

Sharing High Growth Across Generations: Pensions and Demographic Transition in China*

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Abstract

We analyze intergenerational redistribution in emerging economies with the aid of an overlapping generations model with endogenous labor supply. Growth is initially high but declines over time. A version of the model calibrated to China is used to analyze the welfare effects of alternative pension reforms. Although a reform of the current system is necessary to achieve financial sustainability, delaying its implementation implies large welfare gains for the (poorer) current generations, imposing only small costs on (richer) future generations. In contrast, a fully funded reform harms current generations, with small gains to future generations.

Keywords: China; Demographic transition; Economic growth; Emerging economies; Inequality; Intergenerational redistribution; Labor supply; Migration; Pensions; Poverty; Social discount factor; Social planner; Total fertility rate; Wage growth.

JEL classification: E21, E24, G23, H55, J11, J13, O43, R23.

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1 Introduction

A number of emerging economies are experiencing fast income growth and convergence to developed economies, improving significantly the average living standards of their populations. Their success is often accompanied by increasing disparities, of which intergenerational inequality is an important component. In China, for instance, the present value of earnings for a worker who entered the labor force in 2000 is on average about six times as large as that of a worker who entered in 1970, when China was one of the poorest countries in the world. While young Chinese workers today face much better prospects than did their parents, poverty among the elderly is pervasive, aggravated by the gradual demise of traditional forms of family insurance (Almås and Johnsen 2013, Park *et al.* 2012, Yang 2011, and Yang and Chen 2010).

In this paper, we study how alternative pension systems enable different generations to share the benefits of high growth in emerging countries. We construct an overlapping generation (OLG) model where the economy is initially on a fast convergence trajectory, followed by a slowdown as steady state is approached. We calibrate the model to China based on our earlier work in Song *et al.* (2011), henceforth, SSZ. The model embeds key trends of the growth experience of China: a demographic transition, rural-urban migration, fast wage growth – expected to slow down in future, and financial market imperfections which repress the rate of return on households’ savings.

We use the theory to assess the financial sustainability and welfare properties of alternative reforms. In line with previous studies (e.g., Sin 2005), we find that the current pension system is not financially sustainable, due to the unfavorable demographic transition that will increase the old age dependency ratio in coming years. The welfare effects of alternative sustainable reforms are evaluated from the perspective of a benevolent planner who weighs the utility of different generations with a geometrically declining weight. We take as a conservative benchmark a highly forward-looking (*low-discount*) planner who has no desire to redistribute resources across generations in steady state. We show that in emerging economies even this planner would like to redistribute resources to early generations because these earn much lower wages than future generations. In fact, her optimal policy involves paying generous pensions to the generations who are currently working or already retired, and negative pensions to subsequent generations.¹

We compare the optimal policy to (sustainable) pension reforms that are being discussed in the policy debate. We start with an immediate reform adjusting benefits so as to make the system long-run sustainable (in the sense that the benefits and taxes would not need any future adjustment. This

¹In our calibration, the low-discount planner has an annual discount rate of 0.5%. We show that the drive for redistribution is stronger with a more impatient planner who is endowed, following Nordhaus (2007), with a social discount rate equal to the market interest rate.

policy, which we label as the *benchmark reform*, involves a draconian permanent reduction in the replacement rate, from 60% to 39.1%, for all workers retiring after 2012 without reneging on the outstanding obligations to current retirees. This implies the accumulation of a large pension fund until 2052 to pay for the pensions of future generations retiring in times when the dependency ratio will be very high. The benchmark reform entails large welfare losses relative to the optimal policy, as it cuts pensions for the transition generations, while the planner would like to increase redistribution towards them.

We consider three alternative reforms. The first reform is a *delayed reform*, by which the current rules of the Chinese system remain in place until a future date T . Then, benefits are permanently reduced so as to balance the pension system in the long run. The length of the delay is chosen so as to maximize the low-discount planner's utility. The optimal delay is until 2050, and this policy yields large welfare gains for the transition generations relative to the benchmark reform in 2013. The cohorts retiring between 2013 and 2050 would enjoy welfare gains equivalent, on average, to a 15.9% increase in their lifetime consumption. Later cohorts would only suffer small losses in the form of a slightly lower replacement ratio (and by assumption, all those who retired by 2012 are unaffected).

The second reform is a *fully funded (FF) reform* that replaces the defined benefit transfer-based pension with a fully funded individual account system. To honor existing obligations, the government issues bonds to compensate current workers and retirees for their past contributions. A standard trade-off emerges: all generations retiring after 2059 benefit from the FF reform, whereas earlier generations lose. On the one hand, the FF reform reduces tax distortions on labor supply. On the other hand, it eliminates a redistributive policy that the planner values. We find that both the low-discount planner and, *a fortiori*, the Nordhaus planner prefer the delayed reform to the FF reform.

The third reform is switching to an unfunded pay-as-you-go (*PAYGO*) system where the replacement rate is endogenously determined by the dependency ratio, subject to a sequence of balanced budget conditions for the pension system. Given the demographic transition of China, the PAYGO system yields very generous pensions to early cohorts at the expense of the generations retiring after 2045. This reform yields substantial welfare gains by allowing the poorer current generations to share the benefits of high wage growth with the richer generations entering the labor market when China is a mature economy. The gains outweigh the losses originating from the larger labor supply distortion relative to the FF reform.

The results above accrue in an otherwise standard model. We show that in a mature economy where wages grow at a constant 2% per year, the planner would prefer a FF reform (or, alternatively, the immediate draconian reform) to a delayed reform or to a pure PAYGO system.

The normative predictions of our analysis run against the common wisdom that switching to a

pre-funded pension system is the best response for emerging economies facing adverse demographic dynamics. For instance, Feldstein (1999), Feldstein and Liebman (2006) and Dunaway and Arora (2007) argue that a fully funded reform is the best viable option for China. On the contrary, our policy recommendations are in line with Barr and Diamond (2008), who argue against reforming the pension system in the direction of pre-funded individual accounts.

Our results hinge on two typical features of emerging economies: a high wage growth during transition and a low rate of return on savings (in spite of high returns on investments). In the Chinese case, the forecast of a high wage growth reflects the fact that China's GDP per capita is still below 20% of the US level, leaving ample room for further convergence in technology and productivity. The low rate of return on savings reflect the well-documented fact that China suffers from severe financial market underdevelopment. For instance, Allen *et al.* (2005) document that China has poor investor protection, accounting standards, non-performing loans, etc. relative to its level of development.² Our analysis illustrates a general point that applies to fast-growing emerging economies. Even for economies that are dynamically efficient, the combination of (i) a prolonged period of high wage growth and (ii) a low return on financial savings makes it possible to run a relatively generous pension system over the transition without imposing a large burden on future generations.

We abstract from some potentially important features. First, we consider neither idiosyncratic nor intergenerational risk. Both sources of risk are important and difficult to insure in emerging economies, strengthening the case for a non-funded pension system (see Krueger and Kubler 2006, and Nishiyama and Smetters 2007). Second, we ignore within-cohort inequality. In reality, public pensions also provide some intragenerational redistribution. Last but not least important, we do not consider altruism within families. Public pensions could crowd out private transfers from children to the elderly, reducing the social value of pensions. Although incorporating within-family intergenerational transfers could weaken some of our results, such arrangements appear to be limited and declining over the process of economic development. Cai *et al.* (2006) document that, although retirees in urban China receive transfers from their children in response to negative income shocks (e.g., pension arrears), such transfers provide only very limited insurance. For instance, when income is close to the poverty line, a one yuan temporary reduction in income leads to an increase in net transfers between 10 and 16 cents. Their study concludes that improving the public pension system is unlikely to lead to any significant crowding out of private transfers. This conclusion is shared by Park *et al.* (2012) who add that, irrespective of the public pension system, the effectiveness of the informal private insurance

²Different from us, Feldstein (1999) assumes that the Chinese government has access to a risk-free annual rate of return on the pension fund of 12%. Unsurprisingly, he finds that a fully funded system that collects pension contributions and invests these funds at such a remarkable rate of return will dominate a PAYGO pension system that implicitly delivers the same rate of return as aggregate wage growth.

system is set to decline in future (as it did, for instance, in the recent history of Latin America), since the elderly will have fewer children and more of them will live separately from their children (see also Yang and Chen 2010, and Calvo and Williamson 2008).

The paper is structured as follows. Section 2 presents the model and derive some normative implications. Section 3 calibrates the model to China, specifying the demographic dynamics, an exogenous wage growth process and a set of pension rules. Section 4 studies the welfare effects of alternative pension reforms. Section 5 performs sensitivity analysis. Section 6 extends the analysis to a rural pension system and section 7 concludes. The webpage appendix contains some technical material and a description of the general equilibrium model based on SSZ upon which the forecasts for wages and interest rates are based.

2 Model

This paper constructs a multiperiod OLG model to evaluate quantitatively the welfare implications of alternative pension reforms of China. The model is close in spirit to Auerbach and Kotlikoff (1987), Conesa and Garriga (2008), Conesa and Krueger (1999), Huang *et al.* (1997), and Storesletten (2000).

2.1 Household problem

The model economy is populated by a sequence of overlapping generations of agents. Each agent lives up to $J - J_C$ years and has an unconditional probability of surviving until age j equal to s_j . During their first $J_C - 1$ years (childhood), agents are economically inactive, make no choices, and do not derive any utility. Preferences are defined over consumption and leisure, and are represented by a standard lifetime utility function,

$$U_t = \sum_{j=0}^J s_j \beta^j \left(\log(c_{t,j}) - \frac{(h_{t,j})^{1+\frac{1}{\theta}}}{1+\frac{1}{\theta}} \right), \quad (1)$$

where β is the discount factor, c is consumption, and h is labor supply. Here, t denotes the period in which the agent turns adult (i.e., becomes economically active), and j is the number of years since entering adult life. Thus, U_t is the discounted utility of an agent born in period $t - J_C$.

Workers are active until age J_W . For simplicity, we abstract from an endogenous choice of retirement. Incorporating endogenous retirement would require a more sophisticated model of labor supply, including non-convexities in labor market participation and declining health and productivity in old age, as in e.g. French (2005) and Rogerson and Wallenius (2009). Since China has a mandatory retirement policy, the assumption of exogenous retirement seems reasonable. After retirement, agents receive pension benefits until death. Wages are subject to proportional social security taxes. Adult

workers and retirees can borrow and deposit their savings with banks paying a gross annual interest rate R . A perfect annuity market allows agents to insure against uncertainty about the time of death.

Agents maximize U_t , subject to a lifetime budget constraint,

$$\sum_{j=0}^J \frac{s_j}{R^j} c_{t,j} = \sum_{j=0}^{J_W} \frac{s_j}{R^j} (1 - \tau_{t,j}) \varpi_j \eta_t w_{t+j} h_{t,j} + \sum_{j=J_W+1}^J \frac{s_j}{R^j} b_{t,j}, \quad (2)$$

where $t + j$ denotes time, $b_{t,j}$ denotes the pension benefit accruing in period $t + j$ to a person who became adult in period t , w_{t+j} is the wage rate per efficiency unit at $t + j$, η_t denotes the human capital specific to the cohort turning adult in t , $\tau_{t,j}$ is the labor income tax, and ϖ_j is the efficiency units per hour worked for a worker with j years of experience capturing the experience-wage profile. We abstract from within-cohort differences in human capital. Thus, $(1 - \tau_{t,j}) \varpi_j \eta_t w_{t+j}$ is the after-tax hourly wage rate in period $t + j$ for a worker belonging to cohort t .

2.2 Optimal intergenerational redistribution for an emerging economy

To start with, we characterize the optimal pension policy which maximizes the utility of a benevolent social planner who cares about all present and future generations, and discounts the future generations' utilities geometrically with a discount factor $\phi \in (0, 1)$. The purpose is to illustrate the main point of the paper, namely, that in emerging economies with fast but declining wage growth, even a social planner with a very low social discount rate wishes to redistribute resources from future to current generations. Moreover, the optimal redistribution can be implemented by a pension system that yields a declining sequence of replacement rates.

The key assumption is that the wage growth is relatively fast in the beginning, and eventually converges to a steady-state growth rate g . As discussed in the introduction, this captures a salient feature of emerging economies. To convey the main message, we focus in this section on an economy in which wages grow at the rate $\tilde{g} > g$ until period T (where $T > J$) and at the rate g thereafter. The insights generalize to arbitrary wage sequences featuring a decreasing growth rate. Again for simplicity, we set $\varpi_j = \eta_t = s_j = 1$.³

The optimal allocation (*first best*) maximizes

$$V_0 = \sum_{t=0}^{\infty} \mu_t \phi^t U_t, \quad (3)$$

where U_t is defined in equation (1) and μ_t is the population size of the cohort entering the labor

³This amounts to abstracting from human capital accumulation, a rising age profile of wages, and mortality before age J . This is without loss of generality and the results are robust to allowing $\varpi_j \neq 1$, $\eta_t \neq 1$, and $s_j < 1$. In the quantitative analysis below, we restore all these features.

market in period t .⁴ The maximization is subject to the following resource constraint:

$$\sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^J \frac{c_{t,j}}{R^j} = A_0 + \sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^{J_w} \frac{w_{t+j} h_{t,j}}{R^j}, \quad (4)$$

where A_0 denotes the initial planner's wealth net of promises to generations that enter the labor before time zero. Note that, for the resource constraint to be well-defined, we must assume that, in the long run, $R > (1 + g)(1 + n)$, where n is the long-run population growth rate. This constraint guarantees that the economy is dynamically efficient. Moreover, we assume that $\phi < (1 + n)^{-1}$, so as to ensure that the transversality condition of the planner's problem holds. Standard analysis yields the first-best allocation:

$$c_{t,0} = \lambda^{-1} (\phi R)^t, \quad (5)$$

$$c_{t,j} = c_{t,0} (\beta R)^j, \text{ for } j \in \{1, 2, \dots, J\}, \quad (6)$$

$$h_{t,j} = \left(\frac{w_{t+j}}{c_{t,j}} \right)^\theta, \text{ for } j \in \{0, 1, \dots, J_w\}. \quad (7)$$

where λ is the Lagrange multiplier associated with the resource constraint (note that λ is inversely related to A_0). The optimal consumption sequence is independent of the wage sequence. Over the life cycle the planner chooses the same consumption growth as do individuals (see equation (6)), whereas consumption grows across cohorts by the factor ϕR (see equation (5)), independently of the wage dynamics. Finally, labor supply is increasing the larger is the wage relative to consumption (see equation (7)).

Next, suppose that the planner faces a standard implementability constraint: any (Ramsey) allocation must be a competitive equilibrium. Suppose, in addition, that the only instrument at her disposal is a pension system comprising a sequence of taxes and pension replacement rates $\{\zeta_t, \tau_t\}_{t=0}^{\infty}$, where cohort t 's labor income is taxed at the flat rate τ_t , and the cohort receives a pension $b_{t,j}$. To achieve an analytical characterization, it is convenient to define cohort k 's pension replacement rate ζ_k as the ratio between the present value of its pensions and that of its after-tax labor income: $\zeta_k = \left(\sum_{j=J_w+1}^J b_{k,j} R^{-j} \right) / \left(\sum_{j=0}^{J_w} (1 - \tau_t) w_{k+j} \bar{h}_{k,j} R^{-j} \right)$, where $\bar{h}_{k,j}$ is the average labor supply of workers of cohort k with experience j .

The following proposition (proof in the appendix) establishes that the first best can be implemented by setting the tax rate to zero and choosing a suitable replacement rate sequence.

Proposition 1 *The first-best allocation can be implemented by a Ramsey sequence of cohort-specific taxes and pension replacement rates. These sequences have the following characterization:*

⁴We ignore the generations born before $t = 0$, since we assume that the planner cannot change the utility promised to these generations.

- (1) Taxes are zero in all periods, $\tau_{t,j} = 0$ for all t and j ;
(2) The pension replacement rate sequence is:

$$\frac{1 + \zeta_{t+1}}{1 + \zeta_t} = \left(\frac{\phi R}{1 + g} \right)^{1+\theta} \times \left(\frac{1 + g}{1 + \tilde{g}} \right)^{1+\theta} \times F(t), \quad (8)$$

where $F(t)$ is a continuous non-decreasing function of the birth date t such that $F(t) = 1$ for all $t \leq T - J_w$, $F(t) = \left(\frac{1 + \tilde{g}}{1 + g} \right)^{1+\theta} > 1$ for all $t > T$ and $F(t)$ is increasing in t for intermediate values. The expressions for $F(t)$ and ζ_0 are given in the appendix.

The particular case in which $\phi = (1 + g)/R$ is especially revealing. In this case, the planner would engage in no intergenerational redistribution in a mature economy where $\tilde{g} = g$.⁵ However, if $\tilde{g} > g$, the benefit sequence is monotonically decreasing during the transition. Thus, the optimal pension system redistributes resources from the steady-state generations to the transition generations.

In Proposition 1, some cohorts may earn negative pensions. It is straightforward to extend the result to a setting where pensions are constrained to be non-negative (see Corollary 2 in the appendix). In this case, pensions may be set to zero for some cohorts, and so these cohorts face positive social security taxes. Finally, the theory yields the normative prediction that no generation should ever be taxed when working and earn pension benefits in old age, as this creates an inefficient labor supply wedge.

3 Parametrizing the model

This section parametrizes the model. We first describe the demographic model, then calibrate the rest of the model, and finally specify a pension system.

3.1 Demographic model

Since China faces a major demographic transition that affects the viability of the pension system, we construct in this section a detailed demographic model. We assume an exogenous population dynamics model and provide a detailed account of internal rural-urban migration since this has important effects on the sustainability of the system.

Throughout the 1950s and 1960s, the total fertility rate (henceforth, TFR) of China was between five and six. High fertility, together with declining mortality, brought about a rapid expansion of the total population. The 1982 census estimates a population size of one billion, 70% higher than in the 1953 census. The view that a booming population is a burden on the development process led the government to introduce measures to curb fertility during the 1970s, culminating in the one-child

⁵To see why, note that the right-hand side of equation (8) would be unity if $\tilde{g} = g$, so ζ_t must be constant.

policy of 1978. This policy imposes severe sanctions on couples having more than one child. The policy underwent a few reforms and is currently more lenient to rural families and ethnic minorities. Today's TFR is below replacement level, although there is no consensus about its exact level. Estimates based on the 2000 census and earlier surveys range between 1.5 and 1.8 (e.g., Zhang and Zhao, 2006). Recent estimates suggest a TFR of about 1.6 (Zeng 2007).

3.1.1 Natural population projections

We consider, first, a model without rural-urban migration, which is referred to as the *natural* population dynamics. We break down the population by birth place (rural vs. urban), age, and gender. The initial population size and distribution are matched to the adjusted 2000 census data.⁶ There is consensus among demographers that birth rates have been underreported, causing a deficit of 30 to 37 million children in the 2000 census.⁷ To heed this concern, we take the rural-urban population and age-gender distribution from the 2000 census – with the subsequent National Bureau of Statistics (NBS) revisions – and then amend this by adding the missing children for each age group, according to the estimates of Zhai and Chen (2007) (see also Goodkind 2004).

The initial group-specific mortality rates are also estimated from the 2000 census, yielding a life expectancy at birth of 71.1 years, which is very close to the World Development Indicator figure in the same year (71.2). Life expectancy is likely to continue to increase as China becomes richer. Therefore, we set the mortality rates in 2020, 2050, and 2080 to match the demographic projection by Zeng (2007) and use linear interpolation over the intermediate periods. We assume no further change after 2080. This implies a long-run life expectancy of 81.9 years.

The age-specific urban and rural fertility rates for 2000 and 2005 are estimated using the 2000 census and the 2005 one-percent population survey, respectively. We interpolate linearly the years 2001-2004, and assume age-specific fertility rates to remain constant at the 2005 level over the period 2006-2012. This yields average urban and rural TFRs of 1.2 and 1.98, respectively.⁸ Between 2013 and 2050, we assume age-specific fertility rates to remain constant in rural areas. In November 2013 the third plenum of the Chinese Communist Party's 18th Party Congress announced the plan allowing couples to have two children if one of them is an only child. This policy has been rapidly implemented

⁶The 2000 census data are broadly regarded as a reliable source (see, e.g., Lavelly, 2001; Goodkind, 2004). The total population was originally estimated to be 1.24 billion, later revised by the NBS to 1.27 billion (see the Main Data Bulletin of 2000 National Population Census). The NBS also adjusted the urban-to-rural population ratio from 36.9% to 36%.

⁷See Goodkind (2004). A similar estimate is obtained by Zhang and Cui (2003), who use primary school enrolments to back out the actual child population.

⁸The acute gender imbalance is taken into account in our model. However, demographers view it as unlikely that such imbalance will persist at the current high levels. Following Zeng (2007), we assume that the urban gender ratio will decline linearly from 1.145 to 1.05 from 2000 to 2030, and that the rural gender imbalance falls from 1.19 to 1.06 over the same time interval. No change is assumed thereafter. Our results are robust to plausible changes in the gender imbalance.

by provinces. Zeng (2007) estimates that such a policy would increase the urban TFR from 1.2 to 1.8 (*second scenario* in Zeng, 2007). This is in line with the explicit target of the Chinese authorities, as outlined by the National Health and Family Planning Commission (source: Xinhuanet November 15, 2013).

A long-run TFR of 1.8 implies an ever-shrinking population. We follow the United Nations population forecasts and assume that in the long run the population will be stable. This requires that the TFR converges to 2.08, which is the reproduction rate in our model, in the long run. In order to smooth the demographic change, we assume that both rural and urban fertility rates start growing in 2051, and we use a linear interpolation of the TFRs for the years 2051-2099. Since long-run forecasts are subject to large uncertainty, we also consider an alternative scenario with lower fertility.

3.1.2 Rural-urban migration

Rural-urban migration has been a prominent feature of the Chinese economy since the 1990s. There are two categories of rural-urban migrants. The first category comprises all individuals who physically move from rural to urban areas. It includes both people who change their registered permanent residence (i.e., *hukou* workers) and people who reside and work in urban areas but retain an official residence in a rural area (*non-hukou* urban workers).⁹ The second category comprises all individuals who do not move but whose place of registered residence switches from being classified as rural into being classified as urban.¹⁰ We define the sum of the two categories as the net migration flow (NMF).

We propose a simple model of migration where the age- and gender-specific emigration rates are fixed over time. Although emigration rates are likely to respond to the urban-rural wage gap, pension and health care entitlements for migrants, the rural old-age dependency ratio, and so on, we will abstract from this and maintain that the demographic development only depends on the age distribution of rural workers. It is generally difficult, even for developed countries, to predict the internal migration patterns (see Kaplan and Schulhofer-Wohl 2012). In China, pervasive legal and administrative regulations compound this problem.

We start by estimating the NMF and its associated distribution across age and gender. This

⁹There are important differences across these two subcategories. Most non resident workers are currently not covered by any form of urban social insurance including pensions. However, some relaxation of the system has occurred in recent years. The system underwent some reforms in 2005, and in 2006 the central government abolished the hukou requirement for civil servants (Chan and Buckingham, 2008). Since there are no reliable estimates of the number of non-hukou workers, and in addition there is uncertainty about how the legislation will evolve in future years, we decided not to distinguish explicitly between the two categories of migrants in the model. This assumption is of importance with regard to the coverage of different types of workers in the Chinese pension system. We return to this discussion below.

¹⁰This was a sizeable group in the 1990s: according to *China Civil Affairs Statistical Yearbooks*, a total of 8,439 new towns were established from 1990 to 2000 and 44 million rural citizens became urban citizens (Hu, 2003). However, the importance of reclassified areas has declined after 2000. Only 24 prefectures were reclassified as prefecture-level cities in 2000-2009, while 88 prefectures were reclassified in 1991-2000.

estimation is the backbone of our projection of migration and the implied rural and urban population dynamics. We use the 2000 census to construct a projection of the *natural* rural and urban population until 2005 based on the method described in section 3.1.1. We can then estimate the NMF and its distribution across age groups by taking the difference between the 2005 projection of the *natural* population and the realized population distribution according to the 2005 survey.¹¹ The technical details of the estimation can be found in the appendix.

According to our estimates, the overall NMF between 2001 and 2005 was 88 million, corresponding to 10.9% of the rural population in 2000.¹² Survey data show that the urban population grows at an annual 4.1% rate between 2000 and 2005. Hence, 89% of the Chinese urban population growth during those years appears to be accounted for by rural-urban migration. Our estimate implies an annual flow of 17.6 million migrants between 2001 to 2005, equal to an annual 2.3% of the rural population. This figure is in line with estimates of earlier studies. For instance, Hu (2003) estimates an annual flow between 17.5 and 19.5 million in the period 1996–2000.

The estimated age-gender-specific migration rates are shown in figure 1. Both the female and male migration rates peak at age fifteen, with 15.4% for females and 12.1% for males. The migration rate falls gradually at later ages, remaining above 1% until age thirty-nine for females and until age forty for males. Migration becomes negligible after age forty.

To incorporate rural-urban migration in our population projection, we make two assumptions. First, the age-gender-specific migration rates remain constant after 2005 at the level of our estimates for the period 2000–2005. Second, once the migrants have moved to an urban area, their fertility and mortality rates are assumed to be the same as those of urban residents.

Figure 2 shows the resulting projected population dynamics (solid lines). For comparison, we also plot the natural population dynamics (i.e., the population model without migration [dotted lines]). The rural population declines throughout the whole period. The urban population share increases from 51% in 2011 to 81% in 2050 and to over 95% in 2100. In absolute terms, the urban population increases from 470 million in 2000 to its long-run 1.1 billion level in 2050. Between 2050 and 2100

¹¹Our method is related to Johnson (2003), who also exploits *natural* population growth rates. Our work is different from Johnson’s in three respects. First, his focus is on migration across provinces, whereas we estimate rural-urban migration. Second, Johnson only estimates the total migration flow, whereas we obtain a full age-gender structure of migration. Finally, our estimation takes care of measurement error in the census and survey (see discussion above), which were not considered in previous studies.

¹²There are a number of inconsistencies across censuses and surveys. Notable examples include changes in the definition of city population and urban area (see, e.g., Zhou and Ma, 2003; Duan and Sun, 2006). Such inconsistencies could potentially bias our estimates. In particular, the definition of urban population in the 2005 survey is inconsistent with that in the 2000 census. In the 2000 census, urban population refers to the resident population (*changzhu renkou*) of the place of enumeration who had resided there for at least six months on census day. The minimum requirement was removed in the 2005 survey. Therefore, relative to the 2005 survey definition, rural population tends to be over-counted in the 2000 census. This tends to bias our NMF estimates downward.

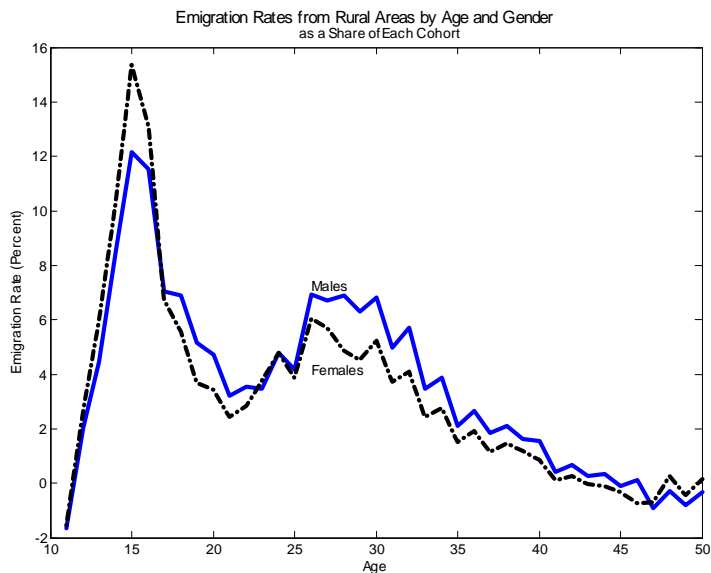


Figure 1: The figure shows rural-urban migration rates by age and gender as a share of each cohort. The estimates are smoothed by five-year moving averages.

there are two opposite forces that tend to stabilize the urban population: on the one hand, fertility is below replacement in urban areas until 2100; on the other hand, there is still sizeable immigration from rural areas.

Figure 3 plots the old-age dependency ratio (i.e., the number of retirees as percentage of individuals in working age [18-60]) broken down by rural and urban areas (solid lines).¹³ We also plot, for contrast, the old-age dependency ratio in the no migration counterfactual (dashed lines). Rural-urban migration is very important for the projection. The projected urban old-age dependency ratio is 52% in 2050, but it would be as high as 82% in the no migration counterfactual. This is an important statistic, since the Chinese pension system only covers urban workers, so its sustainability hinges on the urban old-age dependency ratio.

3.2 Calibration of wage and interest rate process

In this section, we calibrate the wage and interest rate process. We set the age-wage profile $\{\varpi_j\}_{j=23}^{59}$ equal to the one estimated by Song and Yang (2010) for Chinese urban workers. This implies an average annual return to experience of 0.5%.

Urban hourly wages (holding human capital constant) are assumed to grow at 5.7% between 2000

¹³In China, the official retirement age is 55 for females and 60 for males. In the rest of the paper, we ignore this distinction and assume that all individuals retire at age 60, anticipating that the age of retirement is likely to increase in the near future. We also consider the effect of changes in the retirement age.

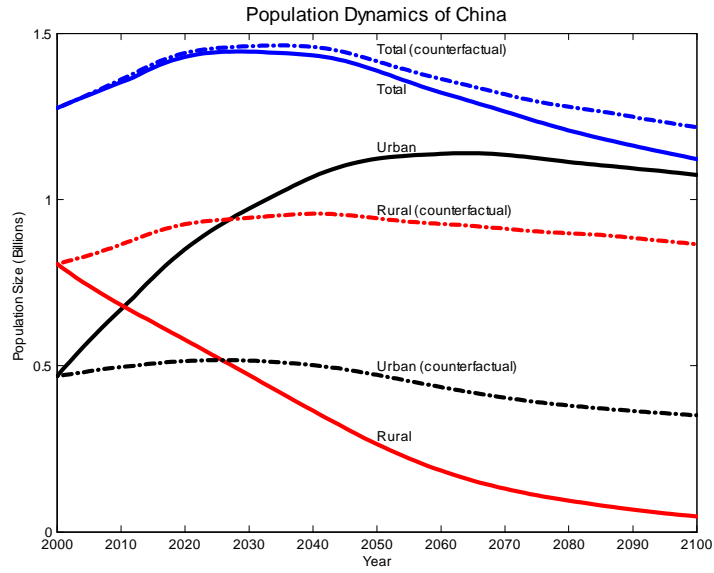


Figure 2: The figure shows the projected population dynamics for 2000-2100 (solid lines) broken down by rural and urban population. The dashed lines show the corresponding natural population dynamics (i.e., the counterfactual projection under a zero urban-rural migration scenario).

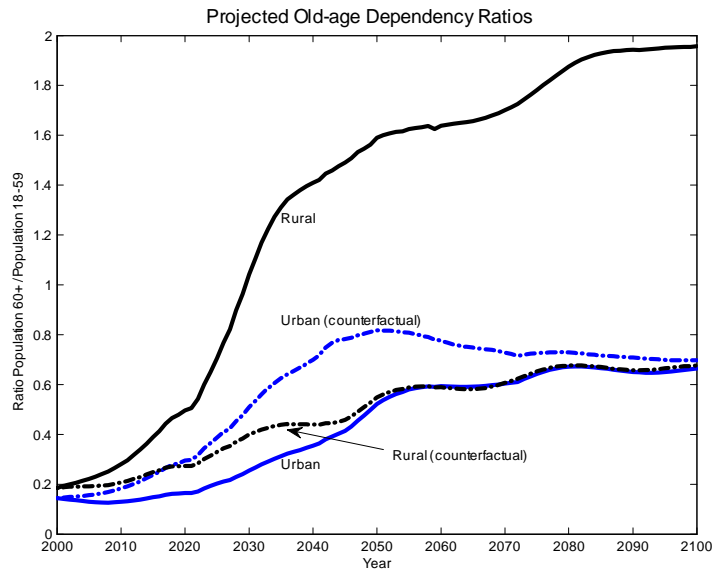


Figure 3: The figure shows the projected old-age dependency ratios, defined as the ratio of population 60+ over population 18-59, for 2000-2100 (solid lines) broken down on urban and rural population. The dashed lines show the corresponding ratios under the zero migration counterfactual (i.e., the natural population dynamics).

and 2013. This is consistent with the estimate of Ge and Yang (2014) for workers with only middle school education. We base the future wage sequence – which is essential for the quantitative results of the paper – on the (smoothed) forecast generated by a calibrated dynamic general-equilibrium model with credit market imperfections close in spirit to SSZ. That model is laid out in detail in the appendix (see, especially, figure III). This yields an annual growth of 4.9% for the period 2013-2031, followed by an annual growth of 3.6% for 2031-2040. After 2040, wages grow at 2% per year, in line with wage growth in the United States over the last century.

There has been substantial human capital accumulation in China over the last two decades. To incorporate this aspect, we assume that each generation has a cohort-specific education level, which is matched to the average years of education by cohort according to Barro and Lee (2013) – see figure IV in the appendix. The values for cohorts born after 1990 are extrapolated linearly, assuming that the growth in the years of schooling ceases in year 2000 when it reaches an average of 12 years, which is the current level for the US. We assume an annual return of 10% per year of education.¹⁴ Since younger cohorts have more years of education, wage growth across cohorts will exceed that shown in figure III (note though that the education level for an individual remains constant over each individual work life).

The average wage growth in the economy compounds the productivity growth per efficiency unit of labor shown in figure III with the effect of increasing educational attainment of the labor force. In addition, there is a small effect arising from changes in the age composition of workers: as we shall see, the experience-wage profile is upward sloping, so an ageing workforce implies somewhat higher average wages. When all these effects are incorporated, the average annual growth rate in the period 2012-2050 is 4.8%. This is a conservative forecast in light of the wage growth the last two decades (for example, Ge and Yang 2014, who estimate an annual 7.7% average wage growth in the period 1992-2007). However, our projected wage growth is in line with existing studies: Citibank forecasts an annual growth rate of GDP per capita of 5% over the period 2010-2050 (Buiters and Rahbari 2011, p.63). If the labor share remained constant, wage growth should remain aligned with GDP growth. In section 5.1 we perform some sensitivity analysis of the speed of future wage growth.

The rate of return on capital is very large in China (Bai *et al.* 2006). However, these high rates of return appear to have been inaccessible to the government and to the vast majority of workers and retirees. Indeed, in addition to housing and consumer durables, bank deposits are the main asset held by Chinese households in their portfolio. For example, in 2002 more than 68% of households' financial assets were held in terms of bank deposits and bonds, and for the median decile of households

¹⁴Zhang *et al.* (2005) estimated returns to education in urban areas of six provinces from 1988 to 2001. The average returns were 10.3% in 2001.

this share is 75% (Chinese Household Income Project 2002, henceforth CHIP). Moreover, aggregate household deposits in Chinese banks amounted to 76.6% of GDP in 2009 (China Statistical Yearbook 2010). High rates of return on capital do not appear to have been available to the government, either. Its portfolio consists mainly of low-yield bonds denominated in foreign currency and equity in state-owned enterprises, whose rate of return is lower than the rate of return to private firms (Dollar and Wei 2007).

SSZ provides an explanation – based on large credit market imperfections – for why neither the government nor the workers have access to the high rates of return of private firms. In this section, we simply assume that the annual rate of return for private and government savings is $R = 1.025$. We view a 2.5% annual return for the government savings as realistic. According to the National Council for Social Security Fund, the average share of pension funds invested in stock markets was 19% in 2003-2011.¹⁵ Assuming an average 6% annual return on stock and a 1.75% return on the remaining portfolio yields an average annual return of roughly 2.5%. This is also in line with the return on best-practice Western pension funds. For instance, the Credit Suisse Swiss Pension Fund has achieved a 2.25% annual rate of return between 2000-12. Concerning the return on private savings, a one-year real deposit rate in Chinese banks – the most typical saving instrument of private agents – was 1.75% during 1998-2005 (nominal deposit rate minus CPI inflation). Given that some households have access to savings instruments that yield higher returns, a 2.5% return seems a plausible assumption also for private agents. Note that our economy is dynamically efficient. Assuming $R < 1.02$ would imply that the rate of return is lower than the long-run growth rate of the economy, implying dynamic inefficiency. In such a scenario, there would be no need for a pension reform due to a well-understood mechanism (Abel *et al.* 1989).

In the appendix, we show that the wage rate dynamics in figure III and the assumed interest rate path are a close approximation to the equilibrium outcome of a calibrated dynamic general equilibrium model similar to SSZ, but augmented with the demographic model outlined above and a pension system. In the general equilibrium model, the wage and interest rate sequences are sufficient to compute the optimal decisions of workers and retirees about consumption and labor supply, as well as the sequence of budget constraints faced by the government. The model in SSZ matches well a number of salient macroeconomic trends for the recent period: output growth, wage growth, return to capital, transition from state-owned to private firms, and foreign surplus accumulation. The calibrated model is shown to yield plausible growth forecasts (although these are obviously subject to great uncertainty). The growth rate of GDP per worker remains about 7.5% per year until 2020. After 2020, productivity growth is forecasted to slow down. On average, China is expected to grow

¹⁵Source: http://www.ssf.gov.cn/xw/xw_gl/201205/t20120509_4619.html.

at a rate of 6.5% between 2013 and 2040. The contribution of human capital is 0.8% per year, due to the entry of more educated young cohorts in the labor force. In this scenario, the GDP per capita in China will be 68% of the US level by 2040, remaining broadly stable thereafter.

3.3 Calibration of preferences and wealth distribution

One period is defined as a year and agents can live up to 100 years ($J = 100$). The demographic process (mortality, migration, and fertility) is described in section 3.1. Agents become adult (i.e., economically active) at age $J_C = 22$ and retire at age 60, which is the male retirement age in China (so $J_W = 59$).¹⁶ Hence, workers retire after 38 years of work. The discount factor is set to $\beta = 1.0164$ to capture the average urban household savings rate in China between 2000-2012 (i.e., 25%). This is slightly higher than the value estimated by Hurd (1989) for the United States (i.e., 1.011). As a robustness check, in section 5 we consider an alternative economy where β is lower for all people born after 2013. The Frisch elasticity of labor supply in (1) is set to $\theta = 0.5$, in line with standard estimates in labor economics (Keane 2011).

Finally, we set the initial distribution of household wealth to match the empirical distribution of financial wealth in 1995 in the CHIP.¹⁷ We exclude households with dependents over the age of 22, though the results are not sensitive to controls on family structure. Given the 1995 wealth distribution, we simulate the model over the 1995-2000 period, assuming an annual wage growth of 5.7%, excluding human capital growth. The distribution of private wealth in 2000 is then obtained endogenously.

3.4 The current pension system

In this section, we lay out a set of taxes and pension entitlements that replicate the main features of China's current pension system. A more comprehensive description of the Chinese system can be found in the appendix.

The current Chinese system was originally introduced in 1986 and underwent a major reform in 1997. Before 1986, urban firms (which were almost entirely state owned at that time) were responsible for paying pensions to their former employees. This enterprise-based system became untenable in a market economy where firms can go bankrupt and workers can change jobs. The 1986 reform introduced a defined benefits system whose administration was assigned to municipalities. The new

¹⁶We have repeated the analysis assuming a retirement age of 57 for all workers. This is a weighted average of the male and female retirement age, according to the current statutory rules. The results are reported in the appendix. The fiscal imbalances of the system are larger. However, this does not change the main welfare results of the paper. We have opted for using a retirement age of 60 as a benchmark because we believe the pension age is likely to increase as the health of the Chinese population improves with economic progress.

¹⁷We exclude housing wealth in 1995 for two reasons. First, the data are highly uncertain. Second, the dynamics of housing wealth distribution are driven by valuation effects that reflect, partly, increasing cost of housing services. Including housing in the initial wealth distribution would have negligible consequences.

system came under financial distress, mostly due to firms evading their obligations to pay pension contributions for their workers.

The subsequent 1997 reform reduced the replacement rates for future retirees and tried to enforce social security contributions more strictly. The 1997 system has two tiers (plus a voluntary third tier). The first is a standard transfer-based basic pension system with resource pooling at the provincial level. The second is an individual accounts system. However, as documented by Sin (2005, p.2), “*the individual accounts are essentially ‘empty accounts’ since most of the cash flow surplus has been diverted to supplement the cash flow deficits of the social pooling account.*” Due to its low capitalization, the system can be viewed as broadly transfer-based, although it permits, as does the US Social Security system, the accumulation of a trust fund to smooth the aging of the population. Since the individual accounts are largely notional, we decided to ignore any distinction between the different pension pillars in our analysis.

We model the pension system as a defined benefits plan, subject to the intertemporal budget constraint, (11). In the appendix, we discuss more explicitly how the institutional details are mapped into the model. In line with the actual Chinese system, pensions are partly indexed to wage growth. We approximate the benefit rule by a linear combination of the average earnings of the beneficiary at the time of retirement and the current wage of workers, with weights 60% and 40%, respectively.¹⁸ More formally, the pension received at period $t + j$ by an agent who worked until period $t + J_W$ (and who became adult in period t) is:¹⁹

$$b_{t,t+j} = q_{t+J_W} \cdot (0.6 \cdot \bar{y}_{t+J_W} + 0.4 \cdot \bar{y}_{t+j-1}), \quad (9)$$

where $j > J_W$, and q_t denotes the replacement rate in period t and \bar{y}_t is the average pre-tax labor earnings for workers in period t :

$$\bar{y}_t \equiv \frac{w_t \sum_{j=0}^{J_w} \mu_{t-j} s_j \eta_{t-j} \varpi_j h_{t-j,t}}{\sum_{j=0}^{J_w} \mu_{t-j} s_j}, \quad (10)$$

where $\mu_{t-j} s_j$ is the number of agents of cohort $t - j$ (i.e., who became economically active in period $t - j$) who have survived until period t . In line with the 1997 reform (see Sin 2005), we assume that

¹⁸The current Chinese system specifies a partial indexation based on the increase in (regional) nominal wages. According to Sin (2005), the level of such indexation has ranged historically between 40% and 60%. In her study, she assumes a 60% indexation to nominal wage growth. Throughout our analysis, we abstract from inflation and assume a 40% indexation to real wage growth. Over the twenty years following the 2013 reform, the two approaches yield the same real pension growth as long as the annual inflation rate is 2.65%. However, the two approaches yield different indexation in the long run. Since any inflation forecast over long horizons would be speculative, we prefer to assume a real wage indexation, although this is not, strictly speaking, what the law says.

¹⁹Alternatively, the law of motion of pension benefits can be expressed as $b_{t,t+j} = b_{t+J_W+1} (0.6 + 0.4 \times (\bar{y}_{t+j-1}/\bar{y}_{t+J_W}))$. Note that the definition of the *replacement rate* in this section is different from that in the theoretical section 2.2. To avoid confusion we use a different notation (q_k instead of ζ_k).

pensioners retiring before 1997 continued to earn a 78% replacement rate throughout their retirement. Moreover, those retiring between 1997 and 2011 are entitled to a 60% replacement rate. We assume a constant social security tax (τ) equal to 20%, in line with the empirical evidence.²⁰

The current pension system of China covers only a fraction of the urban workers. The coverage rate has grown from 45% in 2001 to 60% in 2011 (see *China Statistical Yearbook* 2012). In the baseline model, we therefore assume a constant coverage rate of 60%. Workers who are not covered neither pay the social security tax nor do they receive pensions.

The coverage rate of migrant workers is a key issue. Since we do not have direct information about their coverage, we have simply assumed that rural immigrants get the same coverage rate as urban workers. This seems a reasonable compromise between two considerations. On the one hand, the coverage of migrant workers (especially low-skill non-hukou workers) is lower than that of non-migrant urban residents; on the other hand, the total coverage has been growing since 1997.²¹

3.5 The government budget constraint

The pension system is said to be *financially balanced* if, given an initial pension trust fund, A_0 , the government intertemporal budget constraint holds, i.e.,

$$\sum_{t=0}^{\infty} R^{-t} \left(\sum_{j=J_W+1}^J \mu_{t-j} s_j b_{t-j,t} - \tau_t \sum_{j=0}^{J_W} \mu_{t-j} s_j \varpi_j \eta_{t-j} w_t h_{t-j,t} \right) \leq A_0. \quad (11)$$

We set the initial wealth, A_0 , equal to 1% of GDP. This matches the observation from the National Statistics Bureau of China, according to which the pension trust fund amounted to 110 billion RMB in 2001. In a previous version of this paper, we assumed that all initial government wealth (amounting to 71% of GDP) can be committed to the pension system. In spite of the apparent large difference in initial wealth, the welfare effects of alternative reforms are almost identical. The main difference is that the size of the fiscal adjustment needed to balance the budget is smaller when the pension system has a larger initial fund.

3.6 The benchmark reform

Under our calibration of the model, the current pension system is not balanced. In other words, the intertemporal budget constraint, (11), would not be satisfied if the current rules were to remain in

²⁰The statutory contribution rate including both basic pensions and individual accounts is 28%. However, there is evidence that a significant share of the contributions is evaded, even for workers who formally participated in the system. See the appendix for details.

²¹According to a recent document issued by the National Population and Family Planning Commission, 28% of migrant workers are covered by the pension system (Table 5-1, 2010 Compilation of Research Findings on the National Floating Population).

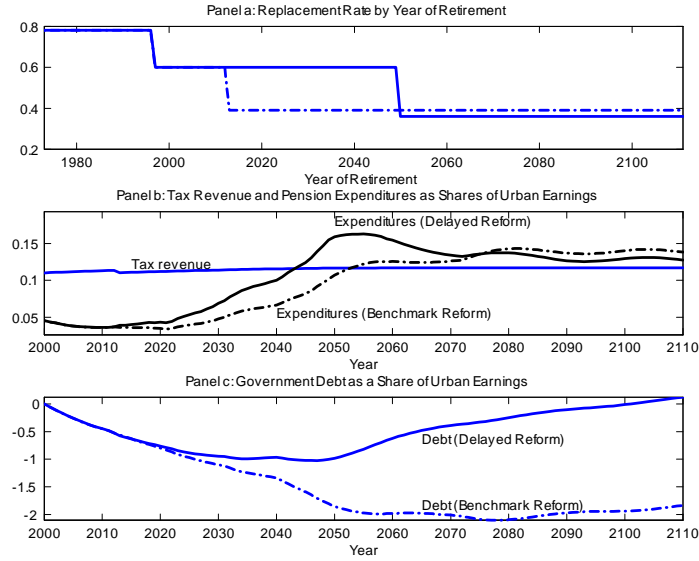


Figure 4: Panel *a* shows the replacement rate q_t for the benchmark reform (dashed line) versus the case when the reform is delayed until 2052. Panel *b* shows tax revenue and expenditures, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2052 is solid). Panel *c* shows the evolution of government debt, expressed as a share of aggregate urban labor income (the benchmark reform is dashed and the delay-until-2052 is solid). Negative values indicate a surplus.

place forever. For the intertemporal budget constraint to hold, it is necessary either to reduce pension benefits or to increase contributions.

We construct a benchmark pension system to which we compare alternative reforms. To ensure that this system is financially viable, we assume that (i) the existing rules apply for all workers who are already retired by 2013; (ii) the social security tax remains constant at $\tau = 20\%$ for all cohorts; (iii) for workers retiring in 2013 or later, the replacement rate is amended and set permanently to a new level q which is the highest constant level consistent with the intertemporal budget constraint, (11). All households are assumed to anticipate that the benchmark reform will take place in 2013. We refer to such a scenario as the *benchmark reform*.²²

The benchmark reform entails a large reduction in the replacement rate, from 60% to 39.1%. Namely, pensions must be cut by a third in order for the system to be financially sustainable. Such an adjustment is consistent with the existing estimates of the World Bank (see Sin, 2005, p.30). Alternatively, if one were to keep the replacement rate constant at the initial 60% and to increase taxes permanently so as to satisfy (11), then τ should increase from 20% to 30.7% as of year 2013.

Figure 4 shows the evolution of the replacement rate by cohort under the benchmark reform (panel

²²We cannot take as our benchmark an unbalanced system that retains the current statutory rules forever, since it would not make sense to compare its welfare properties with those associated with financially sustainable reforms.

a, dashed line). The replacement rate is 78% until 1997 and then falls to 60%. Under the benchmark reform, it falls further to 39.1% in 2013, remaining constant thereafter. Panel *b* (dashed line) shows that such a reform implies that the pension system runs a surplus until 2052. The government builds up a government trust fund amounting to 210% of urban labor earnings by 2080 (panel *c*, dashed line). The interests earned by the trust fund are used to finance the pension system deficit after 2052.²³

4 Alternative pension reforms

The theoretical analysis of section 2 shows that a social planner with a discount factor no higher than $(1 + g) / R$ (where, recall, g is the long run growth rate, and not the transitional wage growth in an emerging economy) wants to redistribute in favor of the poorer earlier generations. The benchmark reform, to the opposite, reduces current pension payments drastically in order to guarantee the financial sustainability of the pension in the long run.

In this section, we consider a set of alternative reforms that are also financially sustainable, but distribute the costs and benefits of the adjustment in a different way from the benchmark reform. We first consider a set of theoretically motivated reforms along the lines of Proposition 1 and Corollary 2. This provides a useful benchmark quantifying how large welfare gain one could possibly achieve through intergenerational redistribution. Then, we consider a set of policy reforms entailing less radical changes of the existing rules. We view these experiments as useful because they correspond closely to actual reforms that have been on the agenda of the policy debate in China and other countries. Each alternative policy reform is introduced as a “surprise”. Namely, agents expect the benchmark reform, but when 2013 arrives, unexpectedly, they learn that a different reform will take place. Subsequently, perfect foresight is assumed. This assumption is not essential. The main results are qualitatively identical and quantitatively very similar if one assumes that all reforms are perfectly anticipated in year 2000.

4.1 The welfare criterion

Since the main goal of our analysis is to quantify the welfare implications of different reforms, we first introduce a welfare criterion analogous to that used in the theoretical analysis of section 2. To this end, we measure, for each cohort, the equivalent consumption variation of each alternative reform relative to the benchmark reform. Namely, we calculate what (percentage) change in lifetime consumption

²³Note that in panel *c* the government net wealth (excluding debt) is falling sharply between 2000 and 2020 when expressed as a share of urban earnings, even though the government is running a surplus. This is because urban earnings are rising very rapidly due to both high wage growth and growth in the number of urban workers.

would make agents in each cohort indifferent between the benchmark and the alternative reform.²⁴ We then aggregate the welfare effects of different cohorts by means of a utilitarian social welfare function, where the weight of the future generation decays geometrically with a constant factor ϕ , as in section 2.2. The planner’s welfare function includes utilities of all agents alive in 2013 and the objective function is evaluated in year 2013 (decisions made before 2013 are held constant). Then, the equivalent variation is given by the value ω solving

$$\sum_{t=1935}^{\infty} \mu_t \phi^t \sum_{j=0}^J \beta^j u((1 + \omega) c_{t,t+j}^{BENCH}, h_{t,t+j}^{BENCH}) = \sum_{t=1935}^{\infty} \mu_t \phi^t \sum_{j=0}^J \beta^j u(c_{t,t+j}^*, h_{t,t+j}^*), \quad (12)$$

where superscripts *BENCH* stand for the allocation in the benchmark reform and asterisks stand for the allocation in the alternative reform.²⁵

The planner experiences a welfare gain (loss) from the alternative allocation whenever $\omega > 0$ ($\omega < 0$). We shall consider two particular values of the intergenerational discount factor, ϕ . First, $\phi = (1 + g) / R$, which is the benchmark discount factor discussed in section 2.2 (see Proposition 1 and Corollary 2) corresponding to a planner who prefers zero intergenerational redistribution in steady state. Since in our calibration $R = 1.025$ and $g = 0.02$, such a planner has an annual discount rate of 0.5%, a small number relative to standard calibrations.²⁶ For this reason, we label the planner with $\phi = (1 + g) / R$ as the *low-discount planner*. As a robustness, following Nordhaus (2007), we consider the case of $\phi = R^{-1}$, namely, the planner discounts future utilities at the market interest rate. We label such a planner as the *high-discount planner*. Relative to the low-discount benchmark, the high-discount planner will demand more intergenerational redistribution in favor of the earlier generations.

4.2 Theory-driven reforms

In this section, we compute the pension systems that implement the optimal policies of a low-discount planner, and compare it with the benchmark reform. In addition to the unconstrained optimum corresponding to Proposition 1 and labeled “first best”, we consider (i) a policy where the pension system is constrained to have non-negative pensions (labeled “second best”), and (ii) a more restrictive environment in which the planner cannot increase the generosity of the pension system relative to the

²⁴Note that we measure welfare effects relative to increases in *lifetime* consumption even for people who are alive in 2012. This approach makes it easier to compare welfare effects across generations.

²⁵Note that we sum over agents alive or yet unborn in 2012. The oldest person alive became an adult in 1935, which is why the summations over cohorts indexed by t start from 1935.

²⁶Most macroeconomic studies assume discount rates in the range of 3-5%. In the debate on global warming, Nordhaus suggests a 3% discount rate. Stern argues that this is ethically indefensible, and proposes to apply a 0.1% discount rate, although many economists criticize this low rate for yielding counterfactual implications (for instance, governments should accumulate assets rather than run debt). In this paper, we emphasize the quantitative normative prediction of the model when it is calibrated with the discount rates of 0.5% and 2.5%, which we regard as a conservative criterion.

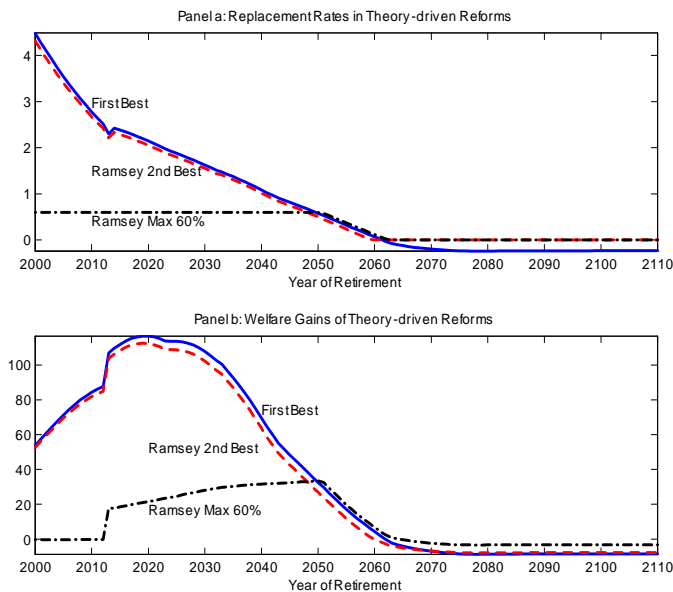


Figure 5: Panel *a* plots the sequence of cohort-specific replacement rates in the first best reform (blue solid line), second-best Ramsey reform with non-negative pensions (red dashed line), and Ramsey reform where future replacement rates are bounded between zero and 60% (black dash-dotted line). Panel *b* plots the corresponding consumption equivalent welfare gains for each cohort.

existing rules, namely, future replacement rates cannot exceed 60% (whereas the existing rules apply for the agents already retired in 2013).

The two panels of figure 5 show, respectively, the sequence of cohort-specific replacement rates in each of the three alternative reforms (upper panel), and the consumption equivalent welfare gain for each cohort relative to the benchmark reform (lower panel). The panels display only generations retiring after 2000.²⁷

Consider the first-best reform. The replacement rate is 230% for the cohort retiring in 2013. Thereafter, it falls roughly linearly with the retirement date until it reaches -23.7% in 2075. There are huge welfare gains for the transition generations – exceeding 100% for those retiring between 2013 and 2033. The welfare gains fall over time and converge to -8.7% for the cohort retiring after 2075. All generations retiring before 2062 gain from the reform. The welfare gain accruing to the low-discount planner is 3.7% of consumption. In the case of the high-discount planner the gain is a staggering 41.7%.

The second best reform (subject to non-negative benefits) yields a similar picture, although it delivers slightly lower replacement rates for the transition generations, reaching zero for cohorts retiring

²⁷The efficient scheme involves large transfers to the generations already retired. For instance, those retiring in 1990 receive a replacement rate equal to 738% in the first-best and to 698% in the second-best reform.

after 2060. Taxes are zero for cohorts retiring before 2060, implying that the system builds up a debt that is financed by taxes on future generations. In steady state, the tax rate reaches 10.2%. The welfare gain to the low-discount planner amounts to 3.6% of consumption.²⁸

Finally, consider the constrained Ramsey allocation where the replacement rate must stay between 0 and 60%. In this case, the replacement rate is exactly 60% for all cohorts retiring until 2050. The replacement rate falls and reaches zero in 2063. The steady-state taxes are lower (5.7%), because the pension system is less generous with the transition generation and does not build up such a large debt as in the previous case. The welfare gain to the low-discount planner is now substantially lower but still significant, being equal to 2% of consumption.

In conclusion, the quantitative normative analysis of this section has shown that even a planner with a very high weight on future generations would use the pension system to implement a radical intergenerational redistribution *in spite* of the averse demographics.

4.3 Policy-driven reforms

The benchmark reform achieves financial balance through a draconian permanent reduction in pension entitlements for all agents retiring after 2012. The analysis in section 4.2 shows that such adjustment puts too large a burden on current generations relative to the normative benchmark.

The optimal pension policies discussed above are informative about how to improve on the benchmark reform, but arguably difficult to implement. For instance, much of the current debate focuses on whether reforms reducing the generosity of the system are urgent or can be postponed, and on whether China should adopt rules that nudge the system in a more funded direction.

In this section, we consider a set of alternative sustainable reforms that speak more directly to the policy debate, and that would alter less radically the existing rules. We consider three types of reforms:

1. *Delayed reform*: we assume that the current rules are kept in place until period T (where $T > 2013$), in the sense that the current replacement rate ($q_t = 60\%$) applies for those who retire until period T , and taxes remain at 20%. Thereafter, the replacement rates are adjusted permanently so as to satisfy (11). Note that, since the current system is not financially balanced, a delay requires a larger cut in replacement rates after T . Year T is chosen optimally so as to maximize the planner's welfare. This reform entails a key aspect of the optimal policy:

²⁸We computed the first- and second-best (and the corresponding benchmark) reforms under the alternative assumption that $A_{2013} = 0$. The results are similar. The welfare gain of the first best increases from 3.75% to 3.79%, while the second best delivers smaller gains (3.67% vs. 3.64%). The planner delivers positive pensions until 2058, and the steady-state tax rate reaches 10.2%.

the replacement rate is decreasing over time, providing intergenerational distribution from the future richer generations to the current poorer transition generation.

2. *Fully-funded (FF) reform*: we replace the current transfer-based system with a mandatory saving-based scheme in 2013. In the FF reform scenario, defined benefit transfers are abolished in 2013. However, the government does not default on its outstanding liabilities (see footnote 30 for details). This reform entails an aspect of the optimal policy: it reduces the distortion caused by the social security tax, although it does not provide any intergenerational redistribution.
3. *Pay-as-you-go (PAYGO) reform*: we impose an annual balanced budget requirement to the pension system, keeping the social security tax at 20%. The benefit rate is endogenously determined by the tax revenue (which is, in turn, affected by the demographic structure and endogenous labor supply). Given the demographic transition and the initially high wage growth, this reform yields high pensions to the earlier generations, and low pensions to the future ones – in line with the optimal policy.

4.3.1 Delayed reform

We start by computing the optimal delay of the benefit cut. The optimal T for the low-discount planner turns out to be 2050. Namely, the current replacement rate continues to apply for all workers starting their employment before 2012, and the new lower replacement rate applies to workers starting their employment earliest 2012. This means that lower pensions will start being paid in 2050, and by 2090 all retirees will earn the new lower replacement rate.

Due to the delay, the fund accumulates initially a lower surplus, forcing a larger reduction of the replacement rate after 2050. Thus, relative to the benchmark reform, the delay shifts the burden of the adjustment from the current (poorer) generations to (richer) future generations.

Figure 4 describes the welfare gains of delaying the reform until 2050. Panel *a* shows that the post-reform replacement rate now falls to 36%, which is only 3.1 percentage points lower than the replacement rate granted by the benchmark reform. Panel *b* shows that the pension expenditure is higher than in the benchmark reform until 2075. Moreover, already in 2044 the system runs a deficit.

Figure 6 shows the welfare gains of four reforms relative to the benchmark, broken down by the year of retirement of each cohort. Consider the delayed reform experiment: There are large gains for agents retiring between 2013 and 2049, on average over 15.9% of their lifetime consumption. The main reason is that delaying the reform enables the transition generation to share the gains from high wage growth after 2013, to which pension payments are (partially) indexed. All generations retiring after 2050 lose, although their welfare losses are quantitatively small, being less than 1.7% of their

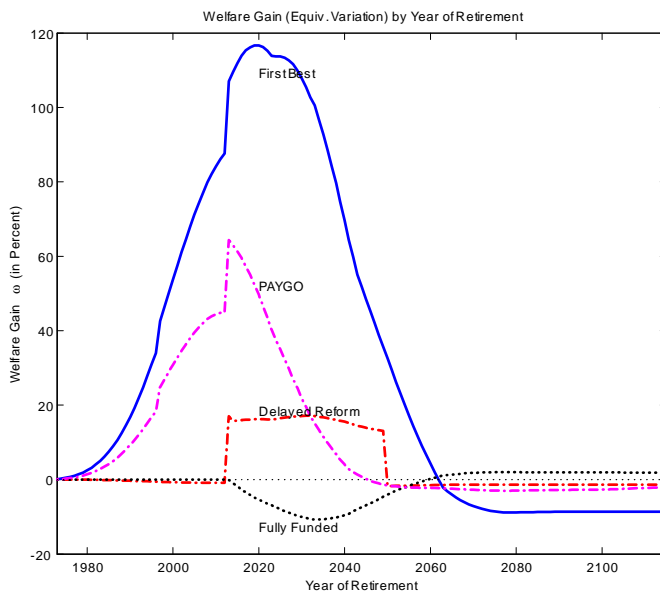


Figure 6: The figure shows welfare gains of the policy-driven alternative reforms relative to the benchmark reform for each cohort. For comparison, the welfare effects of the first-best policy is also plotted. The gains (ω) are expressed as percentage increases in consumption (see eq. 12).

lifetime consumption. Relative to the first best, the delayed reform implies too little intergenerational redistribution from future to current generations. Moreover, it entails labor supply distortions that are absent in the first-best reform. Yet, the low-discount planner enjoys a 0.9% welfare gain, corresponding to roughly one quarter of the potential gain in the first best, and half of the welfare gain obtained in the planning allocation subject to the constraint that the replacement rate must lie between zero and 60%.

Figure 7 shows the welfare gains/losses of delaying the reform until year T . The figure displays two curves: in the upper curve, we have the consumption equivalent variation of the high-discount planner, while in the lower curve we have that of the low-discount planner. As discussed above, it is optimal for the low-discount planner to delay the reform until 2050. The same delay would yield a much larger welfare gain (6.4%) for the high-discount planner whose utility is increasing in the entire range plotted by the figure.

4.3.2 Fully Funded Reform

Consider, next, switching to a FF system, i.e., a pure contribution-based pension system featuring no intergenerational transfers, where agents are forced to save for their old age in a fund that has access to the same rate of return as that of private savers. As long as agents are rational and have

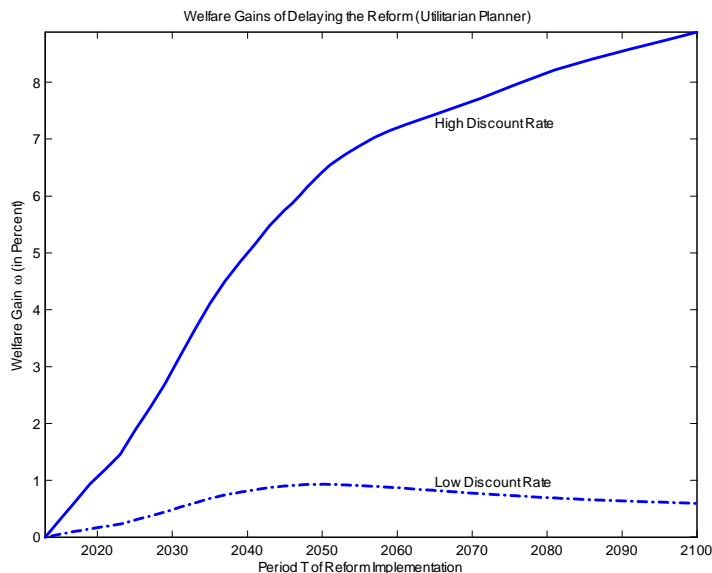


Figure 7: The figure shows the consumption equivalent gain/loss accruing to a high-discount planner (solid line) and to a low-discount planner (dashed line) of delaying the reform until time T relative to the benchmark reform. When $\omega > 0$, the planner strictly prefers the delayed reform over the benchmark reform.

time-consistent preferences, and mandatory savings do not exceed the savings that agents would make privately in the absence of a pension system, a FF system is equivalent to no pension system.²⁹ As discussed above, the government does not default on existing claims: all workers and retirees who have contributed to the pension system are refunded the present value of the pension rights they have accumulated.³⁰ Since the social security tax is abolished, the existing liabilities are financed by issuing government debt. This debt is rolled over and serviced by a constant labor income tax (implying that the outstanding debt level can fluctuate over time). This scheme is similar to that adopted in the 1981 pension reform of Chile.

Figure 8 shows the outcome of this reform. The old system is terminated in 2013, but people with accumulated pension rights are compensated as discussed above. To finance such a pension buy out scheme, government debt must increase to over 200% of urban labor earnings in 2013. A permanent 0.6% annual tax is needed to service the debt. The government debt first declines as a share of total labor earnings due to high wage growth in that period, and then stabilizes at a level about 60% of labor earnings around 2040. Future generations live in a low-tax society with no intergenerational

²⁹Bohn (2011) shows that such equivalence breaks down in the presence of political or financial constraints. These aspects are ignored in our paper.

³⁰In particular, people who have already retired are given an asset worth the present value of the pensions according to the old rules. Since there are perfect annuity markets, this is equivalent to the pre-reform scenario for those agents. People who are still working and have contributed to the system are compensated in proportion to the number of years of contributions.

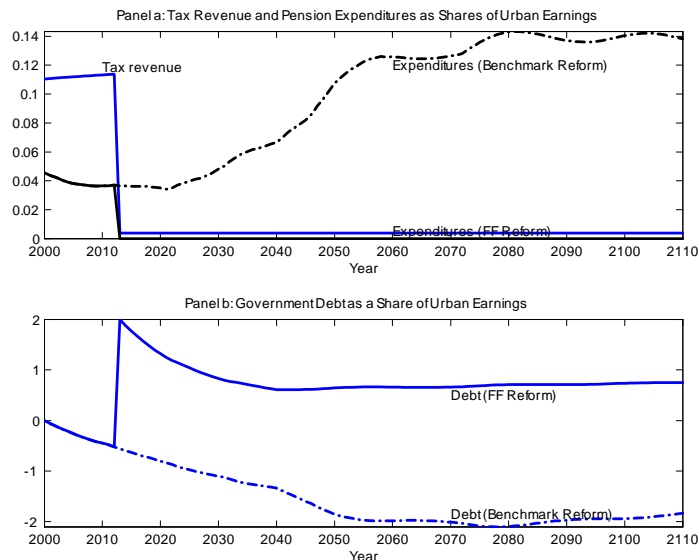


Figure 8: The figure shows outcomes for the fully funded reform (solid lines) versus the benchmark reform (dashed lines). Panel *a* shows the replacement rates. Panel *b* shows the government debt as a share of aggregate urban labor income.

transfers.

As shown in figure 6, the distributional effects are opposite to those of the delayed reforms. The cohorts retiring between 2013 and 2059 are harmed by the FF reform relative to the benchmark. There is no effect on earlier generations, since those are fully compensated by assumption. The losses are also modest for cohorts retiring soon after 2013, since these have earned almost full pension rights by 2013. However, the losses increase for later cohorts and become as large as 10.6% for those retiring in 2030-2035. For such cohorts, the system based on intergenerational transfer is attractive, since wage growth is high during their retirement age (implying fast-growing pensions), whereas the returns on savings are low. Losses fade away for cohorts retiring after 2050 and turn into gains for those retiring after 2059. However, the long-run gains are modest.

The FF reform yields a 0.2% consumption equivalent gain for the low-discount planner. This small gain arises from two opposite effects: on the one hand, the FF reform reduces the labor supply distortion, due to the lower taxes; on the other hand, it does worse than the benchmark reform in terms of the intergenerational redistribution desired by the planner. As the high-discount planner values intergenerational redistribution more than the low-discount planner, the former strictly prefers the benchmark over the FF reform, with a consumption equivalent discounted loss of 3.3%.

4.3.3 Pay-as-you-go reform

The delayed reform experiment was restricted by design to yield a two-tier replacement rate (pre- and post-reform) with a maximum replacement rate of 60% for the generations before the reform. In contrast, the optimal policy features a declining benefit sequence with very high replacement rates for the initial generations (particularly, for those already retired). In an aging economy, a pure PAYGO system would precisely yield a smooth decline in replacement rates. However, relative to the optimal policy, a PAYGO entails tax distortions that the planner dislikes, as we showed.

In this section, we consider the effect of switching to a PAYGO. We maintain the contribution rate fixed at $\tau = 20\%$ and assume that the benefits equal the total contributions in each year. Therefore, the pension benefits b_t in period t are endogenously determined by the following formula:³¹

$$b_t = \frac{\tau \sum_{j=0}^{J_W} \mu_{t-j} s_j \varpi_j \eta_{t-j} w_t h_{t-j,t}}{\sum_{j=J_W+1}^J \mu_{t-j} s_j}.$$

Figure 9 shows the outcome of this reform. Panel *a* reports the pension benefits as a fraction of the average earnings by year. Note that this notion of replacement rate is different from that used in the previous experiments (panel *a* of figures 4 and 8); there the replacement rate was cohort specific and was computed according to equation (9) by the year of retirement of each cohort. Until 2053, the PAYGO reform implies larger average pensions than does the benchmark reform.

Panel *b* shows the lifetime pension as a share of the average wage in the year of retirement, by cohort. This is also larger than in the benchmark reform until the cohort retiring in 2045. We should note that, contrary to the previous experiments which were neutral vis-à-vis cohorts retiring before 2013, here even earlier cohorts benefit from the PAYGO reform, since the favorable demographic balance yields higher pensions than what they were promised. This can be seen in panel *b* of figure 9 and figure 6. Welfare gains are very pronounced for all cohorts retiring before 2045, especially so for those retiring right after 2013, who would suffer a significant pension cut in the benchmark reform. These cohorts retire in times when the old-age dependency ratio is still very low, so benefits are large. Generations retiring after 2045 instead lose.

Due to the strong redistribution in favor of poorer early generations, in spite of the tax distortion, the utilitarian welfare is significantly higher under the PAYGO reform than in the benchmark reform, for both a high- and low-discount planner. The consumption equivalent gains relative to the benchmark reform are, respectively, 12.4% and 1.6% for urban workers. These gains are larger than under all alternative reforms (including delayed and FF reform).

³¹Note that the pension system has accumulated some wealth before 2012. We assume that this wealth is rebated to the workers in a similar fashion as the implicit burden of debt was shared in the fully funded experiment. In particular, the government introduces a permanent reduction δ in the labor income tax, in such a way that the present value of this

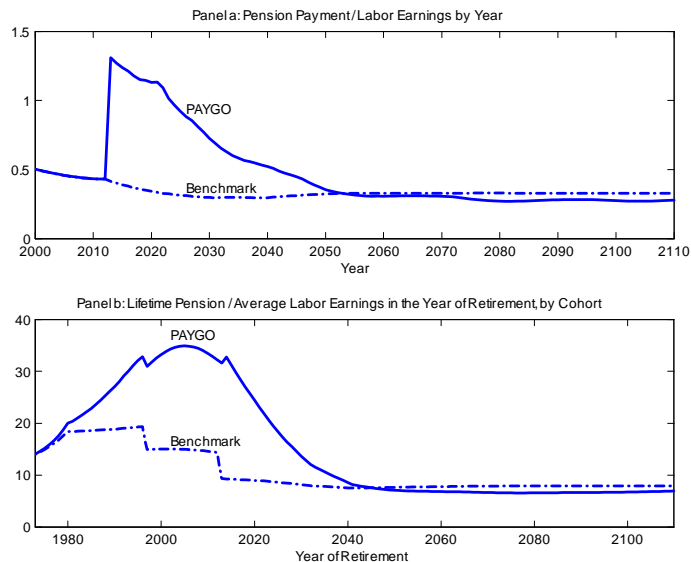


Figure 9: Panel *a* shows the average pension payments in year t as a share of average wages in year t for the PAYGO (solid) and the benchmark reform (dashed line). Panel *b* shows the ratio of the lifetime pensions (discounted to the year of retirement) to the average labor earnings just before retirement for each cohort.

5 Sensitivity analysis

In this section, we study how the main results of the previous section depend on structural features of the model economy: wage growth, population dynamics, and interest rate. We also show that the results are robust to modeling the pension system as comprising two separate budgets for the defined benefit and individual account component. We refer to the calibration of the model used in the previous section as the *baseline economy*. Table 1 summarizes the results discussed throughout this section. Each column reports the welfare effects of different reforms accruing to the high- and low-discount planner relative to a particular environment.

5.1 Lower wage growth

In the analysis above, Chinese wages grow fast over the next twenty-five years, and converge to 54% of the US level by 2040. Thereafter, the gap remains constant. In the theoretical analysis of section 2, the sequence of fast convergence followed by a growth slowdown is the key source for the welfare gain of intergenerational redistribution. In this section, we consider two alternative wage scenarios; (1) zero growth over and above the 2% long-run growth so the long-run wages are lower than in the baseline scenario (no convergence), and (2) slower wage growth, i.e., a slower convergence to the same tax subsidy equals the 2012 accumulated pension funds. In our calibration, we obtain $\delta = 0.59\%$.

Planner's discount rate	Delayed until 2050		Delayed until 2100		Fully Funded		PAYGO	
	high	low	high	low	high	low	high	low
Baseline parameterization	6.4%	0.9%	8.9%	0.6%	-3.3%	0.2%	12.4%	1.6%
Slow wage convergence	6.4%	1.0%	9.0%	0.7%	-3.6%	0.1%	12.3%	1.7%
Low wage growth	3.3%	-0.1%	5.6%	-0.4%	-0.6%	0.8%	5.0%	-0.1%
Low fertility	8.5%	3.2%	11.2%	0.5%	-2.6%	-0.5%	14.9%	4.8%
Slow migration	6.5%	0.9%	8.7%	0.6%	-3.3%	0.2%	11.5%	1.6%
High interest rate	3.2%	-0.1%	4.9%	-0.5%	0.4%	0.5%	9.5%	-0.1%
Two separate pillars	6.2%	1.0%	7.8%	0.8%	-2.2%	-0.1%	7.6%	1.2%

Table 1: The table summarizes the welfare effects (measured in terms of compensated variation in consumption for the high- and low-discount rate planners, respectively) of alternative pension reforms relative to the benchmark 2013 reform.

wage level as in the baseline scenario. As we shall see, the welfare implications of pension reforms differ sharply across these two alternative wage growth scenarios.

5.1.1 Scenario 1: Low wage growth (no convergence)

In no convergence scenario, we assume wage growth to be constant and equal to 2% after 2013. In this case, the benchmark reform implies a replacement rate of 40.4%.³²

The welfare effects of the alternative reforms (assuming the low wage growth) are displayed in the first row of panels in figure 10 and aggregated in the second row of table 1. In general, the welfare gains of the earlier generations relative to the benchmark 2013 reform are significantly smaller than in the baseline wage growth economy. For instance, if the reform is delayed until 2050 (yielding a replacement rate of 37%) the cohorts retiring between 2013 and 2049 experience a welfare gain ranging between 8.3% and 9.8%. The cost imposed on future generations remains similar in magnitude to that of the baseline economy. For the low-discount planner, there is a tiny loss from delaying. The high-discount planner continues to enjoy a positive welfare gain (3.3%), albeit significantly lower than in the baseline economy. This is not surprising, since the high-discount planner wants a declining replacement rate sequence even in steady state (see Proposition 1).

As in the baseline case, the FF alternative reform harms earlier cohorts, whereas it benefits all cohorts retiring after 2046. However, the relative losses of the earlier cohorts are significantly smaller than in the baseline economy. For instance, the cohort that is most negatively affected by the FF reform suffers a loss of 3.9% in the low wage growth economy, compared to a 10.7% loss in the baseline economy. The low-discount planner would now prefer the FF reform over any of the alternatives –

³²Note that in the low wage growth economy, the present value of the pension payments is lower than in the baseline economy, since pensions are partially indexed to the wage growth. Thus, pensions are actually lower, in spite of the slightly higher replacement rate.

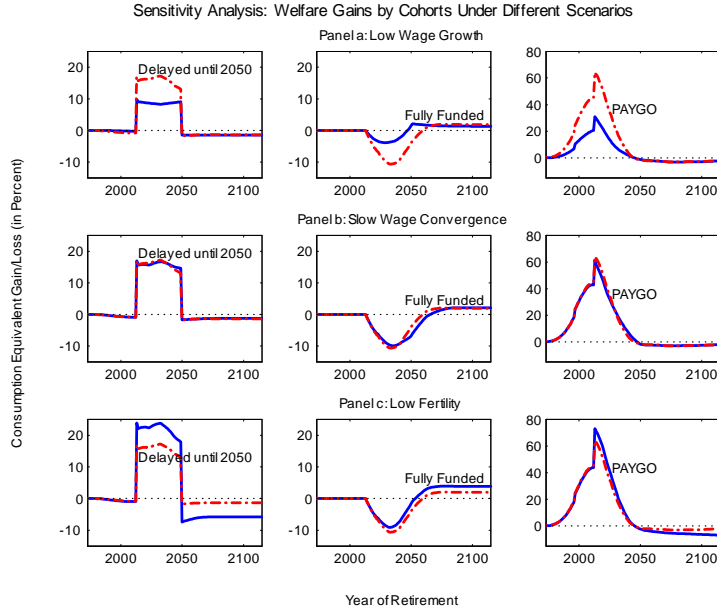


Figure 10: The figure shows consumption equivalent gains/losses accruing to different cohorts in three alternative scenarios. The top panels refer to the slow wage converge scenario of section 5.1.2. The middle panels refer to the low wage growth (no convergence) scenario of section 5.1.1. The bottom panels refer to the low fertility scenario of section 5.2. In each panel, the dashed lines refer to the welfare gains under the benchmark calibration (see section 4). The left-hand panels show the consumption equivalent gains/losses associated with delaying the reform until 2052 (solid lines). The center panels show the consumption equivalent gains/losses associated with a fully funded reform (solid lines). The right-hand panels show the consumption equivalent gains/losses associated with a PAYGO reform (solid lines).

the welfare gain arising from the reduction in the tax wedge. Finally, the large welfare gains from the PAYGO alternative reform by and large vanish. The low-discount planner would now prefer the benchmark reform to the PAYGO reform.

5.1.2 Scenario 2: Slower convergence

In this scenario, we assume an annual wage growth of 4% until 2050, and 2% thereafter. From 2050 and onward, the wage gap between China and the US is 54%, as in the baseline scenario.

The results of this experiment are quantitatively similar to the baseline case. Delaying the reform until 2050 requires lowering the replacement rate (relative to the benchmark 2013 reform) by 3 percentage points, as in the baseline wage growth scenario. The mid-left panel of figure 10 plots the welfare gains/losses of generations retiring between 2000 and 2110 in the case of a delay of the reform until 2050. The continuous line refers to the slow wage growth scenario, whereas the dashed line refers to the baseline wage growth scenario, for comparison. From the social planner's standpoint, the net

effect of delaying the reform is about the same: delaying the reform until 2050 delivers a consumption-equivalent welfare gain to the low (high) discount planner of 1.0% (6.4%), approximately the same as in the baseline scenario (see the third row of table 1).³³

The distribution of welfare gains in the FF and PAYGO experiments are essentially the same as in the baseline economy (see mid-center and mid-right panels of figure 10). The PAYGO reform continues to dominate over all alternative options: a gain of 1.7% (12.3%) accrues the low (high) discount planner, compared to 1.6% (12.4%) in the baseline case.

5.1.3 Summary

In summary, wage convergence, a typical feature of emerging economies, is critical for the welfare gains of delaying a reform (or of switching to PAYGO as opposed to a FF system). It is the convergence per se rather than its speed that matters. We have considered two scenarios in which the average Chinese wage converges to 54% of the US level (an assumption that we regard as realistic, if conservative). In one case, convergence ends in 2040, in another it takes until 2050. The welfare implications of the alternative pension reforms considered are essentially identical. In contrast, the results are very different, even reversed, if we shut down the process of wage convergence. The comparison with a constant 2% wage growth scenario is especially revealing, since it is consistent with the standard assumption for pension analyses of developed economies.

5.2 Lower fertility

Our forecasts are based on the assumption that the TFR will increase to 1.8 already in 2013. In this section, we consider an alternative lower fertility scenario along the lines of scenario 1 in Zeng (2007). In this case, the rural and urban TFRs are assumed to be 1.98 and 1.2 forever, implying an ever-shrinking total population. We view this as a lower bound to reasonable fertility forecasts. Next, we consider the welfare effects of the two alternative reforms. The three bottom panels of figure 10 show the age distribution of the welfare effects and the gains are aggregated in the fourth row of table 1.

Under this low-fertility scenario, the benchmark reform requires an even more draconian adjustment. The replacement rate must be set equal to 33.4% as of 2013. Delaying the reform is now substantially more costly. A reform in 2050 requires a replacement rate of 20.8%. The trade-off between current and future generations becomes sharper than in the baseline economy. On the one

³³For simplicity, we report the welfare gain of delaying the reform until the same year as was optimal in the baseline scenario, i.e., $T = 2050$. However, with slower convergence the low-discount planner would find it optimal to delay the reform until 2052. The reason is that there are now more poor generations, and thus the planner would want to retain for longer the old generous replacement rate.

hand, there are larger gains for the cohorts retiring between 2013 and 2050 relative to the benchmark reform. On the other hand, the delay is more costly for the future generations. Aggregating gains and losses yields a gain for the low-discount planner of 3.2%, significantly larger than in the baseline economy. The FF reform exhibits larger losses than in the baseline model (even the low-discount planner prefers the benchmark to a FF reform). Moreover, the PAYGO reform yields larger gains than in the benchmark reform.

The reason for the larger gains from delaying the reform or switching to PAYGO is related to the fact that an economy with a low population growth is intrinsically poorer – which is reflected in a lower replacement rate in the benchmark case. Thus, sticking to the current rule (60% replacement rate for the earlier generations) implies more intergenerational redistribution than in the baseline economy. Since we have shown that the planner would like substantially larger replacement rates than 60% for the transition generation (see figure 5), the low population growth relaxes the constraint for the planner. Thus the planner has a stronger preference for the delayed reform than in the richer baseline economy. A similar argument applies to the PAYGO reform.

5.3 Slower migration

In the baseline case, the future age-specific migration rates are assumed to be time invariant. One might find it plausible that as urbanization proceeds, the migration rates will dwindle. We considered the following alternative experiment: we scaled down all migration rates to 55.2% of the baseline rates. This implies that the urban share of the total population is 67.6% in 2050, compared to 80.9% in the baseline economy. We view this as a lower bound to a realistic description of the migration process. The results are quantitatively similar. In fact, the adjustment of the replacement rate required to achieve financial sustainability is slightly lower (a difference at the second digit) under slow migration than in the baseline scenario. Intuitively, in the initial years (i.e., until 2038) the migration flow is larger in the baseline scenario. However, after 2039 the slow migration scenario implies a larger migration flow (i.e., migrants per year), since more people are left in the rural areas and fertility remains high there (see figure VIII in the appendix). Thus, in the slow migration scenario more migrants enter the urban sector when wages are already high and wages and pensions grow slowly. This makes for a larger contribution to the pension system than does a massive migration in the first period, when productivity is still low and wage and pension growth are higher. The comparison between alternative reforms yields similar results to the baseline model (see table 1).

5.4 High interest rate

In the macroeconomic literature on pension reforms in developed economies, it is common to assume that the return on the assets owned by the pension fund is equal to the marginal return to capital. In this paper, we have calibrated the return on assets to 2.5%. However, the empirical rate of return on capital in China has been argued to be much higher (see discussion above). To get a sense of the role of this assumption, we now consider a scenario in which the interest rate is much higher – equal to 6% – between 2013 and 2050.³⁴

There are two main differences between the scenarios with lower and higher interest rates. First, delaying the reform yields much smaller gains for the transitional generations, and in fact the low-discount planner is essentially indifferent between the benchmark reform and a delay until 2050. Second, the FF reform entails larger gains for the future generations and smaller losses for the current generations relative to the baseline calibration. As should be expected, when the interest rate is significantly higher than the average growth rate, the PAYGO system becomes less appealing, because the gains to current generations are smaller. In particular, the low-discount planner prefers the FF to the PAYGO reform.

5.5 A two-pillar system with perfect separation

In the analysis so far we have ignored an important institutional feature of the Chinese pension system, namely, the distinction (introduced with the 1997 reform) between a defined benefit (*first pillar*) component granting a 35% replacement rate and an individual account (*second pillar*) component estimated to pay an average 24.3% replacement rate (see Hu *et al.* 2007). As discussed above, our choice is motivated by the observation that the second pillar is largely notional, due to its undercapitalization. Although the two pillars are formally managed by different authorities, it is unclear to what extent the commitment not to engage in cross-subsidization is credible. This motivates our choice to treat the two pillars as being part of the same fungible pool of resources in the main analysis above. In this section, we explore the alternative assumption that individual accounts belong to a totally separate budget and cannot be reneged upon. Thus, a sustainable reform can only pertain to the first pillar.

An important feature that must be taken into account is that the 1997 reform makes provisions for generations that have not accumulated significant individual accounts. For instance, a worker retiring in the year 2000 would only have had three years to build up her account at the time of the reform. Therefore, in order to capture the formal rules of the system, one must take into account that the move towards a two-pillar system is gradual and implies no default vis-a-vis the generations that

³⁴See Song *et al.* (2014) for an extensive discussion of the interest rate policy and capital market constraints in China.

contributed to the pre-reform system. More specifically, we assume that the new two-pillar system applies in its integrity to the generations entering the labor force after 1997, while the application is gradual for earlier generations. Although the details of the actual implementation are somewhat opaque, we assume a linearly declining first-pillar replacement rate from 78% in 1996 to 35% in 2035. Recall that in our model individual accounts can be ignored as they are equivalent to personal savings. We set the post-reform social security tax rate pertaining to the first pillar to 12%. This takes into account the high evasion rates that are common in China.³⁵ This contribution rate starts applying already in 1998 and, as before, is kept constant over time and across experiments.

As in the baseline economy, the system based on the 1997 rules is not sustainable. In particular, while individual accounts are sustainable by construction, the first pillar is severely underfunded. In line with the analysis in section 3, we set as our benchmark a draconian reform that reduces the replacement rate suddenly and permanently to a new constant level in 2013 so as to meet the intertemporal budget constraint. The new replacement rate is in this case 23.2%. Note that this level is substantially lower than the statutory 35% replacement rate. Moreover, it applies right away to all generations retiring from 2013 and onwards.

We contrast the benchmark reform to a delayed reform in which the statutory rules continue to apply until 2049. Namely, the replacement rate declines gradually to 35% in 2035, and remains constant until 2049 when the sustainable reform is applied. The replacement rate that applies from 2050 and onwards is 21%, more than two percentage points less than in the draconian reform.

Panel *a* of figure 11 displays the replacement rate by the year of retirement in the benchmark (dotted line) and delayed (solid line) reform. Panel *b* of figure 11 shows the associated welfare gains broken down by cohorts. Relative to the baseline economy of section 2 which does not distinguish between the two pillars, there are now larger gains for the cohorts retiring earlier than 2028, and smaller (but still substantial) gains for cohorts retiring 2028-2049. The reason is that the statutory replacement rate in the two pillar system declines gradually, so the older cohorts have more to gain from the delay than in the baseline economy. The consumption equivalent gain for the low-discount planner is now marginally larger. The comparison between the benchmark reform and other alternatives (fully-funded, PAYGO) yield similar results to the baseline economy: the PAYGO yields a 1.2% welfare gain, whereas the FF reform is approximately equivalent to the benchmark draconian reform (see the last row of table 1).

We conclude that our results are qualitatively and quantitatively robust to modelling the Chinese

³⁵Recall that the statutory contribution rates for the first and second pillars are 20% and 8%, respectively. We assume there is tax evasion only for the first pillar. The assumption is based on the substitutability between wages and contributions to the second pillar under a fully consolidated individual account. This implies an actual contribution rate of 12% to the first pillar.

pension system more closely to its statutory rules, assuming full commitment on individual accounts.

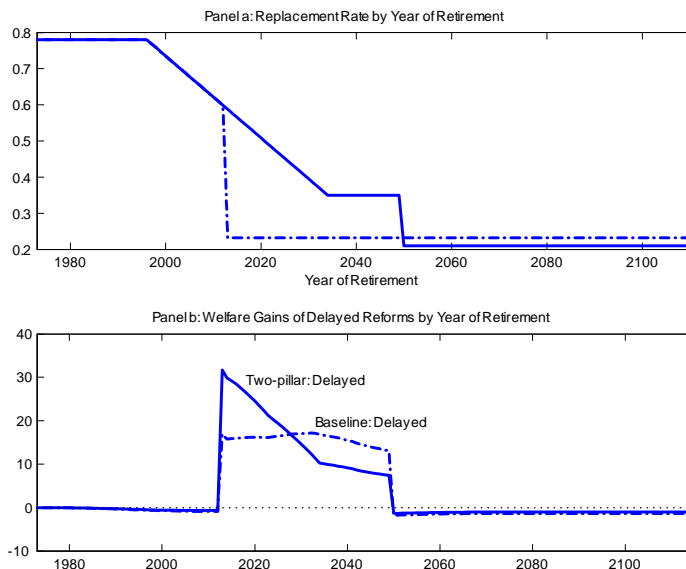


Figure 11: Panel *a* shows the replacement rate q_t for the two-pillar benchmark reform (dashed line) versus the case when the reform of the two-pillar system is delayed until 2050 (solid line). Panel *b* shows the welfare gains of delaying the reform of the two-pillar system relative to the two-pillar benchmark reform for each cohort (solid line). It also reports, for comparison, the welfare gain of delaying the reform in the baseline economy (dashed line, cf. figure 4). The gains (ω) are expressed as percentage increases in consumption (see eq. 12).

6 Rural Pension

The vast majority of people living in rural areas are not covered by the current Chinese pension. In accordance with this fact, we have so far maintained the assumption that only urban workers are part of the pension system. In this section, to contribute to the lively policy debate on this issue, we study the welfare implications of extending the system to rural workers.

Although a rural and an urban pension system could in principle be separate programs, we assume here that there is a consolidated intertemporal budget constraint, namely, the government can transfer funds across the rural and urban budgets. This is consistent with the observation that the modest rural pension system that China is currently introducing is heavily underfunded, suggesting that the government implicitly anticipates a resource transfer from urban to rural areas. The modified

consolidated government budget constraint then becomes

$$A_0 + \sum_{t=0}^{\infty} R^{-t} \left(\sum_{j=0}^{J_W} \varpi_j [\tau_t \mu_{t-j} s_j w_t h_{t-j,t} + \tau_t^r \mu_{t-j}^r s_j w_t^r h_{t-j,t}^r] - \sum_{j=J_W+1}^J [\mu_{t-j} s_j b_{t-j,t} + \mu_{t-j}^r s_j b_{t-j,t}^r] \right) \geq 0, \quad (13)$$

where superscripts r denote variables pertaining to the rural areas, whereas urban variables are defined, as above, without any superscript.

We assume the rural wage rate to be 54% of the urban wage in 2000, consistent with the empirical evidence from the China Health and Nutrition Survey. The annual rural wage growth is assumed to be on average 4.1% between 2000-2024, and 2% thereafter (see figure VI in the appendix).

We consider two experiments. In the first (*low-scale reform*), we introduce a rural pension system with rules that are different from those applying to urban areas in 2013. This experiment mimics the rules of the new old-age programs that the Chinese government is currently introducing for rural areas (see appendix). Based on the current policies, we set the rural replacement rate (q_t^r) and contribution rate (τ_t^r) to 20% and 6%, respectively. These rates are assumed to remain constant forever. Moreover, we assume that all rural inhabitants older than retirement age in 2013 are eligible for this pension. Introducing such a scheme in 2013 would worsen the fiscal imbalance. Restoring the fiscal balance through a reform in 2013 requires the replacement rate of urban workers to be cut to $q_t = 37.8\%$, i.e., 1.3 percentage points lower than in the benchmark reform without rural pensions. Hence, the rural pension implies a net transfer from urban to rural inhabitants.

A low-discount planner who only cares for urban households participating in the pension system would incur a welfare loss of less than 0.7% from expanding the pension system to rural inhabitants. In contrast, a low-discount planner who only cares for rural households would incur a welfare gain of 12%. When weighting rural and urban households by their respective population shares, one obtains an aggregate welfare gain of 1.7% relative to the benchmark reform.

The second experiment (*drastic reform*) consists of turning the Chinese pension system into a universal system, pooling all Chinese workers and retirees – in both rural and urban areas – into a system with common rules. As of 2013, all workers contribute 20% of their wage. In addition, the system bails out all workers who did not contribute to the system in the past. Namely, all workers are paid benefits according to the new rule even though they had not made any contribution in the past. Although rural and urban retirees have the same replacement rate, pension benefits are proportional to the group-specific wages (i.e., rural [urban] wages for rural [urban] workers). As in the benchmark reform above, the replacement rate is adjusted in 2013 so as to satisfy the intertemporal budget constraint of the universal pension system. Although we ignore issues with the political and administrative feasibility of such a radical reform, this experiment provides us with an interesting

upper bound of the effect of a universal system.

The additional fiscal imbalance from turning the system into a universal one is surprisingly small: the replacement rate must be reduced to $q_t = 38\%$ from 2013 onward, relative to 39.1% in the benchmark reform. The welfare loss for urban workers participating in the system is very limited (marginally lower than in the low-scale reform). In contrast, there are sizable welfare gains for rural workers and for the urban workers who are not currently participating in the system (on average, 14.1% and 0.8%, respectively, if evaluated by a low-discount planner).

To understand why this reform can give so large gains with such a modest additional fiscal burden, it is important to emphasize that (i) the earnings of rural workers are on average much lower than those of urban workers; and (ii) the rural population is declining rapidly over time. Both factors make pension transfers to the rural sector relatively inexpensive. It is important to note that our calculations ignore any cost of administering and enforcing the system. In particular, the benefit would decrease if the enforcement of the social security tax in rural areas proves to be more difficult than in urban areas.

7 Conclusions

Pension systems have been a key instrument for sharing high growth across generations in Western economies after World War II and could potentially play the same role in emerging countries. However, the prospect of an adverse demographic transition threatens the fiscal sustainability of non-funded pension systems. In this paper, we analyze the positive and normative effects of alternative pension reforms with the aid of a dynamic model calibrated to China.

A number of studies before us argue that China must reform its pension system to achieve long-run balance (see, e.g., Sin 2005, Dunaway and Arora 2007, Salditt *et al.* 2007, and Lu 2011). Our analysis concurs with this view, but shows that rushing into a draconian reform would have large unequalizing effects: it would harm current generations and only mildly benefit future generations. In a fast-growing society like China, this would imply dispensing with a powerful institution redistributing resources from richer future generations to poorer current ones. Even a planner with an annual discount rate as low as 0.5% would prefer an unfunded pay-as-you-go system to both an immediate sustainable reform and to a reform that pre-funds the pension system.

The results are subject to some *caveats*. First, financial sustainability could be aided by increasing the retirement age. In the working paper version, we show that increasing retirement age by six years would restore financial sustainability. However, this would not alter the desire to use the pension system to achieve intergenerational redistribution in favor of the earlier generations. Second, we do

not consider the effects of pension reforms on future fertility (see Courdacier *et al.* 2013). Finally, we abstract from the crowding out effect of public pensions on within-family old-age care. We believe that extending the analysis in these directions would not overturn our main insights. Our results obtain in a standard OLG model that predicts that, in a mature economy with steady wage growth and perfect capital markets, a fully funded system outperforms an unfunded PAYGO system. This sharp contrast illustrates the general principle that mechanically transposing policy advice from mature to developing or emerging economies may be misleading (see Acemoglu *et al.* 2006).

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Online Appendix to “Sharing High Growth Across Generations: Pensions and Demographic Transition in China”

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A Technical analysis and extensions related to section 2

We now restate and prove Proposition 1, which characterizes the optimal allocation and the associated pension policy. For simplicity, and without loss of generality, we abstract from a hump-shaped age-profile of wages (so the age profile is flat and $\eta_j = 1$), human capital deepening over time (so $\varpi_j = 1$), and mortality before J (so $s_j = 1$ and all agents survive until age J , at which point they die for sure).

Proposition 1 (restated) *Consider an economy where wages grow at the constant rate \tilde{g} during the transition and $g < \tilde{g}$ in steady state, i.e., $g_t = \tilde{g}$ for $t \in \{0, 1, \dots, T\}$, and $g_t = g$ for $t > T$. The size of the cohort born in period t is denoted μ_t and s_j denotes the unconditional probability of surviving until age j . Agents live for $J \geq 2$ periods and retire after $J_W < J$ periods. The optimal allocation (first best) solves the following planning program.³⁶*

$$\sum_{t=0}^{\infty} \mu_t \phi^t \sum_{j=0}^J \beta^j \left(\log(c_{t,j}) - \frac{h_{t,j}^{1+\frac{1}{\theta}}}{1+\frac{1}{\theta}} \right), \quad (14)$$

subject to

$$\begin{aligned} \sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^J \frac{c_{t,j}}{R^j} &= A_0 + \sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^{J_w} \frac{w_{t+j} h_{t,j}}{R^j} \\ h_{t,j} &= 0 \text{ for all } j > J_w, \end{aligned}$$

where $c_{t,j}$ and $h_{t,j}$ are consumption and labor supply of an individual of age j born at date t . Then, the first-best allocation is given by:

$$\begin{aligned} c_{t,0} &= \lambda^{-1} (\phi R)^t, \\ c_{t,j} &= c_{t,0} (\beta R)^j, \text{ for } j \in \{1, 2, \dots, J\}, \\ h_{t,j} &= \begin{cases} \left(\frac{w_{t+j}}{c_{t,j}} \right)^\theta & \text{for } j \in \{0, 1, \dots, J_w\} \\ 0 & \text{for } j \in \{J_w + 1, J_w + 2, \dots, J\} \end{cases}. \end{aligned}$$

³⁶We ignore for simplicity the generations born before $t = 0$.

where λ is a decreasing function of A_0 .

Consider a cohort born at k , and let $W_k = \sum_{j=0}^{J_w} (1 - \tau_{t,j}) w_{k+j} \bar{h}_{k,j} R^{-j}$ denote the present value of expected (after-tax) labor income for a representative household, where $\bar{h}_{k,j}$ is the average labor supply of workers of cohort k with experience j . Denote by $b_{k,j}$ the pension paid to a retiree of cohort k and age j . Define cohort k 's pension replacement rate ζ_k as the present value of pensions as a share of W_k , i.e., $\zeta_k = \left(\sum_{j=J_w+1}^J b_{k,j} R^{-j} \right) / W_k$. The first-best allocation can be implemented by a Ramsey sequence of cohort-specific taxes and pension replacement rates. These sequences are characterized as follows:

- (1) Taxes are zero in all periods, $\tau_{t,j} = 0$ for all t and j ;
- (2) The pension replacement sequence satisfies

$$\frac{1 + \zeta_{t+1}}{1 + \zeta_t} = \left(\frac{\phi R}{1 + g} \frac{1 + g}{1 + \tilde{g}} \right)^{1+\theta} \times F(t), \quad (15)$$

where

$$F(t) = \begin{cases} 1 & \text{if } t \leq T - J_w \\ \frac{\sum_{j=0}^{T-t} \beta^j \left(\frac{1+\tilde{g}}{\beta R} \right)^{(1+\theta) \cdot j} + \left(\frac{1+\tilde{g}}{\beta R} \right)^{(1+\theta) \cdot (T-t)} \sum_{j=T-t+1}^{J_w} \beta^j \left(\frac{1+g}{\beta R} \right)^{(1+\theta) \cdot (j-(T-t))}}{\sum_{j=0}^{T-(t+1)} \beta^j \left(\frac{1+\tilde{g}}{\beta R} \right)^{(1+\theta) \cdot j} + \left(\frac{1+\tilde{g}}{\beta R} \right)^{(1+\theta) \cdot (T-(t+1))} \sum_{j=T-t}^{J_w} \beta^j \left(\frac{1+g}{\beta R} \right)^{(1+\theta) \cdot (j-(T-(t+1)))}} & \text{if } t \in \{T - J_w + 1, \dots, T\} \\ \left(\frac{1+\tilde{g}}{1+g} \right)^{1+\theta} & \text{if } t > T \end{cases} \quad (16)$$

is a non-decreasing function of the birth date t . Finally ζ_0 is given by

$$1 + \zeta_0 = \frac{\sum_{j=0}^J \beta^j}{\sum_{j=0}^{J_w} \beta^j \left(\frac{w_j}{(\beta R)^j} \right)^{1+\theta}} \times \frac{1}{\lambda^{1+\theta}}. \quad (17)$$

Proof. The characterization of the first-best allocation, (5)–(7) follows from the problem (14)–(4) using standard methods. Consider, next, the Ramsey policy. Since $\tau_{t,j} = 0$, the intratemporal first-order condition implies equation (7). The Euler equation implies that $c_{t,j} = (\beta R)^j c_{t,0}$ as in (6). Next, plugging in (6) and (7) into the budget constraint, and recalling that ζ_t is proportional to the present value of earnings, yields

$$\sum_{j=0}^J \frac{(\beta R)^j}{R^j} c_{t,0} = (1 + \zeta_t) \sum_{j=0}^{J_w} \frac{w_{t+j}}{R^j} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^\theta (c_{t,0})^{-\theta}.$$

Solving for $c_{t,0}$ yields

$$(c_{t,0})^{1+\theta} = (1 + \zeta_t) \frac{\sum_{j=0}^{J_w} w_{t+j} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^\theta R^{-j}}{\sum_{j=0}^J \beta^j}.$$

Lagging the expression, taking the ratio of $c_{t+1,0}/c_{t,0}$, and using (8)–(16), yields

$$\left(\frac{c_{t+1,0}}{c_{t,0}} \right)^{1+\theta} = \left(\frac{\phi R}{1 + g} \frac{1 + g}{1 + \tilde{g}} \right)^{1+\theta} \times F(t) \times \frac{\sum_{j=0}^{J_w} \beta^j \left(\frac{w_{t+1+j}}{(\beta R)^j} \right)^{1+\theta}}{\sum_{j=0}^{J_w} \beta^j \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta}}.$$

We now show that replacing $F(t)$ by its expression in (16) yields $c_{t+1,0}/c_{t,0} = \phi R$, which is consistent with the optimality condition (5).

Suppose, first, that $t > T$. Then, replacing $F(t)$ by its expression in (16) and simplifying terms yields

$$\left(\frac{c_{t+1,0}}{c_{t,0}}\right)^{1+\theta} = \left(\frac{\phi R}{1+g} \frac{1+g}{1+\tilde{g}}\right)^{1+\theta} \times \left(\frac{1+\tilde{g}}{1+g}\right)^{1+\theta} \times (1+g)^{1+\theta} = (\phi R)^{1+\theta},$$

which is consistent with (5).

Suppose, next, that $t \in \{T - J_w + 1, \dots, T\}$. Then, proceeding as above,

$$\begin{aligned} \left(\frac{c_{t+1,0}}{c_{t,0}}\right)^{1+\theta} &= \left(\frac{\phi R}{1+g} \frac{1+g}{1+\tilde{g}}\right)^{1+\theta} \times \\ &\frac{\sum_{j=0}^{T-t} \beta^j \left(\frac{1+\tilde{g}}{\beta R}\right)^{(1+\theta) \cdot j} + \left(\frac{1+\tilde{g}}{\beta R}\right)^{(1+\theta) \cdot (T-t)} \sum_{j=T-t+1}^{J_w} \beta^j \left(\frac{1+g}{\beta R}\right)^{(1+\theta) \cdot (j-(T-t))}}{\sum_{j=0}^{T-(t+1)} \beta^j \left(\frac{1+\tilde{g}}{\beta R}\right)^{(1+\theta) \cdot j} + \left(\frac{1+\tilde{g}}{\beta R}\right)^{(1+\theta) \cdot (T-(t+1))} \sum_{j=T-t}^{J_w} \beta^j \left(\frac{1+g}{\beta R}\right)^{(1+\theta) \cdot (j-(T-(t+1)))}} \times \frac{\sum_{j=0}^{J_w} \beta^j \left(\frac{w_{t+1+j}}{(\beta R)^j}\right)^{1+\theta}}{\sum_{j=0}^{J_w} \beta^j \left(\frac{w_{t+j}}{(\beta R)^j}\right)^{1+\theta}}. \end{aligned}$$

Then, simplifying terms yields

$$\left(\frac{c_{t+1,0}}{c_{t,0}}\right)^{1+\theta} = \left(\frac{\phi R}{1+g} \frac{1+g}{1+\tilde{g}}\right)^{1+\theta} \times \left(\frac{w_{t+1}}{w_t}\right)^{1+\theta} = (\phi R)^{1+\theta},$$

which is again consistent with (5).

Suppose, finally, that $t \leq T - J_w$. Then, proceeding as above,

$$\left(\frac{c_{t+1,0}}{c_{t,0}}\right)^{1+\theta} = \left(\frac{\phi R}{1+g} \frac{1+g}{1+\tilde{g}}\right)^{1+\theta} \times 1 \times (1+\tilde{g})^{1+\theta} = (\phi R)^{1+\theta},$$

which is again consistent with (5).

Finally, we show that the individual optimization yields $c_{0,0} = \lambda^{-1}$ proving that the entire Ramsey sequence satisfies the first-best condition (5). To this aim, note that

$$c_{0,0} \sum_{j=0}^J \beta^j = (1 + \zeta_0) \times \sum_{j=0}^{J_w} \beta^j \left(\frac{w_j}{(\beta R)^j}\right)^{1+\theta} c_{0,0}^{-\theta}.$$

Collecting terms and replacing ζ_0 by (17) yields $c_{0,0} = \lambda^{-1}$. ■

Corollary 1 *Suppose $\phi = (1+g)/R$. Then, the optimal pension benefit sequence is strictly decreasing for all transition generations, $t \leq T$, and constant for all generations born after the end of the transition, $\zeta_t = \zeta_L$ for all $t > T$.*

$$\frac{1 + \tilde{\zeta}_{t+1}}{1 + \tilde{\zeta}_t} = \left(\frac{1+g}{1+\tilde{g}}\right)^{1+\theta}.$$

Proof. The proof follows from (8)-(16), recalling that $\tilde{g} > g$. ■

Corollary 2 *Consider the environment of Proposition 1. Suppose $\phi = (1+g)/R$, $A_0 \geq 0$, and that the Ramsey implementation is subject to the additional constraint that pensions are non-negative, i.e., $\zeta_t \geq 0$ for all t . The second-best Ramsey allocation has the following characterization: Either the*

constraint $\zeta_t \geq 0$ is never binding (A_0 is very large), and the first best can be implemented by the policy described in Proposition 1, or there exists $\hat{T} < \infty$ such that:

(1) If $t < \hat{T}$, then, up to an increase in λ (implying a lower $c_{0,0}$), the Ramsey policy sequence is identical to the unconstrained policy sequence that implements first best, i.e., taxes are zero in all periods, $\tau_{t,j} = 0$ for all t and j , and pensions are given by (8)–(17);

(2) If $t \geq \hat{T}$, then, $\zeta_t = 0$ and taxes are constant and positive for the cohort, $\tau_{t,j} = \tau_t > 0$.

Proof. The second-best Ramsey problem can be formulated as follows

$$\max_{\{\tau_{t,j}, c_{t,j}, h_{t,j}\}_{j=1}^{J_w}, \zeta_t}_{t=0}^{\infty} \sum_{t=0}^{\infty} \mu_t \phi^t \sum_{j=0}^J \beta^j \left(\log(c_{t,j}) - \frac{h_{t,j}^{1+\frac{1}{\theta}}}{1+\frac{1}{\theta}} \right), \quad (18)$$

subject to the non-negative-pension constraint $\zeta_t \geq 0$, to the resource constraint

$$\sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^J \frac{c_{t,j}}{R^j} = A_0 + \sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^{J_w} \frac{w_{t+j} h_{t,j}}{R^j},$$

and to the constraint that households optimize given the fiscal policy sequence $\left\{ \{\tau_{t,j}\}_{j=1}^{J_w}, \zeta_t \right\}_{t=0}^{\infty}$.

Household optimization implies

$$\begin{aligned} c_{t,j} &= c_{t,0} (\beta R)^j, \\ h_{t,j} &= \begin{cases} (1 - \tau_{t,j})^\theta \left(\frac{w_{t+j}}{(\beta R)^j} \right)^\theta (c_{t,0})^{-\theta} & \text{for } j \in \{0, 1, \dots, J_w\} \\ 0 & \text{for } j \in \{J_w + 1, J_w + 2, \dots, J\} \end{cases}, \\ \sum_{j=0}^J \beta^j c_{t,0} &= (1 + \zeta_t) \sum_{j=0}^{J_w} \beta^j (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta}. \end{aligned}$$

We use the household's optimal decisions substitute out the labor supply from the planner constraints. Moreover, the Euler equation of consumers allows us to express the problem as a function of $c_{t,0}$ rather than of the entire consumption sequence of each cohort. This leaves only the resource constraint and the non-negative pension constraint, expressed in terms of tax rates and the sequence $\{c_{t,0}\}_{t=0}^{\infty}$. Using these constraints, we can express the second-best problem in terms of the following Lagrangian:

$$\begin{aligned} L &= \sum_{t=0}^{\infty} \phi^t \left(\sum_{j=0}^J \beta^j \log(c_{t,0} (\beta R)^j) - \sum_{j=0}^{J_w} \beta^j \frac{(1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-(1+\theta)}}{1 + \frac{1}{\theta}} \right) + \\ &\quad + \xi_t \left(\sum_{j=0}^J \beta^j c_{t,0} - \sum_{j=0}^{J_w} \beta^j (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta} \right) \\ &\quad + \lambda \left(\sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^{J_w} \beta^j (1 - \tau_{t,j})^\theta \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta} - \sum_{t=0}^{\infty} \frac{\mu_t}{R^t} \sum_{j=0}^J \beta^j c_{t,0} \right) \end{aligned}$$

where $\xi_t \geq 0$ is the Lagrangian multiplier associated with the constraint $\zeta_t \geq 0$, and $\lambda > 0$ is the Lagrange multiplier associated with the resource constraint.

The FOCs with respect to $c_{t,0}$ and $\tau_{t,j}$ yield, respectively:

$$\begin{aligned} \frac{\partial L}{\partial c_{t,0}} &= \phi^t \left(\sum_j \beta^j \frac{1}{c_{t,0}} + \sum^{J_w} \beta^j \theta (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} c_{t,0}^{-(2+\theta)} + \right. \\ &\quad \left. \xi_t \left(\sum \beta^j + \theta \sum^{J_w} \beta^j (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-(1+\theta)} \right) \right) - \\ &\quad \lambda \frac{\mu_t}{R^t} \left(\sum_j^{J_w} \theta \beta^j (1 - \tau_{t,j})^\theta \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-(1+\theta)} + \sum_j \beta^j \right) = 0, \end{aligned} \quad (19)$$

$$\begin{aligned} \frac{\partial L}{\partial \tau_{t,j}} &= \phi^t \left(\beta^j \theta (1 - \tau_{t,j})^\theta \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-(1+\theta)} + \xi_t \left((1 + \theta) \beta^j (1 - \tau_{t,j})^\theta \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta} \right) \right) - \\ &\quad \lambda \left(\frac{1}{R^t} \theta \beta^j (1 - \tau_{t,j})^{\theta-1} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta} \right) = 0. \end{aligned} \quad (20)$$

Consider, next, two separate cases:

1. $\xi_t = 0$, i.e., the constraint $\zeta_t \geq 0$ is slack. In this case, the problem is identical to the implementation of the first best in Proposition 1, up to an increase in the value of λ . In particular, letting $\tau_{t,j} = \tau_t = 0$ implies that $c_{t,0} = \lambda^{-1} (\phi R)^t$ (see equation (5)) and $h_{t,j} = \left(\frac{w_{t+j}}{c_{t,j}} \right)^\theta$, for $j \in \{0, 1, \dots, J_w\}$ (see equation (7)). Since λ is larger, consumption is lower and labor supply is higher. Moreover, if the constraint is slack at $t > 0$, it must also be slack for all $k \leq t$. To see why, note that the pension sequence ζ_t given by (8)-(17) is non-increasing, so $\zeta_t > 0$ (and, thus, $\xi_t = 0$) implies $\zeta_k > 0$ (thus, again, $\xi_k = 0$) for all $k < t$.
2. $\xi_t > 0$, i.e., the constraint that pensions cannot be negative is binding. Thus, $\zeta_t = 0$ and the individual budget constraint yields:

$$\sum \beta^j c_{t,0} = \sum^{J_w} \beta^j (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} (c_{t,0})^{-\theta} \quad (21)$$

Combining (19)-(20) yields:

$$\phi^t \left(\sum_j \beta^j \frac{1}{c_{t,0}} + \xi_t \left(\sum \beta^j - \sum^{J_w} \beta^j (1 - \tau_{t,j})^{1+\theta} \left(\frac{w_{t+j}}{(\beta R)^j} \right)^{1+\theta} c_{t,0}^{-\theta-1} \right) \right) - \lambda \left(\frac{1}{R^t} \sum_j \beta^j \right) = 0.$$

Substituting into this expression the budget constraint, (21), implies:

$$\begin{aligned} \mu_t \phi^t \sum_j \beta^j \frac{1}{c_{t,0}} - \lambda \frac{\mu_t}{R^t} \sum_j \beta^j &= 0 \Rightarrow \\ c_{t,0} &= \lambda^{-1} (\phi R)^t. \end{aligned}$$

Finally, substituting this condition into (20), and solving for τ_t , after rearranging terms, yields:

$$\tau_{t,j} = \tau_t = \frac{\xi_t (1 + \theta) c_{t,0}}{\theta + \xi_t (1 + \theta) c_{t,0}} > 0,$$

where the inequality follows from the assumption that $\xi_t > 0$. Finally, we can prove by *reductio ad absurdum* that if $\xi_t > 0$, then $\xi_k > 0$ for all $k > t$. Suppose not, and $\exists k > t$ such that $\zeta_k > 0$. Then, for the argument provided in the proof of part 1 of this proposition, the non-negativity constraint should be slack for all $k' < k$, including $k' = t$, raising a contradiction.

Finally, note that either the constraint $\zeta_t \geq 0$ is slack for all T , and then the first best can be implemented, or there exist a T such that the constraint is slack for all $t < T$ and is binding for all $t \geq T$.

■

B Estimation method of the rural-urban migration

In this appendix, we present the estimation method of the rural-urban migration. $n_{2000}^{h,i,j}$ and $n_{2005}^{h,i,j}$ represent the population of group (h, i, j) in the 2000 census and 2005 survey, respectively, where $h \in \{u, r\}$, $i \in \{f, m\}$, and $j \in \{0, 1, \dots, 100\}$ stand for residential status (u for urban and r for rural residents), gender (f for females and m for males), and age, respectively. $\hat{n}_{2005}^{h,i,j}$ represents the projected “natural” population in 2005. Denote $m^{i,j}$ the net flow of the rural-urban migration from 2000 to 2005. We observe $n_{2000}^{h,i,j}$ and $n_{2005}^{h,i,j}$ from the 2000 census and 2005 survey. Moreover, we can use $n_{2000}^{h,i,j}$, together with the observed birth and mortality rates, to project $\hat{n}_{2005}^{h,i,j}$; i.e., the “natural” population in 2005. In other words, both $n_{2005}^{h,i,j}$ and $\hat{n}_{2005}^{h,i,j}$ in (22) and (23) are observable. The 2005 urban and rural population gender-age structure can thus be composed into three parts:

$$n_{2005}^{u,i,j} = \hat{n}_{2005}^{u,i,j} + m^{i,j} + \varepsilon^{u,i,j}, \quad (22)$$

$$n_{2005}^{r,i,j} = \hat{n}_{2005}^{r,i,j} - m^{i,j} + \varepsilon^{r,i,j}, \quad (23)$$

where $\varepsilon^{h,i,j}$ captures measurement errors in the census and survey.

In the ideal case with no measurement errors, either (22) or (23) can back out $m^{i,j}$. The measurement error on the total population, $\sum_{h,i,j} \varepsilon^{h,i,j}$, is small. When $\sum_{h,i,j} \varepsilon^{h,i,j} = 0$, (22) and (23) imply that the projected total population, $\sum_{h,i,j} \hat{n}_{2005}^{h,i,j}$, would be equal to the total population in the 2005 survey, $\sum_{h,i,j} n_{2005}^{h,i,j}$. The difference between $\sum_{h,i,j} \hat{n}_{2005}^{h,i,j}$ and $\sum_{h,i,j} n_{2005}^{h,i,j}$ is less than 1%.³⁷ However, the match of the sum of the rural and urban population in each gender-age group is less perfect. Figure A-1 plots the projected 2005 “natural” population gender-age structure (solid line) and the 2005 survey data (dotted line). The discrepancy between the two lines reveals the measurement error on the population of each gender-age group, $\varepsilon^{i,j}$, where

$$\varepsilon^{i,j} \equiv \sum_h \varepsilon^{h,i,j} = \sum_h \left(n_{2005}^{h,i,j} - \hat{n}_{2005}^{h,i,j} \right). \quad (24)$$

Figure I suggests $\varepsilon^{i,j}$ to be quantitatively important.³⁸ To understand how $\varepsilon^{i,j}$ affects the estimated migration gender-age structure, let us assume the measurement error on urban population, $\varepsilon^{u,i,j}$, is proportional to $\varepsilon^{i,j}$:

$$\varepsilon^{u,i,j} = \pi \cdot \varepsilon^{i,j}, \quad (25)$$

³⁷Despite the small discrepancy, to avoid biased estimates, we adjust $n_{2000}^{h,i,j}$ by a scale of κ , where κ is calibrated to 1.0073 by matching the projected 2005 total population with the 2005 survey data. $\kappa = 1.0073$ suggests the discrepancy of the total population to be less than 1%.

³⁸If all the discrepancies are due to sampling errors in the 2005 survey, the comparison between the two lines in figure I indicates that a major drawback of the 2005 survey is the undercounted young labor force (age 16 to 40). Our calculation suggests 66 million young labor force (11% of total young labor force) missing from the 2005 survey.

where $\pi \in [0, 1]$. It follows that the measurement error for the rural population is

$$\varepsilon^{r,i,j} = (1 - \pi) \cdot \varepsilon^{i,j}. \quad (26)$$

Rearranging (22) gives the net flow of migration:

$$\begin{aligned} \sum_i \sum_j m^{i,j} &= \sum_i \sum_j \left(n_{2005}^{u,i,j} - \hat{n}_{2005}^{u,i,j} \right) - \pi \sum_i \sum_j \varepsilon^{i,j} \\ &= \sum_i \sum_j \left(n_{2005}^{u,i,j} - \hat{n}_{2005}^{u,i,j} \right) - \pi \sum_h \sum_i \sum_j \left(n_{2005}^{h,i,j} - \hat{n}_{2005}^{h,i,j} \right). \end{aligned} \quad (27)$$

The second equality comes from (24). Let us consider two extreme cases of π . When $\pi = 1$, (27) can be written as

$$\sum_i \sum_j m^{i,j} = \underbrace{\sum_i \sum_j \hat{n}_{2005}^{r,i,j}}_{\text{projected "natural" rural population}} - \underbrace{\sum_i \sum_j n_{2005}^{r,i,j}}_{\text{rural population in the survey data}}.$$

When $\pi = 0$, (27) reduces to

$$\sum_i \sum_j m^{i,j} = \underbrace{\sum_i \sum_j n_{2005}^{u,i,j}}_{\text{urban population in the survey data}} - \underbrace{\sum_i \sum_j \hat{n}_{2005}^{u,i,j}}_{\text{projected "natural" urban population}}.$$

Therefore, the choice of π boils down to the choice of using rural or urban population to back out migration. It has been widely acknowledged that the urban population survey tends to underestimate the “floating population,” that is, rural migrants without *hukou* - the local household registration status (e.g., Liang and Ma 2004). So, we set $\pi = 1$. We will discuss the results using $\pi = 0.5$.

It is instructive to compare the actual migration structure with our estimates. The migration *flow* structure is hard to obtain. However, the migration *stock* structure may shed some light on the *flow* structure. The age structure of migrants in the 2000 census is presented in the second row of Table A-1, which has a high concentration in the 15-29 age group. The same pattern also appears in our estimates under $\pi = 1$ (the third row). $\pi = 0.5$ results in a much more dispersed age structure (the fourth row). This provides a justification for using $\pi = 1$.³⁹

Table A-1 Age distribution of migration (percent)

age	<15	15-29	30-44	45-59	60+
migration stock in the 2000 census	9.0	60.5	22.2	5.8	2.5
estimated flow from 2000 to 2005 with $\pi = 1$	25.8	64.8	26.5	-8.6	-8.6
estimated flow from 2000 to 2005 with $\pi = 0.5$	17.8	39.5	27.7	8.9	6.1

Note: The age structure in the 2000 census is from Liang and Ma (2004).

³⁹One caveat is that the data from the 2000 census are the age structure of narrowly defined migrants, whereas our estimate is on broadly defined migrants including urbanized population.

Finally, we compute $mr^{i,j}$, the age-gender specific migration rate defined as the average annual net flow of migration per hundred rural population with gender i and age j . We assume that $mr^{i,j}$ is time-invariant and the mortality rates for migrants are the same as those for rural residents. Then, $m^{i,j}$ can be written as follows:

$$\begin{aligned}
m^{i,j} = & \underbrace{mr^{i,j-5} n_{2000}^{r,i,j-5}}_{\text{migration of 2000}} \underbrace{\left(1 - d_{2000}^{r,i,j-1}\right) \cdots \left(1 - d_{2000}^{r,i,j-5}\right)}_{\text{survival rate from 2000 to 2005}} \\
& + \underbrace{mr^{i,j-4} \left(1 - mr^{r,j-5}\right) n_{2000}^{r,i,j-5}}_{\text{migration of 2001}} \underbrace{\left(1 - d_{2000}^{r,i,j-1}\right) \cdots \left(1 - d_{2000}^{r,i,j-5}\right)}_{\text{survival rate from 2001 to 2005}} \\
& + \underbrace{mr^{i,j-3} \left(1 - mr^{r,j-4}\right) \left(1 - mr^{r,j-5}\right) n_{2000}^{r,i,j-5}}_{\text{migration of 2002}} \underbrace{\left(1 - d_{2000}^{r,i,j-1}\right) \cdots \left(1 - d_{2000}^{r,i,j-5}\right)}_{\text{survival rate from 2001 to 2005}} \\
& + \underbrace{mr^{i,j-2} \left(1 - mr^{r,j-3}\right) \left(1 - mr^{r,j-4}\right) \left(1 - mr^{r,j-5}\right) n_{2000}^{r,i,j-5}}_{\text{migration of 2003}} \underbrace{\left(1 - d_{2000}^{r,i,j-1}\right) \cdots \left(1 - d_{2000}^{r,i,j-5}\right)}_{\text{survival rate from 2001 to 2005}} \\
& + \underbrace{mr^{i,j-1} \left(1 - mr^{r,j-2}\right) \cdots \left(1 - mr^{r,j-5}\right) n_{2000}^{r,i,j-5}}_{\text{migration of 2004}} \underbrace{\left(1 - d_{2000}^{r,i,j-1}\right) \cdots \left(1 - d_{2000}^{r,i,j-5}\right)}_{\text{survival rate from 2001 to 2005}}.
\end{aligned}$$

Here, $n_{2000}^{r,i,j-5}$ is the mortality rate of rural residents in the 2000 census. In other words, $m^{i,j}$ measures an accumulated migration stock from 2000 to 2005. The above equation allows us to back out the age-gender specific migration rates. Specifically, for $j = J + 5$:

$$\begin{aligned}
m^{i,J+5} &= \underbrace{mr^{i,J} \hat{n}_{2000}^{r,i,J}}_{\text{migration of 2000}} \underbrace{\left(1 - d_{2000}^{r,i,J+4}\right) \cdots \left(1 - d_{2000}^{r,i,J+4}\right)}_{\text{survival rate from 2000 to 2005}} \\
\Rightarrow mr^{i,J} &= \frac{m^{i,J+5}}{n_{2000}^{r,i,J} \left(1 - d_{2000}^{r,i,J+4}\right) \cdots \left(1 - d_{2000}^{r,i,J}\right)}.
\end{aligned}$$

For $j = J + 4$:

$$\begin{aligned}
m^{i,J+4} &= \underbrace{mr^{i,J-1} \hat{n}_{2000}^{r,i,J-1}}_{\text{migration of 2000}} \underbrace{\left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}_{\text{survival rate from 2000 to 2005}} \\
&+ \underbrace{mr^{i,J} \left(1 - mr^{r,J-1}\right) n_{2000}^{r,i,J-1}}_{\text{migration of 2001}} \underbrace{\left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}_{\text{survival rate from 2000 to 2005}} \\
\Rightarrow mr^{i,J-1} &= \frac{m^{i,J+4} - mr^{i,J} n_{2000}^{r,i,J-1} \left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}{\left(1 - mr^{i,J}\right) n_{2000}^{r,i,J-1} \left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}.
\end{aligned}$$

All the migration rates can thus be solved in a recursive way.

C Details on the Chinese pension system

This appendix provides a description of the basic features of the Chinese pension system. We start with the urban pension system, and then provide a brief description of the rural pension system, which has been introduced experimentally in 2009.

C.1 The urban pension system

The pre-1997 urban pension system was primarily based on state and urban collective enterprises in a centrally planned economy. Retirees received pensions from their employers, with replacement rates that could be as high as 80 percent (see, e.g., Sin, 2005; OECD, 2007). The coverage was low in the work-unit-based system, though. Many non-state-owned enterprises had no pension scheme for their employees. The coverage rate, measured by the ratio of the number of workers covered by the system to the urban employment, was merely 44% in 1992 according to *China Statistical Yearbook 2009*. The rapid expansion of the private sector caused a growing disproportion between the number of contributors and beneficiaries and, therefore, a severe financial distress for the old system (Zhao and Xu, 2002). To deal with the issue, the government initiated a transition from the traditional system to a public pension system in the early 1990s. The new system was implemented nationwide after the State Council issued “A Decision on Establishing a Unified Basic Pension System for Enterprise Workers (Document 26)” in 1997.

The reformed system mainly consists of two pillars. The first pillar, funded by 17% wage taxes paid by enterprises, guarantees a minimum replacement rate of 20% of local average wage for retirees with a minimum of 15 years of contribution. It is worth emphasizing that the pension fund is managed by local governments (previously at the city level and now at the provincial level). The second pillar provides pensions from individual accounts financed by a contribution of 3% and 8% social security tax paid by enterprises and workers, respectively. There is a third pillar adding to individual accounts through voluntary contribution. The return of individual accounts is adjusted according to bank deposit rates. The system also defines monthly pension benefits from individual accounts equaling the account balance at retirement divided by 120.

More recently, a new reform was implemented after the State Council issued “A Decision on Improving the Basic Pension System for Enterprise Workers (Document 38)” in 2005. The reform adjusted the proportion of taxes paid by enterprises and individuals and the proportion of contribution for individual accounts. Individual accounts are now funded by the social security 8% tax paid by workers only.⁴⁰ The first and second pillars deliver target replacement rates of 35% and 24.2%, respectively (Hu, Stewart and Yermo, 2007).

Two features of the current urban pension system is particularly important for our modeling. First, the pension reform was cohort-specific. There were three types of cohorts when the pension reform took place: cohorts entering the labor market after 1997 (*Xinren*), cohorts retiring before 1997 (*Laoren*) and cohorts in-between (*Zhongren*). Pension contributions and benefits of *Xinren* are entirely determined by the new rule. According to Item 5 in Document 26, the government commits to pay *Laoren* the same pension benefits as those in the old system subject to an annual adjustment by wage growth and inflation. For *Zhongren*, their contributions follow the new rule, while their benefits consist of two components: (1) pensions from the new system identical to those for *Xinren*, and (2) a transitional pension that smooths the pension gap between *Laoren* and *Xinren*. For simplicity, we ignore *Zhongren* and take pensioners retiring before and after 1997 as *Laoren* and *Xinren*, respectively. Following Sin (2005), we set the replacement rate for *Laoren* and *Xinren* to 78% and 60%, respectively.

Second, like private savings, pension funds are allowed to invest in domestic stock markets. The

⁴⁰The reform also adjusted the pension benefits. The replacement rate of an individual is now determined by years of contribution: A one year contribution increases the replacement rate of a wage index averaged from local and individual wages by one percentage point. However, the article did not state explicitly how to compute the wage index.

In practice, the index appears to differ across provinces. For instance, the increase in the average pension benefits per retiree in 2011 was almost the same across Beijing and GanSu (the monthly increase was RMB210 in Beijing and RMB196 in GanSu), though the average wage in Beijing is more than two times as high as that in GanSu and the gap has been rather stable over time.

baseline model assumes the annual rate of returns to pension funds to be 2.5%, which is identical to the rate of returns to private savings. According to the latest information released by the National Council for Social Security Fund, the average share of pension funds invested in stock markets was 19.22% in 2003-2011.⁴¹ If 20% of pension funds have access to the market with an annual return of 6% and the rest of the funds gain an annual return of 1.75% as the one-year bank deposits, the average annual rate of returns would be equal to 2.6%, almost equal to 2.5% set in the baseline model.

It is also worth emphasizing that the actual urban pension system deviates from statutory regulations in a number of ways and our model has been adapted to capture some major discrepancies. First, the individual accounts are basically empty. Despite the recent efforts made by the central government to fund these empty individual accounts, there are only 270 billion RMB in all individual accounts of around 200 million workers participating in the urban pension system.⁴² Therefore, we take the individual accounts as notional and ignore any distinction between the different pension pillars throughout the paper. In addition, we assume that 40% of pension benefits are indexed to wage growth. The level of indexation is set on the conservative side since the actual level is between 40% and 60% (see Sin, 2005).

Second, the statutory contribution rate including both basic pensions and individual accounts is 28%, of which 20% should be paid by firms and 8% should be paid by workers (see the above discussion on Document 26 and 38). However, there is evidence that a significant share of the contributions is evaded. For instance, in the annual National Industrial Survey – which includes all state-owned manufacturing enterprises and all private manufacturing enterprises with revenue above 5 million RMB – the average pension contributions paid by firms in 2004-2007 amounts to 11% of the average wages, 9 percentage points below the statutory rate.⁴³ Most evasion comes from privately owned firms, whose contribution rate is a merely 7%.

The actual contribution rate is substantially lower than the statutory rate even for workers participating in the system. A simple way of estimating the actual contribution rate conditional on participation is to look at the following ratio:

$$\begin{aligned}
 BR &\equiv \frac{\text{per retiree pension benefits}}{\text{per worker pension contributions}} \\
 &\equiv \frac{\frac{\text{total pension fund expenditure}}{\text{total retirees covered by the system}}}{\frac{\text{total pension fund revenue - government subsidy}}{\text{total workers covered by the system}}}
 \end{aligned}$$

If the replacement rate is indeed 60%, a contribution rate of 28% would imply BR to be 2.1. However, we find that the average BR in the data from 1997 to 2009 is 3.1, much higher than 2.1 by the statutory contribution rate. With a targeted replacement rate of 60%, the ratio of 3.1 would imply an actual contribution rate of 19.4%.⁴⁴ So, we set the actual contribution rate to 20% in the paper.

Finally, although the coverage rate of the urban pension system is still relatively low, it has grown from about 40% in 1998 to 57% in 2009, where we measure the coverage rate by the number of

⁴¹Source: http://www.ssf.gov.cn/xw/xw_gl/201205/t20120509_4619.html.

⁴²The number of 270 billion RMB comes from the information released by the Ministry of Human Resources and Social Security in the 2012 National People's Congress. Source: <http://lianghui.people.com.cn/2012npc/GB/239293/17320248.html>

⁴³In addition, with a labor income share less than 20%, wages appear to be severely underreported.

⁴⁴All the data are available from *China Statistical Yearbook*, except for the government subsidies. Fortunately, since 2010, the Ministry of Finance has started to publicize detailed expenditure items. The government subsidy to the pension fund amounted to 191 billion RMB in 2010, accounting for 21% of the total government social security and employment expenditure. We then use 21% to back out annual government subsidy to pension funds from annual total government social security and employment expenditure, which is available from *China Statistical Yearbook*.

employees participating in the pension system as a share of the number of urban employees.⁴⁵ There is a concern that the rapidly growing size of migrant workers might lead to downward-biased urban employment. Our estimation suggests that the urban population (including migrants) between age 22 and 60 increases by 130 million from 2000 to 2009. A labor participation rate of 80% would imply an increase of 104 million in the urban employment, whereas the increase by the official statistics is 79 million. Restoring the 25 million “missing” urban employment would lower the pension coverage rate from 57% to 53% in 2009. Our baseline model assumes a constant coverage rate of 60%, reflecting a trade-off between the low coverage of the current pension system and the potentially higher one in the future.

C.2 The rural pension system

The pre-2009 rural pension program had two features. First, it was “fully-funded” in the sense that pension benefits were essentially determined by contributions to individual accounts. Second, the coverage rate was low since farmers did not have incentives to participate. A pilot pension program was launched for rural residents in 2009. Like those in the urban pension system, the new rural program entails two benefit components. The first one is referred to as basic pension, mainly financed by the Ministry of Finance, and the second one is referred to as pension from individual account. If a migrant worker who joined the urban pension system returns to her home town, the money accumulated in her account will be transferred to her new account in the rural pension program. The program was first implemented in 10% of cities and counties on a trial basis. The government targeted to extend the program to 60% of cities and counties in 2011. Many of the cities and counties report high participation rates (above 80%). This is not surprising since the program is heavily subsidized (see below for more details).

We then lay out some basic features of the new program upon which the model is based. According to “Instructions on New Rural Pension Experiments” issued by the State Council in 2009, the new program pays a basic pension of RMB55 (\$8.7) per month. Suppose that the rural wage equals the rural per capita annual net income, which was RMB5153 in 2009 (*China Statistical Yearbook* 2010). Then, the basic pension would correspond to a replacement rate of 12.8%. Notice that provinces are allowed to choose more generous rural pensions. So, the replacement rate of 9% should be viewed as a lower bound.⁴⁶ In practice, some places set a much higher basic pension standard. Beijing, for instance, increased the level to RMB280. The monthly basic pension in Shanghai has a range from RMB150 to RMB300, dependent of age, years of contribution and status in the old pension program.⁴⁷ Since the rural per capita net income in Beijing and Shanghai is about 1.4 times higher than the average level in China, a monthly pension of RMB280 would imply a replacement rate of 27.2%. In the quantitative exercise, we then set the replacement rate to 20% to match the average of the basic level of 12.8% and the high level of 27.2%.⁴⁸ On the contribution side, rural residents in

⁴⁵Both numbers are obtained from *China Statistical Yearbook* 2010.

⁴⁶The Ministry of Human Resources and Social Security has made it clear that there is no upper bound for basic pension and local governments may increase basic pension according to their public financing capacity.

⁴⁷See “Detailed Rules for the Implementation of Beijing Urban-Rural Household Pension Plans,” Beijing Municipal Labor and Social Security Bureau, 2009 and “Implementation Guidelines of State Council’s Instructions on New Rural Pension Experiments,” Shanghai Municipal Government, 2010.

⁴⁸All rural residents above age 60 are entitled to a basic pension. The only condition is that children of a basic pension recipient, if any, should participate in the program. In practice, basic pension might be contingent on years of contribution and status in the old pension program (see the above example from Shanghai).

In addition, an official policy report from the Ministry of Human Resources and Social Security (<http://news.qq.com/a/20090806/000974.htm>) states that by the rule of the new system, a rural worker paying an annual contribution rate of 4% for 15 years should be entitled to pension benefits with a replacement rate of 25%.

Planner's discount rate	Delayed until 2050		Delayed until 2100		Fully Funded		PAYGO	
	high	low	high	low	high	low	high	low
Baseline (ret. age at 60)	6.4%	0.9%	8.9%	0.6%	-3.3%	0.2%	12.4%	1.6%
Retirement age at 57	9.9%	1.3%	13.4%	0.7%	-3.2%	0.3%	11.8%	1.8%

Table 2: The table summarizes the welfare effects (measured in terms of compensated variation in consumption for the high- and low-discount rate planners, respectively) under the alternative assumption about retirement age compared to the results under the baseline calibration.

principle should contribute 4% to 8% of the local average income per capita in the previous year. We take the mean and set a contribution rate of 6%.⁴⁹

The current pension program heavily relies on government subsidy. *China Statistical Yearbook 2010* reports a rural population of 712.88 million. According to the 2005 one-percent population survey, 13.7% of rural population is above age 60. These two numbers give a rural population of 97.66 million who are entitled to a basic pension. This, in turn, implies an annual government subsidy of 64.46 billion RMB, if monthly basic pension is set to RMB55. The central government revenue is 3592 billion RMB in 2009. So, a full-coverage rural pension program in 2009 would require subsidy as a share of the central government revenue of 1.8% and a share of GDP of 0.19%.

D A retirement age of 57

In this section we report the results under an alternative calibration which assumes that the retirement age is 57 instead of 60, as in the benchmark calibration. 57 is an average of the current statutory retirement age for men (60) and women (55). We have opted for using a retirement age of 60 as a benchmark because we expect that the pension age is likely to increase as the health of the population improves with economic progress.

The fiscal imbalance of the system is now larger than under the baseline calibration. Consequently, a larger reduction in replacement rate is required to balance the system. Under the draconian reform the replacement rate now is 32.5%, compared to 39.1% in the baseline calibration. When the reform is delayed until 2050 (2100), the required replacement rate fall to 28.0% (18.3%). The welfare results are reported in Table 2. As is evident from the table, the main conclusions hold up, being even stronger in the sense that delaying the reform would be even more beneficial than under the baseline calibration.

E A dynamic general equilibrium model

In this section, we construct a dynamic general equilibrium model that delivers the wage and interest rate sequence assumed in the baseline model of section 2 as an equilibrium outcome. These prices are sufficient to compute the optimal decisions of workers and retirees (consumption and labor supply) as well as the sequence of budget constraints faced by the government. The model is builds on SSZ, augmented with the demographic model of section 3.1 and the pension system of section 2.

The production sector: The urban production sector consists of two types of firms: (i) *financially integrated* (F) firms, modeled as standard neoclassical firms; and (ii) *entrepreneurial* (E) firms,

⁴⁹Rural residents are allowed to contribute more. But the contribution rate cannot exceed 15% for each person. Moreover, to be eligible for pension from individual account, a rural resident must contribute to the program for at least 15 years. The monthly pension benefit is set equal to the accumulated money in individual account divided by 139 (the same rule applied to the urban pension program).

owned by (old) entrepreneurs, who are residual claimants on the profits. Entrepreneurs delegate the management of their firms to specialized agents called *managers*. E firms can run more productive technologies than F firms (see Song *et al.*, 2011 for the microfoundation of this assumption). However, they are subject to credit constraints that limit their growth. In contrast, the less productive F firms are unconstrained. Motivated by the empirical evidence (see Song *et al.*, 2011) that private firms are more productive and more heavily financially constrained than state-owned enterprises (SOE) in China, we think of F firms as SOE and E firms as privately owned firms.

The technology of F and E firms are described, respectively, by the following production functions:

$$Y_F = K_F^\alpha (AN_F)^{1-\alpha}, \quad Y_E = K_E^\alpha (\chi AN_E)^{1-\alpha},$$

where Y is output and K and N denote capital and labor, respectively. The parameter $\chi > 1$ captures the assumption that E firms are more productive. A labor market-clearing condition requires that $N_{E,t} + N_{F,t} = N_t$, where N_t denotes the total urban labor supply at t , whose dynamics are consistent with the demographic model. The technology parameter A grows at the exogenous rate z_t ; $A_{t+1} = (1 + z_t) A_t$.

The capital stock of F firms, $K_{F,t}$, is *not* a state variable, since F firms have access to frictionless credit markets, and the capital stock adjusts so that the rate of return on capital equals the lending rate. Note that we assume no irreversibility in investments, so F firms can adjust the desired level of capital in every period. Let r_t^l denote the net interest rate at which F firms can raise external funds. Let w denote the market wage. Profit maximization implies that $K_F = AN_F (\alpha / (r_t^l + \delta))^{-\frac{1}{1-\alpha}}$, where δ is the depreciation rate. The capital-labor ratio and the equilibrium are determined by r^l . Thus,

$$w_t \geq (1 - \alpha) \left(\frac{\alpha}{r_t^l + \delta} \right)^{\frac{\alpha}{1-\alpha}} A_t. \quad (28)$$

As long as there are active F firms in equilibrium ($N_F > 0$), equation (28) holds with strict equality.

Let $K_{E,t}$ denote the capital stock of E firms. E firms are subject to an agency problem in the delegation of control to managers. The optimal contract between managers and entrepreneurs requires revenue sharing. We denote by ψ the share of the revenue accruing to managers.⁵⁰ Profit maximization yields, then, the following optimal labor hiring decision:

$$\begin{aligned} N_{Et} &= \arg \max_{\tilde{N}_t} \left\{ (1 - \psi) (K_{Et})^\alpha (\chi A_t \tilde{N}_t)^{1-\alpha} - w_t \tilde{N}_t \right\} \\ &= ((1 - \psi) \chi)^{\frac{1}{\alpha}} \left(\frac{r_t^l + \delta}{\alpha} \right)^{\frac{1}{1-\alpha}} \frac{K_{Et}}{\chi A_t}. \end{aligned} \quad (29)$$

The gross rate of return to capital in E firms is given by

$$\rho_{E,t} = \left((1 - \psi) K_{Et}^\alpha (\chi A_t N_{Et})^{1-\alpha} - w_t N_{Et} + (1 - \delta) K_{Et} \right) / K_{E,t}. \quad (30)$$

We assume that E firms are also subject to a credit constraint, modeled as in Song *et al.* (2011, p. 216). According to such a model, E firms can borrow funds at the same interest rate as F firms, but the incentive-compatibility constraint of entrepreneurs implies that the share of investments financed externally must satisfy the following constraint:

⁵⁰Managers have special skills that are in scarce supply. If a manager were paid less than a share ψ of production, she could "steal" it. No punishment is credible, since the deviating manager could leave the firm and be hired by another entrepreneur. See Song *et al.* (2011) for a more detailed discussion.

$$K_E - \Omega_{E,t} \leq \frac{\sigma \rho_E}{1 + r^l} K_E, \quad (31)$$

where $\Omega_{E,t}$ denotes the stock of entrepreneurial wealth invested in E firms at t, and, hence, $K_E - \Omega_{E,t}$ denotes the external capital of E firms. Thus, the constraint implies that the entrepreneurs can only pledge to repay a share σ of next-period net profits.

Three regimes are possible: (i) during the first stage of the transition, the credit constraint (31) is binding and F firms are active (hence, the wage is pinned down by (28) holding with equality); (ii) during the mature stage of the transition, the credit constraint (31) is binding and F firms are inactive; (iii) eventually, the credit constraint (31) ceases to bind (F firms remain inactive). In regimes (ii) and (iii), (28) holds with strict inequality.

Consider, first, regime (i). Substituting $N_{E,t}$ and w_t into (30) by their equilibrium expressions, (28) and (29), yields the gross rate of return to E firms: $\rho_{E,t} = (1 - \psi) ((1 - \psi) \chi)^{\frac{1-\alpha}{\alpha}} (r_t^l + \delta) + (1 - \delta)$. The corresponding gross rate of return to entrepreneurial investment is given by $R_{E,t} = (\rho_{E,t} K_{E,t} - (1 + r_t^l) (K_{E,t} - \Omega_{E,t})) / \Omega_{E,t}$. We assume that $(1 - \psi)^{\frac{1}{\alpha}} \chi^{\frac{1-\alpha}{\alpha}} > 1$, ensuring that the return to capital is higher in E firms than in F firms (i.e., that $R_{E,t} > r_t^l + 1$). Note that the rate of return to capital is a linear function of r_t^l in both E and F firms. The equilibrium in regime (i) is closed by the condition that employment in the F sector is determined residually, namely,

$$N_{F,t} = N_t - ((1 - \psi) \chi)^{\frac{1}{\alpha}} \left(\frac{r_t^l + \delta}{\alpha} \right)^{\frac{1}{1-\alpha}} \frac{K_{E,t}}{\chi A_t} \geq 0.$$

Consider, next, regime (ii), where only E firms are active ($N_{E,t} = N_t$) and the borrowing constraint is binding, so (31) holds with equality. In this case, the rates of return to capital and labor equal their respective marginal products. More formally, $w_t = (1 - \alpha) (1 - \psi) (\chi A_t)^{1-\alpha} (K_{E,t}/N_t)^\alpha$, and the gross rate of return on entrepreneurial wealth is given by

$$\rho_{E,t} = \left(\alpha (1 - \psi) \chi^{1-\alpha} \left(\frac{K_{E,t}}{A_t N_t} \right)^{\alpha-1} + (1 - \delta) \right),$$

whereas the borrowing constraint implies that $K_{E,t} = \left(1 + \frac{\sigma \rho_{E,t}}{R^l - \sigma \rho_{E,t}} \right) \Omega_{E,t}$. Given the stock of entrepreneurial wealth, $\Omega_{E,t}$, the two last equations pin down $\rho_{E,t}$ and $K_{E,t}$. The rate of return to entrepreneurial investment is then determined by the expression used for regime (i).

Finally, in regime (iii) the rate of return to capital in E firms is identical to the rate of return offered by alternative investment opportunities (e.g., bonds). Namely,

$$R_{E,t} = 1 + r_t^l.$$

Thus, $K_{E,t}$ ceases to be a state variable, and the wage is given by $w_t = (1 - \alpha) (\alpha / (r_t^l + \delta))^{\alpha/(1-\alpha)} \chi A_t$.

In all regimes, the law of motion of entrepreneurial wealth is determined by the optimal saving decisions of managers and entrepreneurs, described below.

The rural production sector consists of rural firms whose technology is assumed to be similar to that of urban F firms, $Y_{Rt} = K_{Rt}^{\alpha_R} (\chi_R A_t N_{Rt})^{1-\alpha_R}$, where $\chi_R < 1$. Like urban F firms, rural firms can raise external funds at the interest rate r_t^l in each period, and adjust their capital accordingly. So, r_t^l pins down capital-labor ratio and wage in the rural economy. This description is aimed to capture, in a simple way, the notion that there are constant returns to labor in rural areas, due to, e.g., rural overpopulation.

Banks: Competitive financial intermediaries (*banks*) with access to perfect international financial markets collect savings from workers and hold assets in the form of loans to domestic firms and foreign bonds. Foreign bonds yield an exogenous net rate of return denoted by r , constant over time. Arbitrage implies that the rate of return on domestic loans, r_t^l , equals the rate of return on foreign bonds, which in turn must equal the deposit rate. However, lending to domestic firms is subject to an *iceberg cost*, ξ , which captures the operational costs, red tape, and so on, associated with granting loans. Thus, ξ is an inverse measure of the efficiency of intermediation. In equilibrium, $r^d = r$ and $r_t^l = (r + \xi_t) / (1 - \xi_t)$, where r_t^l is the lending rate to domestic firms.

Households' saving decisions: Workers and retirees face the problem discussed in section 2, given the equilibrium wage sequence, and having defined $R \equiv 1 + r$. As in the previous section, we hold fixed the share of workers participating in the pension system.

The young managers of E firms earn a managerial compensation m . Throughout their experience as managers, they acquire skills enabling them to become entrepreneurs at a later stage of their lives. The total managerial compensation in period t equals $M_t = \psi Y_{E,t}$. Managers work for J_E years, and during this time can only invest their savings in bank deposits (as can workers) which yields an annual gross return R . As they reach age $J_E + 1$, they retire as managers, and have the option (which they always exercise) to become entrepreneurs. In this case, they invest their wealth in their own business yielding the annual return $R_{E,t}$ and hire managers and workers. Thereafter, they are the residual claimants of the firm's profits. We assume that entrepreneurs are not in the pension system. Their lifetime budget constraint is then given by

$$\sum_{j=0}^{J_E} \frac{s_j}{R^j} c_{t+j} + \sum_{j=J_E+1}^J \frac{1}{R^{J_E}} \frac{s_j}{\prod_{v=t+J_E+1}^{t+j} R_{E,v}} c_{t+j} = \sum_{j=0}^{J_E} \frac{s_j}{R^j} m_{t+j}.$$

The right hand-side is the PDV income from the managerial compensation. The left hand-side yields the PDV of consumption. This is broken down in two parts: the first term is the PDV of consumption when young, when the manager faces a constant rate of return, R ; the second part is the PDV of consumption when being an entrepreneur, and is discounted at the rate R until J_E , and at the entrepreneurial rate of return thereafter.

Mechanics of the model: The dynamic model is defined up to a set of initial conditions including the wealth distribution of entrepreneurs and managers, the wealth of the pension system, the aggregate productivity (A_0), and the population distribution. The engine of growth is the savings of managers and entrepreneurs. If the economy starts in regime (i), then all managerial savings are invested in the entrepreneurial business as soon as each manager becomes an entrepreneur. As long as managerial investments are sufficiently large, the employment share of E firms grows and that of F firms declines over time.

The comparative dynamics of the main parameters is as follows: (i) a high β implies a high propensity to save for managers and entrepreneurs and a high speed of transition; (ii) a high world interest rate (r) and/or a high iceberg intermediation cost (ξ) increases the lending rate, implying a low wage, a high rate of return in E firms, a high managerial compensation, and, hence, a high speed of transition; (iii) a high productivity differential (χ) implies a high rate of return in E firms, a high managerial compensation, and, hence, a high speed of transition; (iv) a high σ implies that entrepreneurs can leverage up their wealth and earn a higher return on their savings, which speeds up the transition; and (v) a high managerial rent (ψ) implies a low rate of return in E firms, a high managerial compensation, and, hence, has ambiguous (and generally non-monotonic) effects on the speed of transition.

Note that the savings of the worker do not matter for the speed of transition, because the lending rate offered by banks depends only on the world market interest rate and on the iceberg cost.

E.1 Calibration

In SSZ, we show that a calibrated version of the model outlined in the previous section matches well a number of salient macroeconomic trends for the recent period. In particular, the model reproduces realistic trends for output growth, wage growth, return to capital, transition from state-owned to private firms, and foreign surplus accumulation. The current model - which incorporates additional features including demographics and the pension system - the model is calibrated to match the same macroeconomic trends after 2000.

We must calibrate two parameters related to the financial system, ξ and σ , and four technology parameters, α, δ, χ and ψ . The parameters α and δ are set exogenously: $\alpha = 0.5$ so that the capital share of output is 0.5 in year 2000 (Bai *et al.*, 2006), and $\delta = 0.1$ so that the annual depreciation rate of capital is 10%.

The remaining parameters are calibrated internally, so as to match a set of empirical moments. We set the parameters ψ and χ so that the model is consistent with two key observations: (i) the capital-output ratio in E firms is 50% of the corresponding ratio in F firms (as documented by SSZ for manufacturing industries, after controlling for three-digit industry type), (ii) the rate of return on capital is 9% larger in E firms than in F firms.⁵¹ The implied parameter values are $\psi = 0.27$ and $\chi = 2.73$. This implies that the TFP of an E firm is 1.65 times larger than the TFP of an F firm.⁵²

We set ξ so as to target an average gross return on capital of 20% in year 2000 (Bai *et al.*, 2006). With $\delta = 10\%$, this implies an average net rate of return on capital of 10%. This average comprises both F firms and E firms. Since the DPE employment share in the period 1998-2000 was on average 10%, this implies $\rho_F = 9.3\%$, so that the initial value for ξ is $\xi_{2000} = 0.062$. After year 2000, we assume that there is gradual financial improvement so ξ falls linearly to zero by year 2024. The motivation for such decline is twofold. First, we believe it is reasonable that banks improve their lending practices over time, so that borrowing-lending spreads will eventually be in line with corresponding spreads in developed economies. Second, a falling ξ will generate capital deepening in F firms and E firms due to cheaper borrowing and higher wages, respectively. Such development helps the model to generate an increasing aggregate investment rate during 2000-2009, which is a clear pattern of aggregate data. If ξ were constant, the model would predict a falling rate (see Song *et al.*, 2011, for further discussion).

We set $\sigma = 0.43$, so that entrepreneurs can borrow 87 cents for each dollar in equity in 2000. This value for σ implies that the growth in the DPE employment share is in line with private employment growth between 2000 and 2008 in urban areas. We set the initial level of productivity, A_{2000} , so that the GDP per capita is 8.3% of the US level in 2000. This yields a GDP per capita equal to 20% of the US level in 2010, in line with the data. Moreover, we set the growth rate of A_t (i.e., the secular exogenous productivity growth) so that the model generates an average labor income growth (controlling for human capital) of 7.5% between 2000-2013. The resulting growth rate in A_t is 2.1% larger than the associated world TFP growth rate during this period. After 2010, the growth rate of A_t in excess of the long-run world rate falls linearly to zero until the TFP level in E firms reaches that of US firms. This occurs in year 2022. Thereafter, the TFP grows at the long-run world rate. Finally, β is calibrated to 1.0164 to match the average aggregate urban household saving rate of 25% in 2000-2010.

In the rural sector, we set $\alpha_R = 0.3$ to match the observed 20% investment rate in the rural area in 2000. The technology gap χ_R is set to 0.75 to capture an observed urban-rural wage gap of 1.84 in

⁵¹Song et al. (2011) document that manufacturing, domestic private enterprises (DPE) have on average a ratio of profits per unit of book-value capital 9% larger than that of SOEs during the period 1998-2007. A similar difference in rate of return on capital is reported by Islam, Dai, and Sakamoto (2006).

⁵²Hsieh and Klenow (2009) estimate TFP across manufacturing firms in China and find that the TFP of DPEs is about 1.65 times larger than the TFP of SOEs.

2000. The rural wage grows over time, due to the exogenous technology growth and to the decreasing lending rate. The rural-urban wage gap implied by the model increases from 1.84 in 2000 to 3.48 in 2040 and stays constant thereafter (see figure VI in the appendix).

The initial conditions are set as follows. Total entrepreneurial wealth in 2000 is set equivalent to 14.6% of urban GDP so that the 2000 DPE employment is 20%. The distribution of that entrepreneurial wealth is obtained by assuming that all entrepreneurs are endowed with the same initial wealth in 1995. The initial wealth for workers, retirees, and managers is set so as to match as the 1995 empirical age distribution of financial wealth for urban households from CHIP. The 2000 distribution of wealth across individuals is then derived endogenously. Finally, the initial government wealth is set to 96% of GDP in 2000 so as to generate a net foreign surplus equal to 12% of GDP in 2000.⁵³

E.2 Simulated output trajectories

The calibrated model yields growth forecasts that we view as plausible. Figure II shows the evolution of productivity and output per capita forecasted by our model. The growth rate of GDP per worker remains about 7.5% per year until 2020 (see upper panel). After 2020, productivity growth is forecasted to slow down. This is driven by two forces: (i) the end of the transition from state-owned to private firms and (ii) the slowdown in technological convergence. The growth rate remains above 7.2% between 2020-2030 and eventually dies off in the following decade. Note that the growth of GDP per capita is lower than that of GDP per worker after 2013, due to the increase in the dependency ratio. On average, China is expected to grow at a rate of 6.5% between 2013 and 2040. The contribution of human capital is 0.8% per year, due to the entry of more educated young cohorts in the labor force. In this scenario, the urban GDP per worker in China will be 73% of the US level by 2040, remaining broadly stable thereafter. The corresponding GDP per capita of China is 68% of the US level in 2040. Total GDP in China is set to surpass that in the United States in 2013 and to become more than twice as large in the long run.

The wage sequence that was assumed in section 2 is now an endogenous outcome. Wages are forecasted to grow at an average of 4.9% until 2031 and to slow down thereafter. What keeps wage growth high after 2020 is mostly capital deepening.⁵⁴

E.2.1 Sensitivity: high savings and foreign surplus

Although the growth forecasts are plausible, the calibrated economy generates a very large amount of savings. For instance, in 2065 the economy has a wealth-GDP ratio exceeding 1000%. This is because the model is calibrated to match urban household saving during 2000-2010. In that period, China experienced high growth and yet a very high saving rate (a total savings rate of 48.2%, and a household savings rate of 25%).

Since our stylized model forecasts an eventual decline in growth, the intertemporal motive would suggest that consumption should have been high before 2010. Therefore, the model requires a sufficiently high discount factor ($\beta = 1.0164$) in order to predict the empirical saving rate during the first decade of the 21st century. In our model, a high β is a stand-in for a number of institutional

⁵³More precisely, government wealth is calculated as a residual. It is equal to the sum of foreign surplus and domestic capital (from both SOE and DPE) minus the stock of private wealth owned by workers and entrepreneurs.

⁵⁴In Section 4 we held the wage sequence constant across the different policy experiments. However, in the general equilibrium model of this section, the wage sequence is endogenous and would in general be affected by alternative reforms. In particular, pension reforms impact labor supply through a wealth effect, and this influences the capital accumulation dynamics during transition. Since the effects are quantitatively small, the results are omitted and are available upon request.

features that are not explicitly considered and that may explain a high propensity to save over and beyond pure preferences (e.g., large precautionary motives or large downpayment requirements for house purchases).⁵⁵

Since it seems implausible that China will continue to save so much, we consider an alternative scenario, where all cohorts entering the labor market after 2013 have $\beta = 0.97$. In such an alternative scenario China’s net foreign position would be zero in the long run. The analysis of the alternative pension arrangements discussed in the previous sections yields essentially the same results as in the high β economy. Thus, the calibration of β is unimportant for the effects of the welfare analysis, which is the main contribution of this paper.

This finding is not surprising since long-term wages and GDP do not hinge on the domestic propensity to save. Although the entrepreneurs’ propensity to save determines the speed of the transition, this does not matter much for welfare (see section 5.1).

E.2.2 Sensitivity: Financial development

The model borrows from SSZ the assumption that E firms are financially constrained. Note that the salience of the financial constraints declines over time as E firms accumulate capital. As the economy enters regime (iii), which occurs in 2040, the financial constraint ceases to bind.

In our baseline calibration, the parameter σ , which regulates borrowing of private firms, is assumed to be constant over time. An exogenous increase in σ – for example, due to financial development – would speed up growth of private firms. Wage growth would accelerate earlier, although the long-run wage level would be unaffected.

To study the effects of financial development on pension reform, we consider a stark experiment in which the borrowing constraint on private firms is completely removed in 2013. This means that state-owned firms vanish, and there is large capital inflow driven by entrepreneurial borrowing. Wages jump upon impact (by 88%) due to the large capital deepening. In 2030, the wage level is still 18.5% above the baseline calibration. In 2040 the wage level is the same as in the benchmark calibration.

Although financial development affects the transition path, it brings little change to the conclusions of the welfare analysis.⁵⁶ The benchmark reform requires a slightly smaller reduction of the replacement rate: 39.8% instead of 39.1%. The delayed reform still entails gains for the transition cohorts, albeit these gains decline faster over time. For instance, delaying a reform until 2050 yields a 17% consumption equivalent gain for the cohort retiring in 2013, but only a 10.5% gain for the cohort retiring in 2049. The losses suffered by the cohorts retiring after 2050 are comparable in size to those in the baseline scenario without financial development. The gains accruing to the high- and low-discount planners are, respectively, 5.3% and 0.5% (6.4% and 0.9% in the baseline scenario).

The FF reform yields slightly better outcomes. All generations retiring after 2050 gain from the reform (2060 in the baseline scenario), and the losses of the earlier cohorts only reach 7% (11% in the baseline scenario). The high-discount planner continues to prefer the benchmark reform to the FF reform, whereas the low-discount planner continues to have the opposite ranking. The PAYGO reform yields even larger gains to the earlier cohorts. Both the high- and the low-discount social planners continue to prefer the PAYGO reform to any alternative policy-driven reform. However, the welfare gap between the PAYGO and the fully funded reform is now smaller, since the planners dislike the concentrated nature of the gains under the PAYGO reform. For instance, the consumption

⁵⁵Chamon *et al.* (2013) and Song and Yang (2010) study household savings in calibrated life-cycle models. They incorporate individual risk and detailed institutional features of the pension system and find that their models are qualitatively consistent with the life-cycle profile of household saving rates. However, both studies find that with a conventional choice of β , their models would imply quantitatively too low savings for the young households.

⁵⁶We focus for simplicity on the policy-driven reforms, and we omit an explicit analysis of the optimal policy.

equivalent gain of the low-discount planner relative to the benchmark reform is 1%, compared with 1.7% in the baseline scenario. Since the fully funded reform also entails a 0.5% gain relative to the benchmark reform, the consumption equivalent gain of the PAYGO relative to the FF reform is only 0.5% (although it remains significantly higher, 12.4%, for the high-discount planner).

In conclusion, financial development mitigates but does not change the welfare implications of alternative reforms.

APPENDIX REFERENCES

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APPENDIX FIGURES

In this section, we provide the appendix figures.

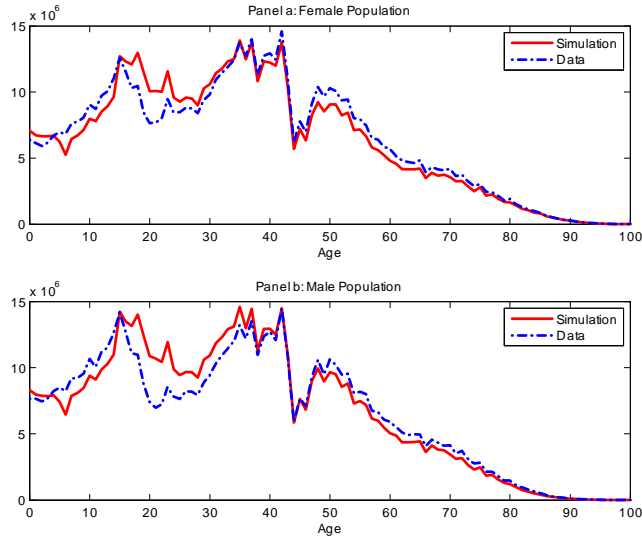


Figure I: The upper panel shows the female population of different ages in 2005, in the survey data (solid line), and in our simulation (dashed line). The lower panel shows the male population in 2005.

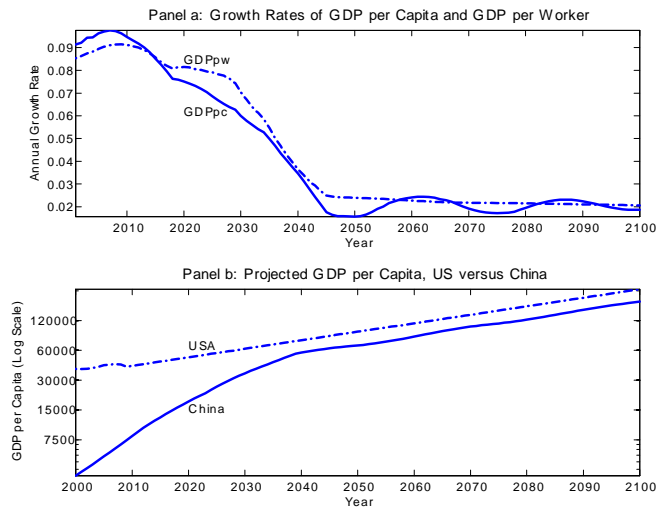


Figure II: The upper panel shows projected annual growth rates in GDP per worker and GDP per capita in the calibrated economy. The lower panel shows projected GDP per capita in levels for China and the US.

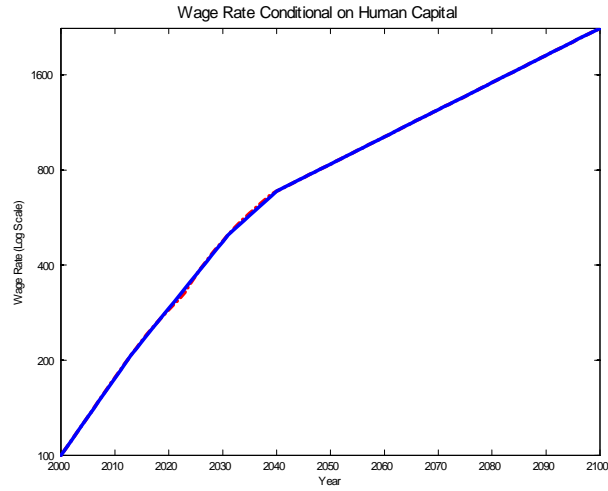


Figure III: The figure shows the assumed hourly wage rate per unit of human capital in urban areas, normalized to 100 in 2000. The solid line is the assumed wage process and the dashed line is the wage process consistent with the endogenous outcome of the general equilibrium model of section E. Note that the two lines are almost indistinguishable.

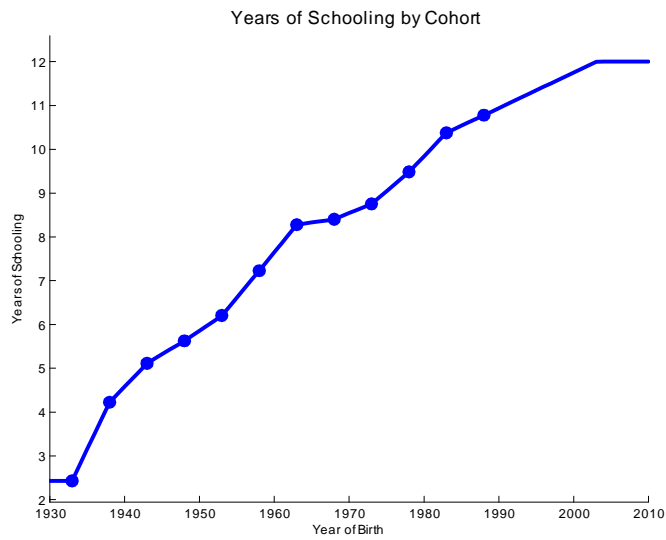


Figure IV: The figure shows the average number of years of schooling for different age cohorts in China. Source: Barro and Lee data set. The values after 1990 are (linearly) extrapolated, assuming the growth in schooling accumulation stagnates at 12 years.

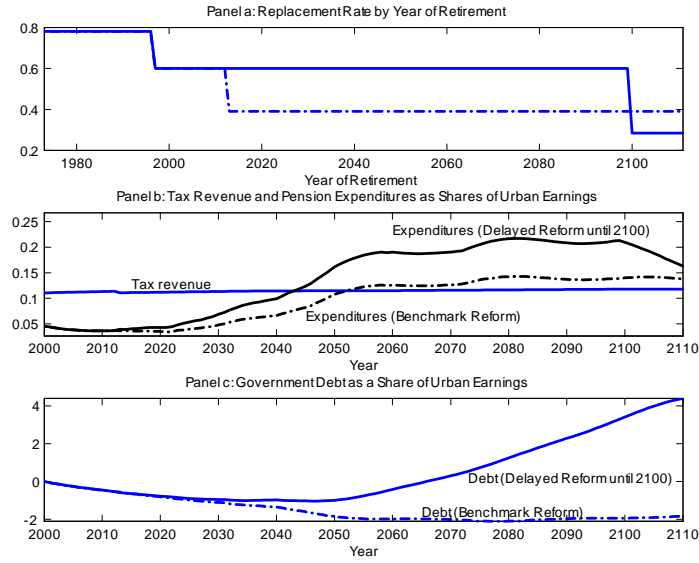


Figure V: Panel (a) shows the replacement rate q_t for the case when the reform is delayed until 2100 (solid line) versus the benchmark reform (dashed line). Panel (b) shows tax revenue and expenditures, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2100 is solid). Panel (c) shows the evolution of government debt, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2100 is solid). Negative values indicate surplus.

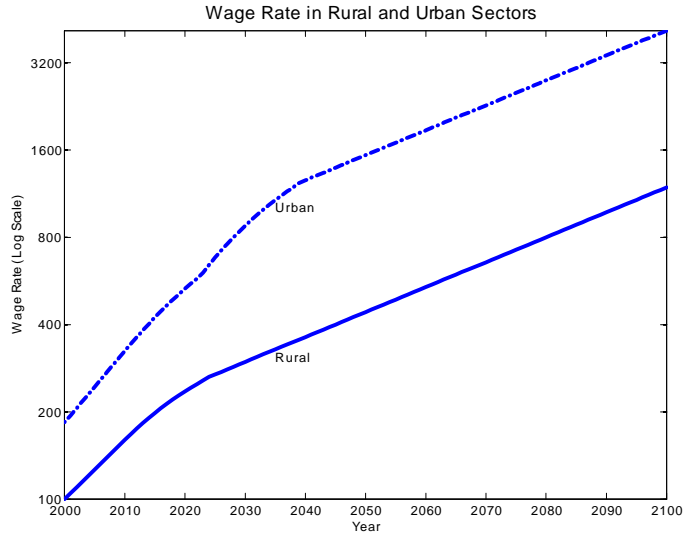


Figure VI: The figure shows the projected hourly wage rate per unit of human capital in urban (dashed line) and rural (continuous line) areas, normalized to 100 in rural areas in 2000. The process is the endogenous outcome of the general equilibrium model of section E.

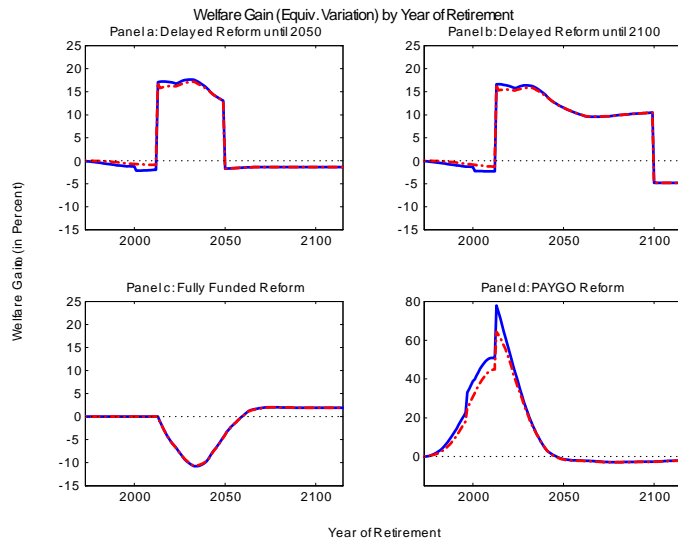


Figure VII: As in figure (6), the solid lines show welfare gains of alternative reforms relative to the benchmark reform for each cohort, but now under the assumption that all the reforms are perfectly anticipated at 2000. The dashed lines are the welfare gains in the baseline scenario, as in figure (6). The gains (ω) are expressed as percentage increases in consumption.

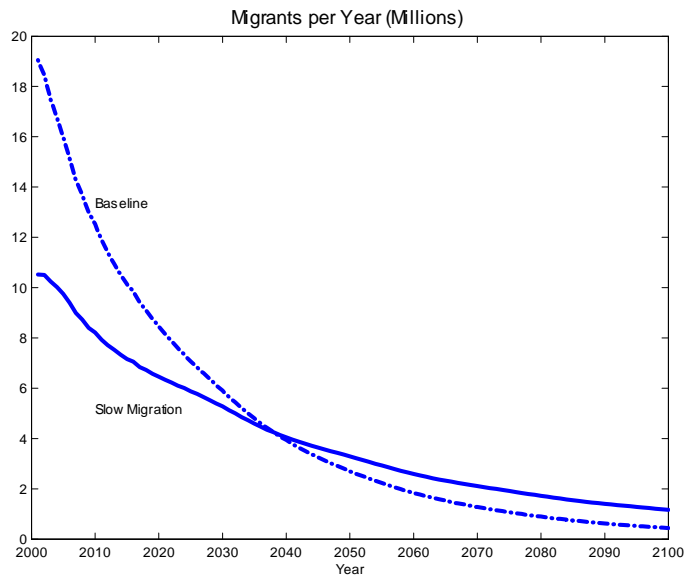


Figure VIII: The migration flow (i.e., the number of migrants per year) in the slow migration and baseline scenarios are shown with the solid and dashed lines, respectively. The migration flow is smaller in the slow migration scenario than in the baseline scenario before 2038, but larger afterwards.