td>
<td>7.18</td>
<td>15.34</td>
<td>Bloomberg</td>
</tr>
<tr>
<td>Return on the Mixed Strategy 6 (^f)</td>
<td>1990-2008</td>
<td>1.53</td>
<td>2.39</td>
<td>Author’s calculation</td>
</tr>
<tr>
<td>Return on the Mixed Strategy 7 (^f)</td>
<td>1990-2008</td>
<td>5.07</td>
<td>6.53</td>
<td>Author’s calculation</td>
</tr>
</tbody>
</table>

\(^a\) Mean of the data observations and Standard Deviation of the data observations. All the data are in real terms.

\(^b\) Yearly inflation rate is proxied by the consumer price index (CPI). Bank Deposit return and government bond return are proxied by one-year bank time deposit rate and ten-year treasury bond yield respectively.

\(^c\) Return on industrial investment is proxied by the average yearly return in Public Utility Index of Shanghai Stock Exchange (SSE) as most industrial investment of pension funds in China concentrates on public utility industry.

\(^d\) Weighted average of returns of Shanghai Stock Exchange (SSE) Index and Shenzhen Stock Exchange (SZE) Index.

\(^e\) Return on global investment is proxied by returns on U.S. equity (500 S&P Index) yield and 30-year treasury bond yield with a 50-50 split and the currency exchange rate risk between RMB and US$ is allowed for.

\(^f\) The mean and the standard deviation of Strategy 6 and 7 are based on the author’s calculations. Please see the footnote 2 of pp. 29 of the Paper for the details on how to calculate the mean and variance of a mixed strategy.
Table 3.1  Effects of Changes in Coverage Rate

<table>
<thead>
<tr>
<th></th>
<th>Baseline Case</th>
<th>Case A&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Case B&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coverage Rate of Young-Age Adults&lt;sup&gt;b&lt;/sup&gt;</strong></td>
<td>0.70</td>
<td>0.65</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Contribution Rate for Social Account (%)</strong></td>
<td>20</td>
<td>20</td>
<td>20</td>
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<tr>
<td><strong>Contribution Rate for Individual Account (%)</strong></td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>Retirement Age</strong></td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>Administration Cost</strong>&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4% (3%)</td>
<td>4.2% (3.2%)</td>
<td>3.5% (2.6%)</td>
</tr>
<tr>
<td><strong>Investment Strategy</strong>&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
</tr>
<tr>
<td><strong>Replacement Ratio (%)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Mean (Change %)</strong></td>
<td>45.6 (0%)</td>
<td>42.2 (-7.4%)</td>
<td>52.9 (16.1%)</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong>&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.2</td>
<td>1.9</td>
<td>2.4</td>
</tr>
</tbody>
</table>

<sup>a</sup> Case A and B refer to the cases where coverage rates of young-age adults are changed to 0.65 and 0.80 respectively.

<sup>b</sup> Coverage rate here is the coverage rate of urban employment, excluding rural employment.

<sup>c</sup> The administration costs 4% (3%) stands for 4% of revenues of the individual account and 3% of social account. Due to the effect of economies of scale, the administration costs change to 4.2% (3.2%) and 3.5% (2.6%) in Case A and B.

<sup>d</sup> The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.

<sup>e</sup> The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
Table 3.14 Effects of Changes in Retirement Age and in Administration Cost

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<th>Change in Retirement Age</th>
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<tr>
<td>Coverage Rate of Young-Age Adults b</td>
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<tr>
<td>Contribution Rate for Social Account (%)</td>
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<tr>
<td>Contribution Rate for Individual Account (%)</td>
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<td>8</td>
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<tr>
<td>Retirement Age</td>
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<td>55</td>
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<tr>
<td>Administration Cost c</td>
<td>4% (3%)</td>
<td>4% (3%)</td>
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<td>Investment Strategy d</td>
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<tr>
<td>Replacement Ratio (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (Change %) e</td>
<td>45.6 (0%)</td>
<td>37.4 (-7.2%)</td>
</tr>
<tr>
<td>Standard Deviation e</td>
<td>2.2</td>
<td>1.6</td>
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</table>

a. Case A and B refer to the cases where retirement ages are changed to 55 and 65 respectively. Case C and D are the ones where administration costs are changed to 5% (4%) and 3% (2%) respectively.
b. Coverage rate here is the coverage rate of urban employment, excluding rural employment.
c. The administration costs 4% (3%) stands for 4% of revenues of the individual account and 3% of social account.
d. The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.
e. The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
Table 3.15  Effects of Different Investment Strategies

<table>
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<th>Case A</th>
<th>Case B</th>
<th>Case C</th>
<th>Case D</th>
<th>Case E</th>
<th>Case F</th>
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<td>Coverage Rate of Young-Age Adults a</td>
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<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
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<tr>
<td>Contribution Rate for Social Account (%)</td>
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<td>20</td>
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<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Administration Cost c</td>
<td>4% (3%)</td>
<td>3.9% (3%)</td>
<td>4.1% (3%)</td>
<td>4.8% (3%)</td>
<td>5% (3%)</td>
<td>5% (3%)</td>
<td>4.5% (3%)</td>
</tr>
<tr>
<td>Investment Strategy d</td>
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<td>100:0:0:0:0:0</td>
<td>0:0:100:00:0:0</td>
<td>0:0:0:100:0:0</td>
<td>0:0:0:0:100:0</td>
<td>0:0:0:0:0:100</td>
<td>10:40:20:20:10</td>
</tr>
<tr>
<td>Replacement Ratio (%)</td>
<td>Mean e</td>
<td>45.6 (0%)</td>
<td>42.7 (-6.5%)</td>
<td>50.1 (9.8%)</td>
<td>83.7 (84.5%)</td>
<td>88.1 (93.3%)</td>
<td>81.8 (80.1%)</td>
</tr>
<tr>
<td>Standard Deviation e</td>
<td>2.2</td>
<td>1.9</td>
<td>2.6</td>
<td>6.5</td>
<td>6.9</td>
<td>6.2</td>
<td>3.0</td>
</tr>
</tbody>
</table>

a. Case A-F refer to the cases where asset allocations are bank deposit only, government bond only, industrial investment only, domestic stock only, global investment only, and an investment portfolio structure of 10:40:20:10 respectively.
b. Coverage rate here is the coverage rate of urban employment, excluding rural employment.
c. The administration costs 4% (3%) stands for 4% of revenues of the individual account and 3% of social account. When the individual account is actively invested in risk asset like stock, the administration costs tend to rise. Thereof, the individual account administration costs change to 3.9%, 4.1%, 4.8%, 5%, 5%, 4.5% in Case A-F.
d. The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.
e. The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
Table 3.16 Pension Replacement Ratio Comparison under Five Scenarios

<table>
<thead>
<tr>
<th>Coverage Rate of Young-Age Adults</th>
<th>Current Pension Policy</th>
<th>Higher Coverage Rate</th>
<th>Higher Retirement Age</th>
<th>Lower Administration Cost</th>
<th>Mixed Investment Strategy</th>
</tr>
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<tbody>
<tr>
<td>Contribution Rate for Social Account</td>
<td>0.2</td>
<td>0.2</td>
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<td>0.15</td>
<td>0.2</td>
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<tr>
<td>Contribution Rate for Individual Account</td>
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<td>0.08</td>
<td>0.13</td>
<td>0.08</td>
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<tr>
<td>Retirement Age</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Administration Cost a</td>
<td>4% (3%)</td>
<td>3.5% (2.6%)</td>
<td>4% (3%)</td>
<td>3% (2%)</td>
<td>4.5% (3%)</td>
</tr>
<tr>
<td>Investment Strategy b</td>
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<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>10:40:20:2:00</td>
</tr>
<tr>
<td>Replacement Ratio (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (Change %) c</td>
<td>45.6 (0%)</td>
<td>52.9 (16.1%)</td>
<td>54.9 (20.3%)</td>
<td>50.9 (11.6%)</td>
<td>66.7 (46.2%)</td>
</tr>
<tr>
<td>Standard Deviation c</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
<td>2.9</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note: a. The administration costs 4% (3%) stands for 4% of revenues of the individual account and 3% of social account.
b. The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.
c. The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
Table 3.17  Results of Combined Effects of Alternative Reform Options

<table>
<thead>
<tr>
<th></th>
<th>Baseline Case</th>
<th>Case A  a</th>
<th>Case B  a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage Rate of Young-Age Adults  b</td>
<td>0.70</td>
<td>0.80</td>
<td>0.65</td>
</tr>
<tr>
<td>Contribution Rate for Social Account (%)</td>
<td>20</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Contribution Rate for Individual Account (%)</td>
<td>8</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Retirement Age</td>
<td>60</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>Administration Cost  c</td>
<td>4% (3%)</td>
<td>3% (2%)</td>
<td>5% (4%)</td>
</tr>
<tr>
<td>Investment Strategy  d</td>
<td>50:50:0:0:0</td>
<td>10:40:20:20:10</td>
<td>100:0:0:0:0</td>
</tr>
<tr>
<td>Replacement Rate (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (Change %)  e</td>
<td>45.6 (0%)</td>
<td>100.7 (120.4%)</td>
<td>30.2 (-33.7%)</td>
</tr>
<tr>
<td>Standard Deviation  e</td>
<td>2.2</td>
<td>4.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

a. Scenario A refers to the case where the replacement ratio is highest of all simulation cases, Scenario B is the case where the replacement ratio is lowest.
b. Coverage rate here is the coverage rate of urban employment, excluding rural employment.
c. The administration costs are 5%, 7%, or 3% of revenues of the individual account and 3%, 4%, or 2% of the social account.
d. The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.
e. The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
Table 3.18  Results of Baseline Case and Alternative Reform Options for 1991 Cohort

<table>
<thead>
<tr>
<th></th>
<th>Baseline Case</th>
<th>Case A</th>
<th>Case B</th>
<th>Case C</th>
<th>Case D</th>
<th>Case E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage Rate of Young-Age Adults (^b)</td>
<td>0.80</td>
<td><strong>0.90</strong></td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>Contribution Rate for Social Account (%)</td>
<td>20</td>
<td>20</td>
<td><strong>15</strong></td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Contribution Rate for Individual Account (%)</td>
<td>8</td>
<td>8</td>
<td>13</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Retirement Age</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>65</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Administration Cost (^c)</td>
<td>4% (2.6%)</td>
<td>4% (2.2%)</td>
<td>4% (2.6%)</td>
<td>4% (2.6%)</td>
<td><strong>3% (2%)</strong></td>
<td>4.5% (2.6%)</td>
</tr>
<tr>
<td>Investment Strategy (^d)</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td>50:50:0:0:0</td>
<td><strong>10:40:20:20:10</strong></td>
</tr>
<tr>
<td>Replacement Ratio (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (Change %)</td>
<td>42.7 (0%)</td>
<td>50.9 (19.2%)</td>
<td>48.9 (14.5%)</td>
<td>51.4 (20.4%)</td>
<td>47.1 (10.1%)</td>
<td>63.2 (48.0%)</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>2.5</td>
<td>2.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>

\(^a\) Case A-E refer to the cases where coverage rate changes to 0.90, contribution rate change to 15\%\/+13\%, retirement age changes to 65, administration costs change to 3\% (2\%), and the investment strategy changes to 10:40:20:20:10 respectively.

\(^b\) Coverage rate here is the coverage rate of urban employment, excluding rural employment.

\(^c\) The administration costs 4\% (2.6\%) stands for 4\% of revenues of the individual account and 2.6\% of social account. Due to the effect of economies of scale, the social account administration costs change to 2.2\% in Case A. As the individual account is actively invested in risk asset like stock, the administration costs, the individual account administration costs change to 4.5\% in Case E.

\(^d\) The five-digit ratio is the assets percentage allocation to bank deposits, government bonds, domestic stocks, industrial investment, and global investment.

\(^e\) The mean and the standard deviation reported in the table are the mean and standard deviation calculated from the 800 stochastic simulation replications. Additionally, the value under the parenthesis next to mean value is the percentage change from the mean value of the baseline case.
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