

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

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## Abstract

Inequality, aging population and old age poverty are salient issues in emerging economies, most notably, China. In this paper, we analyze which policy and institutions emerging economies can adopt to share the benefits of high growth. We derive normative implications with the aid of a stylized dynamic model. We calibrate a version of the model to China, incorporating population dynamics, productivity growth and other structural features of the Chinese economy. A reform is necessary to make the pension system financial balanced. However, an immediate reduction in the generosity of the system is not optimal. Even a planner with a low social discount factor would prefer to defer the reform by forty years. The reason is that the current system transfers resources from the (richer) future generations to (poorer) current generations, imposing only small costs on the former. Reforming the system in a fully funded direction would harm current generations by reducing intergenerational transfers, while yielding only small gains to future generations. Temporarily high wage growth and financial market imperfections, which are common features of emerging economies, are key for these results.

**Keywords:** China; Credit market imperfections; 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 convergence, improving significantly the average living standards of their populations. Their success is often accompanied by increasing inequality. Intergenerational inequality, which is intrinsically correlated with high wage growth, is an important component of total inequality. Take 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 perspectives than did their parents, poverty among the elderly is pervasive, aggravated by the progressive demise of traditional forms of family insurance (see, e.g., Almås and Johnsen (2013), Park *et al.* 2012, Yang and Chen 2010, Yang 2011).

In this paper, we study which policy and institutions emerging countries can adopt to allow different generations to share the benefits of high growth. To address this question, we construct a stylized growth model where the economy is on a convergence trajectory characterized by fast growth initially, followed by a slowdown as the economy approaches its steady state. A benevolent planner weighs the utility of overlapping generations of agents with a geometrically declining weight. For *any* social discount factor, the planner wants to redistribute more intensively during the transition than she does in steady state. We take as our conservative benchmark a highly forward-looking (*low-discount*) planner who has no desire to redistribute across generations in steady state. Yet, such a planner wants redistribution from future to current generations during the transition. The socially desired redistribution can be implemented by a simple defined benefit pension system with declining replacement rates.

We apply the insights of our theory to the analysis of the design of the Chinese pension system. To this aim, we extend the stylized model to a multiperiod OLG model of the Chinese economy based on Song *et al.* (2011) that can be used for a quantitative analysis. The model embeds key trends of the growth experience of China: a demographic transition, rural-urban migration, fast wage growth, and financial market imperfections driving a gap between the high rate of return to industrial investments and the low rate of return to which Chinese households typically have access. We also introduce into the model a stylized pension system that reproduces salient features of the actual urban Chinese pension system.

We use the model to address two related questions: (i) Is a pension system based on the current rules sustainable? (ii) What are the welfare effects of alternative reforms? The answer to the first question is clearcut, and in line with previous studies: due to the demographic transition that is increasing sharply the old age dependency ratio, the current system is not financially balanced and

requires a significant adjustment in either contributions or benefits. We focus on the benefit margin and consider a ("draconian") *benchmark reform* reducing the pension payments to all workers retiring after 2012. The reform does not renege on the outstanding obligations to current retirees – following the pattern of most reforms in OECD countries. This reform entails a sharp permanent reduction of the replacement rate, from 60% to 40%, which would allow the accumulation of a large pension fund until 2051 to pay for the pensions of future generations retiring in times when the dependency ratio will very high.

To address the second question, we consider three alternative reforms. The benchmark welfare criterion is the utility maximization of a low-discount planner, whose social discount rate equals an annual 0.5% in our calibration, who – as discussed above – has no desire to redistribute in steady state. We view this criterion as a lower bound to the societal desire to redistribute from richer future generations to poorer current generations. We also consider a more impatient planner, following Nordhaus (2007), whose social discount rate equals the market interest rate. As shown by the theoretical section, the planner has two goals: to minimize tax distortions, and to redistribute resources towards the poorer earlier generations during the transition.

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 planner's utility. The benchmark low-discount planner wishes to defer such benefit cut until 2051, so that it only affects workers entering the labor force after 2012. This delay yields large welfare gains for the transition generations relative to the draconian benchmark reform in 2013. Quantitatively, the gains accruing to the cohorts retiring before 2051 would be equivalent to a 12% increase in their lifetime consumption. The generations retiring after 2051 would only suffer small losses in the form of a somewhat lower replacement ratio. If the planner has a higher social discount rate, the delay is even larger.

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 fully funded reform, whereas earlier generations lose. The attractiveness to the planner of this system is that it reduces tax distortions on labor supply. However, by ruling out intergenerational transfers that were favoring the initially old workers, this system eliminates a vehicle of redistribution that the planner values. The low-discount planner prefers marginally the FF reform to the draconian adjustment of the current system in 2013, but prefers the delayed reform to the FF reform. This result is strengthened for more impatient planners: the Nordhaus planner suffers large welfare losses in the FF reform.

The third reform is switching to a pure 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. The welfare effects of the *PAYGO* reform are similar, if stronger, to those of a delayed reform. Given the demographic transition of China, the *PAYGO* yields very generous pensions to early cohorts and punishes severely all generations retiring after 2046. This reform is effective in allowing the poorer current generations to share the benefits of high wage growth with the richer generations that will enter the labor market when China is a mature economy. However, it entails a tax distortion.<sup>1</sup>

The results above accrue in an otherwise standard model. We show that if the absence of convergence, e.g., if future wage growth were an average of 2% per year, the results would be in line with conventional wisdom: a FF reform, or alternatively the immediate draconian reform, are preferred to a delayed reform or to a pure *PAYGO* system.

The normative predictions of our theory 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 predictions are aligned with the policy recommendations of Barr and Diamond (2008), arguing against reforming the pension system in the direction of pre-funded individual accounts.<sup>2</sup>

Our results hinge on two common features in emerging economies that are particularly pronounced in China: a high wage growth and a low rate of return on savings (in spite of high returns to investment). 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, nonperforming loans, etc. relative to its level of development.<sup>3</sup> Our analysis illustrates a point that applies more generally to fast-growing

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<sup>1</sup>We also consider hybrid reforms that would enable the planner to both cut distortionary taxes and enforce a decreasing sequence of replacement rates. Such reforms would generate even larger gains, although their political implementation may be more difficult.

<sup>2</sup>Barr and Diamond (2008; ch. 15) suggest that (i) although a pre-funded system may induce higher savings (as it does in our model), this objective does not seem valuable for China; (ii) a pre-funded asset-based system is likely to lead to either low pension returns or high risk due to the large imperfections of the Chinese financial system; and (iii) introducing a funded system would benefit future generations of workers at the expense of today's workers who are relatively poor and subject to great economic uncertainty.

<sup>3</sup>Different 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.

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 to future generations.

The current pension system of China covers only about 60% of urban workers. We analyze the welfare effect of making the system universal, extending its coverage to all rural and urban workers. This issue is topical for various reasons. First, the incidence of old-age poverty is especially severe in rural areas, and internal migration is likely to make the problem even more severe in the coming years. Second, the government of China is currently introducing some form of rural pensions. The recurrent question is to what extent this is affordable, and how generous rural pensions can be, since almost half of today's population lives in rural areas, and these workers have not contributed to the system thus far. We find that extending the coverage of the pension system to rural workers would be relatively inexpensive, even though full benefits were paid to workers who never contributed to the system. As expected, this change would trigger large welfare gains for the poorest part of the Chinese population. The cost is small, since (i) benefits are linked to local wages and rural wages are low; and (ii) the rural population is shrinking.

The paper is structured as follows. Section 2 presents the stylized two-period OLG model from which we derive the normative results that guide the rest of the analysis. Section 3 extends it to a partial equilibrium multiperiod OLG model that incorporates the main features of the Chinese pension system. The model is calibrated to the demographic dynamics, the wage and interest rate process (assumed to be exogenous in this section) and the pension system of China. Section 4 studies the welfare effects of the alternative pension reforms. Section 5 performs sensitivity analysis. Section 6 provides a full general equilibrium model of the Chinese economy based on Song et al. (2011), where the wage and interest rate path assumed in section 3 are equilibrium outcomes. The general equilibrium model allows us to consider reforms that influence the economic transition. Section 7 concludes. Three webpage appendixes (Appendixes A, B and C) contains some technical material, a description of the Chinese pension system, and additional figures.

## **2 A simple model of intergenerational redistribution for an emerging economy**

In this section we lay out a simple two-period model that illustrates the main point of the paper, namely, that in emerging economies with fast but declining wage growth, it is optimal, under fairly general conditions, to redistribute from future to current generations. Moreover, the optimal redis-

tribution can be implemented by a *simple* pension system that gives higher replacement rates to the earlier generations.

Consider an economy populated with overlapping generations of household who work when young. To emphasize the case of a temporarily high wage growth, we assume that wages grow at constant rate  $g$  from period  $t = 1$  and onward, and at a higher rate than in steady state in the first period, so,  $w_1 > (1 + g)w_0$ . We maintain a constant population growth rate  $n$  throughout, although this is not essential for the argument.

The preferences of a household born in period  $t \geq 0$  are given by

$$U_t = \log c_t^Y - \frac{1}{1 + \frac{1}{\theta}} (h_t)^{1 + \frac{1}{\theta}} + \beta \log c_{t+1}^O, \quad (1)$$

where  $c^Y$  and  $c^O$  denote consumption in young and old age, respectively, and  $h$  denotes labor supply (note that the old do not work).

Consider a planner who has an initial stock of resources (or debt) and who can borrow and lend in an international bond market at the gross interest rate  $R$ . The planner's resource constraint is given by

$$\sum_{t=0}^{\infty} \left( \frac{1+n}{R} \right)^t \left( c_t^Y + \frac{c_{t+1}^O}{1+r} - w_t h_t \right) \leq A_0, \quad (2)$$

where  $A_0$  denotes the initial planner's wealth net of promises to the initial generation of old. She is assumed to care about all present and future generations, and to discount the future generations' utilities geometrically, with a discount factor  $\phi \in (0, 1)$ . In order for the resource constraint to be well-defined, we assume that  $R > (1 + g)(1 + n)$ , i.e., the economy is dynamically efficient. Moreover, for the transversality condition of the planner's problem to hold, we must assume that  $\phi < (1 + n)^{-1}$ .

The optimal allocation (*first best*) is characterized by the solution to the following program:

$$\max_{\{c_t^Y, c_t^O, h_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} (\phi(1+n))^t \left( \log c_t^Y + \beta \log c_{t+1}^O - \frac{h_t^{1 + \frac{1}{\theta}}}{1 + \frac{1}{\theta}} \right) - \lambda \left( \sum_{t=0}^{\infty} \left( \frac{1+n}{R} \right)^t \left( c_t^Y + \frac{c_{t+1}^O}{1+r} - w_t h_t \right) - A_0 \right).$$

An interior solution yields:

$$c_t^Y = \lambda^{-1} (\phi R)^t \quad (3)$$

$$h_t^{\frac{1}{\theta}} = \frac{w_1}{1+g} \lambda \left( \phi \left( \frac{R}{1+g} \right) \right)^{-t} \quad \text{for } t \geq 1 \quad (4)$$

$$h_0^{\frac{1}{\theta}} = \frac{w_1}{1+g} \lambda \times \frac{w_0(1+g)}{w_1}. \quad (5)$$

Condition (3) is an intergenerational Euler equation reflecting the planner's preferences for redistribution. Conditions (4)–(5) are optimal labor supply conditions.

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 available to the planner is a pension system comprising a sequence of taxes and pension replacement rates  $\{\zeta_t, \tau_t\}_{t=0}^\infty$ , where labor income of generation  $t$  is taxed at the flat rate  $\tau_t$ , and the generation receives a lump sum pension  $p_t$  proportional to aggregate labor earnings after tax:<sup>4</sup>

$$p_{t+1} = \zeta_t (1 - \tau_t) w_t \bar{h}_t,$$

where  $\bar{h}_t$  is aggregate labor supply.

The budget constraint for the agents is, therefore,

$$h_t (1 - \tau_t) w_t + \frac{p_{t+1}}{R} = c_t^Y + \frac{c_{t+1}^O}{R} \quad (6)$$

Solving the household problem, (1), subject to (6), and recalling that in equilibrium  $h_t = \bar{h}_t$ , the equilibrium labor supply is given by

$$h_t = (1 + \beta)^{\frac{\theta}{1+\theta}} \left(1 + \frac{\zeta_t}{R}\right)^{-\frac{\theta}{1+\theta}}.$$

Moreover, the lifetime consumption growth satisfies a standard Euler equation:  $c_{t+1}^O = \beta R c_t^Y$ .

The following proposition (proof in the appendix) establishes that the first best can be implemented by setting tax to zero and choosing a suitable replacement rate sequence.<sup>5</sup>

**Proposition 1** *The first best allocation is implemented by setting  $\tau_t = 0$  and the replacement rate sequence*

$$\zeta_t = R \left( \left( \left( \phi \frac{R}{1+g} \right)^t \frac{(1+\theta)(1+g)}{\lambda w_1} \right)^{1+\theta} - 1 \right) \quad \text{for all } t \geq 1, \quad (7)$$

and

$$\zeta_0 = R \left( \left( \frac{(1+\theta)(1+g)}{\lambda w_1} \right)^{1+\theta} \left( \frac{w_1}{w_0(1+g)} \right)^{1+\theta} - 1 \right), \quad (8)$$

where  $\lambda$  is the Lagrangean multiplier associated with the planner's budget constraint, being strictly decreasing in  $A_0$ .

Note that, for  $t \geq 1$ , the replacement rate sequence may increase or decrease over time depending on whether  $\phi \geq \frac{1+g}{R}$ . In particular, if  $\phi = \frac{1+g}{R}$ , i.e., the discount rate is equal to the growth-adjusted net

<sup>4</sup>The restriction that pension payments are related to average rather than individual labor supply is without loss of generality, as we will show that this policy implements the first best (although other policies can do that, too).

<sup>5</sup>The proof is straightforward. It amounts to verify that the pension policy, (7)-(8), implies individual consumption and labor supply consistent with the first best allocation (3)-(5).

interest rate, then, the planner has no drive for intergenerational redistribution in steady state.<sup>6</sup> This particular discount factor is, therefore, an interesting benchmark which will be used in the quantitative analysis below. In this case, the optimal policy is particularly simple. We state this formally as a corollary.

**Corollary 1** *If the planner's discount factor is  $\phi = (1 + g) / R$ , then the pension replacement rate is constant for  $t \geq 1$  (i.e.,  $\zeta_t = \zeta$ ). Moreover, the replacement rate of the initial generation is larger than that of the future generations ( $\zeta_0 > \zeta$ ).*

More generally, unless the planner has a strong drive to redistribute, in steady state, from current to future generations, the first best is implemented by a more generous pension scheme to the transition generation. The intuition is simple: the first generation is very poor, relatively speaking, so even a utilitarian planner with limited or no desire to redistribute in steady state would choose a higher pension for the first generation.

Note that the implementation requires no distortion to labor supply. The steady state replacement rate may therefore be negative if  $A_0$  is sufficiently low (or even negative), resulting in a high  $\lambda$ .

Two additional results follow from the analysis above in the particular case in which  $\phi = (1 + g) / R$ . First, suppose that the planner cannot pay negative pensions. Then, for sufficiently low  $A_0$  taxes will be positive and constant in steady state. Second, for any arbitrary constant tax sequence  $\tau_t = \tau$  (where, possibly,  $\tau \neq 0$ ), the planner will set  $\zeta_0 > \zeta$ . Clearly, either of the two constraints implies that the Ramsey allocation will not attain the first best.

### 3 A quantitative multiperiod model for China

Guided by the insights of the simple model laid out in section 2, we now move to the main contribution of the paper, namely, to construct a quantitative model aimed to evaluate the welfare implications of alternative pension reforms of China. In this section, we lay out a multiperiod OLG model close in spirit to Auerbach and Kotlikoff (1987), Conesa and Krueger (1999) and Huang, Imrohglu and Sargent (1997). Then, we specify demographic dynamics, an exogenous wage growth process and a set of pension rules. Finally, we use the model to assess the welfare effects of alternative pension reforms.

#### 3.1 Household

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  $s_j$ .

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<sup>6</sup>Note also that this planner's discount rate is consistent with the standard calibration of infinite-horizon growth models. In particular, the standard steady-state condition of a discrete-time models yields exactly a discount factor of  $(1 + g) / R$ .

During their first  $J_C - 1$  years (childhood), agents are economically inactive, make no choices, and gain no utility. Preferences are defined over consumption and leisure and are represented by a standard lifetime utility function,

$$U_t = \sum_{j=0}^J s_j \beta^j u(c_{t+j}, h_{t+j}),$$

where  $\beta$  is the discount factor,  $c$  is consumption, and  $h$  is labor supply. Here,  $t$  denotes the period in which the agent becomes adult (i.e., economically active). 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 (see, e.g., 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 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,

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

where  $b_{t,t+j}$  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  $t + j$ ,  $\eta_t$  denotes the human capital specific to the cohort turning adult in  $t$  (we abstract from within-cohort differences in human capital across workers),  $\tau_t$  is the labor income tax in period  $t$ , and  $\zeta_j$  is the efficiency units per hour worked for a worker with  $j$  years of experience, which captures the experience-wage profile.

### 3.2 Demographic model

Since China faces a major demographic transition that affects the financial sustainability of the pension system, we construct in this section a detailed demographic model with exogenous population dynamics emphasizing internal migration patterns.

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 estimated 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

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. For instance, rural families are allowed a second birth provided the first child is a girl. In some provinces, *all* rural families are allowed to have a second child provided that a minimum time interval elapses between the first and second birth. Today’s TFR is below replacement level, although there is no uniform consensus about its exact level. Estimates based on the 2000 census and earlier surveys in the 1990s range between 1.5 and 1.8 (e.g., Zhang and Zhao, 2006). Recent estimates suggest a TFR of about 1.6 (see Zeng, 2007).

### 3.2.1 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.<sup>7</sup> There is consensus among demographers that birth rates have been underreported, causing a deficit of 30 to 37 million children in the 2000 census.<sup>8</sup> 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 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 TFR’s of 1.2 and 1.98, respectively.<sup>9</sup> Between 2013 and

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<sup>7</sup>The 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%.

<sup>8</sup>See Goodkind (2004). A similar estimate is obtained by Zhang and Cui (2003), who use primary school enrolments to back out the actual child population.

<sup>9</sup>The 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

2050, we assume age-specific fertility rates to remain constant in rural areas. This is motivated by the observation that, according to the current legislation, a growing share of urban couples (in particular, those in which each spouse is an only child) will be allowed to have two children. In addition, some provinces are discussing a relaxation of the current rule, that would allow even urban couples in which only one spouse is an only child to have two children. Zeng (2007) estimates that such a policy would increase the urban TFR from 1.2 to 1.8 (*second scenario* in Zeng, 2007). Accordingly, we assume that the TFR increases to 1.8 in 2013 and then remains constant until 2050.

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.

### 3.2.2 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 is 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).<sup>10</sup> The second category is all individuals who do not move but whose place of registered residence switches from being classified as rural into being classified as urban.<sup>11</sup> 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

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imbalance.

<sup>10</sup>There 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.

<sup>11</sup>This 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.

distribution of rural workers. It is generally difficult, even for developed countries, to predict the internal migration patterns (see, e.g., 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 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 3.2.1. 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.<sup>12</sup> The technical details of the estimation can be found in Appendix A.

According to our estimates, the overall NMF between 2001 and 2005 was 88 million, corresponding to 10.8% of the rural population in 2000.<sup>13</sup> 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 15.3% for females and 12.2% 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

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<sup>12</sup>Our 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.

<sup>13</sup>There 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.

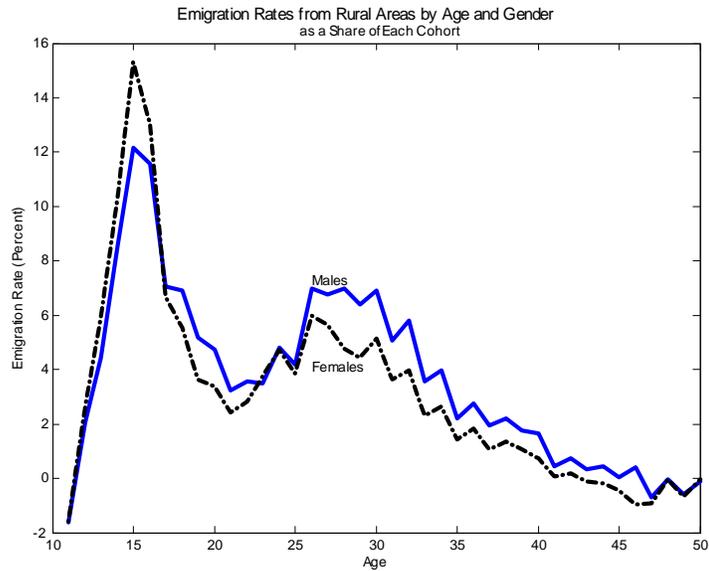


Figure 1: The figure shows rural-urban migration rates by age and gender as a share of each cohort. The estimates are smoothed by five-year moving averages.

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 450 million in 2000 to its long-run 1.2 billion level in 2050. Between 2050 and 2100 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. In contrast, had there been no migration, the urban population would have already started declining in 2008.

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).<sup>14</sup> 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.

<sup>14</sup>In 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.

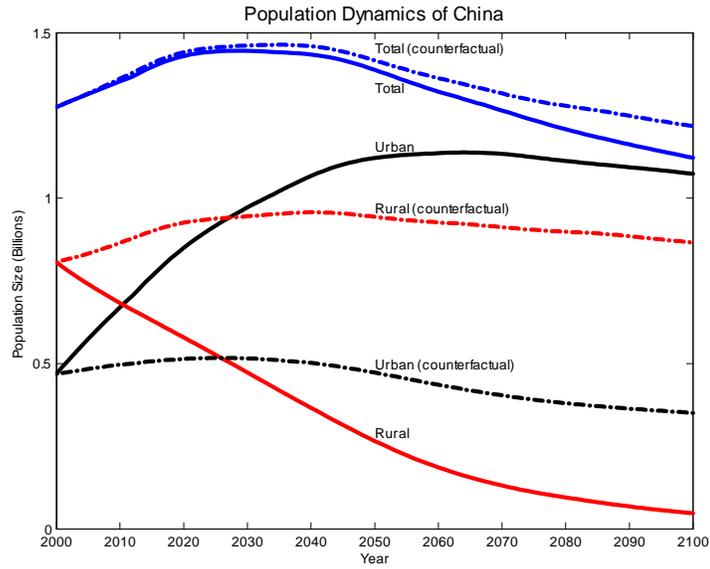


Figure 2: The figure shows the projected population dynamics for 2000-2100 (solid lines) broken down by rural and urban population. The dashed lines show the corresponding natural population dynamics (i.e., the counterfactual projection under a zero urban-rural migration scenario).

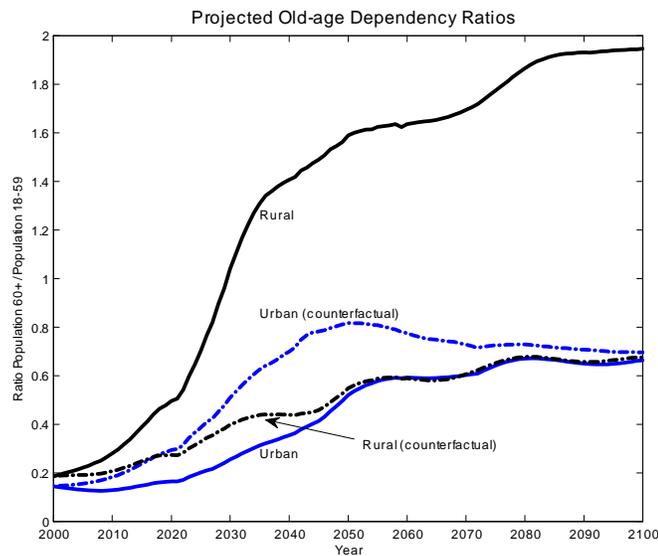


Figure 3: The figure shows the projected old-age dependency ratios, defined as the ratio of population 60+ over population 18-59, for 2000-2100 (solid lines) broken down on urban and rural population. The dashed lines show the corresponding ratios under the zero migration counterfactual (i.e., the natural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

### 3.3 Calibration

In this section, we calibrate the wage process and other key parameters of the model to China. 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 3.2. 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  $J_W = 59$ ). Hence, workers retire after 38 years of work.

The wage growth process is taken as exogenous. In section 6 we show that the assumed wage process is the equilibrium outcome of a calibrated dynamic general-equilibrium model with credit market imperfections close in spirit to Song et al. (2011). We set the age-wage profile  $\{\zeta_j\}_{j=23}^{59}$  equal to the one estimated by Song and Yang (2010) for Chinese urban workers. This implies an average return to experience of 0.5%. In this section of the paper, we take the hourly wage rate as exogenous. The assumed dynamics of urban wages per effective unit of labor is shown in Figure 4: Hourly wages (conditional on human capital) grow at approximately 5.7% between 2000 and 2011. This is in line with the estimate of Ge and Yang (2013) who document that the wage of workers with only middle school education grew by 5.9% over the 1992-2007 period. For the future, we assume an annual growth of 5.1% between 2011 and 2030, subsequently declining to 2.7% between 2030 and 2050. In the long run, wages are assumed to grow at 2% per year, in line with wage growth in the United States over the last century. In section 6, we show that the assumed wage rate dynamics of Figure 4 is the equilibrium outcome of a calibrated version of the model of Song et al. (2011).

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 (2010) (see Figure I in Appendix C). 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.<sup>15</sup> Since younger cohorts have more years of education, wage growth across cohorts will exceed that shown in Figure 4 (note though that the education level for an individual remains constant over each individual worklife).

The average wage growth in the economy compounds the productivity growth per efficiency unit of labor shown in in Figure 4 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

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<sup>15</sup>Zhang 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.

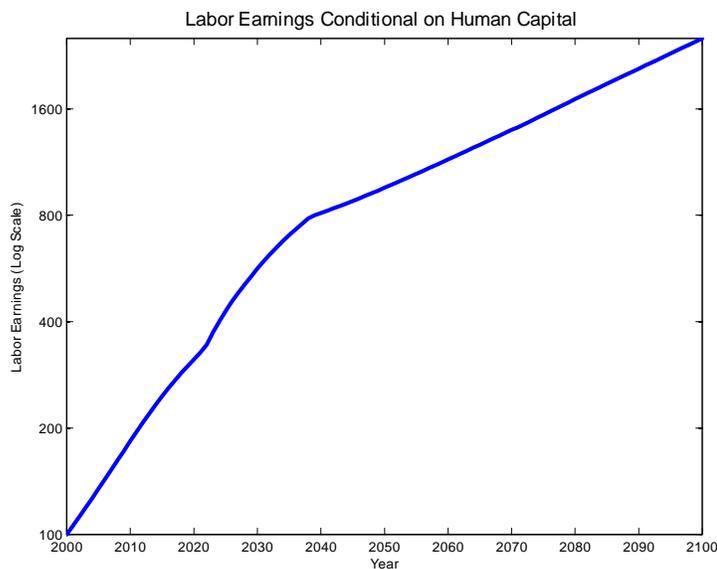


Figure 4: The figure shows the projected hourly wage rate per unit of human capital in urban areas, normalized to 100 in 2000. The process is the endogenous outcome of the general equilibrium model of section 6.

average wages. When all these effects are incorporated, the average annual growth rate in the period 2012-2050 is slightly below 5%. We view this forecast as reasonable in light of existing studies. Ge and Yang (2013) estimate an annual 7.7% average wage growth in the period 1992-2007. Concerning future years, we are not aware of independent long-run forecasts of wage growth. However, Citibank forecasts an annual growth rate of GDP per capita of 5% over the period 2010-2050 (Buiter and Rahbari 2011, p.63). If the labor share remained constant, wage growth should remain aligned with GDP growth. In section 5.1 we do sensitivity analysis on the future wage growth.

The rate of return on capital is very large in China (see, e.g., 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 this share is 75% (source: Chinese Household Income Project, 2002). Moreover, aggregate household deposits in Chinese banks amounted to 76.6% of GDP in 2009 (source: CSY, 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 (see Dollar and Wei, 2007).

Building on Song et al. (2011), the model of section 6 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.<sup>16</sup> 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 (cf. Abel et al., 1989).

Consider, finally, preference parameters: the discount factor is set to  $\beta = 1.0175$  to capture the large private savings in China. This is slightly higher than the value (1.011) that Hurd (1989) estimated for the United States. As a robustness check, we also consider an alternative economy where  $\beta$  is lower for all people born after 2013 (see section 5). In section 6 we document that with  $\beta = 1.0175$  the model economy matches China’s average aggregate saving rate during 2000-2010.

We assume that preferences are represented by the following standard utility function (cfr. equation (1)):

$$u(c, h) = \log c - \frac{1}{1 + \theta} h^{1 + \frac{1}{\theta}},$$

where  $\theta$  is the Frisch elasticity of labor supply. We set  $\theta = 0.5$ , in line with standard estimates in labor economics (Keane, 2011). Note that both the social security tax and pensions in old age distort labor supply.

Finally, we obtain the initial distribution of wealth in year 2000 by assuming that all private agents alive in 1992 had zero wealth. We view this as a reasonable assumption, since China’s market reforms started in 1992 and most private wealth was accumulated thereafter. Given the 1992 distribution of wealth for workers and retirees, we simulate the model over the 1992-2000 period, assuming an annual wage growth of 5.7%, excluding human capital growth. The distribution of private wealth in 2000 is then obtained endogenously.

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<sup>16</sup>Source: [http://www.ssf.gov.cn/xw/xw\\_gl/201205/t20120509\\_4619.html](http://www.ssf.gov.cn/xw/xw_gl/201205/t20120509_4619.html).

### 3.4 The pension system

In this section, we lay out a set of taxes and pension entitlements that replicates the main features of China’s system (see Appendix B for a more detailed description of the actual system).

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 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). Appendix B shows explicitly how the institutional details are mapped into the simple 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. 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:<sup>17</sup>

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

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

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<sup>17</sup>Alternatively, the law of motion of pension benefits can be expressed as  $b_{t,t+j} = b_{t+J_W+1} (0.6 + 0.4 \times (\bar{y}_{t+j-1}/\bar{y}_{t+J_W}))$ .

earnings for workers in period  $t$ :

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

In line with the 1997 reform (see, e.g., Sin, 2005), we assume that 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 ratio.

We assume a constant social security tax ( $\tau$ ) equal to 20%, in line with the empirical evidence.<sup>18</sup>

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 decided to simply assume 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.<sup>19</sup>

### 3.5 The government budget constraint

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

$$\sum_{t=0}^{\infty} R^{-t} \left( \sum_{j=J_w+1}^J N_{t-j,t} b_{t-j,t} - \tau_t \sum_{j=0}^{J_w} N_{t-j,t} \zeta_j \eta_{t-j} w_t h_{t-j,t} \right) \leq A_0, \quad (11)$$

where  $N_{t-j,t}$  is the number (measure) of agents in period  $t$  who became active in period  $t-j$ . Equation (11) is the analogue of equation (2) in the two-period model of section 2.

We set the initial government wealth,  $A_0$ , equal to 71% of GDP in 2000. As we explain below in Section 6.1, this level is consistent with the observed foreign surplus in year 2000, given the (endogenous) level of private wealth in the same year. The entire government wealth is assumed to enter the budget of the pension system.

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<sup>18</sup>The 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 webpage appendix for details.

<sup>19</sup>According 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).

### 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 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  $\tau = 20\%$  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 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*.<sup>20</sup>

The benchmark reform entails a large reduction in the replacement rate, from 60% to 40%. 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 ratio constant at the initial 60% and to increase taxes permanently so as to satisfy (11), then  $\tau$  should increase from 20% to 30.1% as of year 2013.

Figure 5 shows the evolution of the replacement rate by cohort under the benchmark reform (panel (a), dashed line). The replacement rate is 78% until 1997 and then falls to 60%. Under the benchmark reform, it falls further to 40% in 2013, remaining constant thereafter. Panel (b) (dashed line) shows that such a reform implies that the pension system runs a surplus until 2051. The government builds up a government trust fund amounting to 261% 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 2051.<sup>21</sup>

## 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) would want to redistribute in favor of the poorer earlier generations. The

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<sup>20</sup>It is natural to impose financial balance on the assumed benchmark policy. It would not make sense to compare an unbalanced system with reforms that satisfy the intertemporal budget constraint of the government. In particular, we cannot consider as a benchmark an unbalanced system where the current rules are maintained forever.

<sup>21</sup>Note that in panel c the government net wealth (i.e., minus the 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.

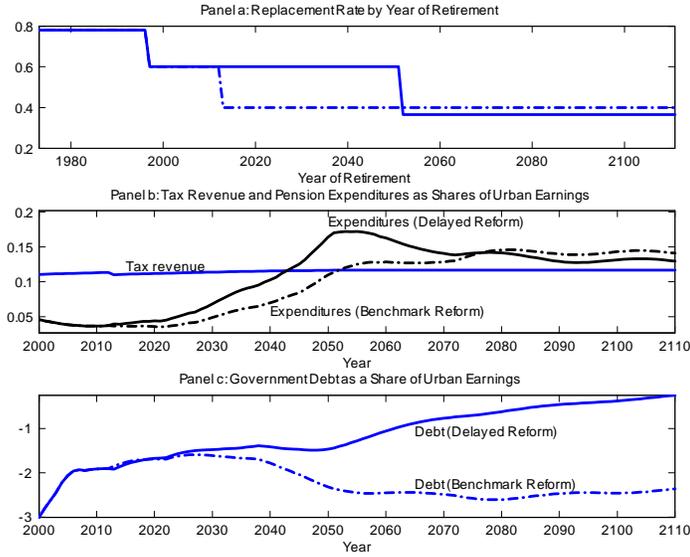


Figure 5: Panel (a) shows the replacement rate  $q_t$  for the benchmark reform (dashed line) versus the case when the reform is delayed until 2052. Panel (b) shows tax revenue and expenditures, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2052 is solid). Panel (c) shows the evolution of government debt, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2052 is solid). Negative values indicate a surplus.

pension system can in principle achieve this objective. However, China is facing a difficult dilemma, as its demographic transition of China puts its financial viability under serious strain. In fact, many commentators suggest that since China cannot afford such a generous pension, it should scale down intergenerational redistribution, and possibly even remove it altogether by switching to a fully funded system (see Feldstein 2006).

The benchmark reform achieves financial balance in a draconian fashion: a permanent reduction in pension entitlements for all agents retiring after 2012. As discussed above, this reform would imply that the current generations engage in a large-scale saving to build up a fund that can pay for the pension of future generations when the dependency ratio is very high. In this section, we consider a set of alternative sustainable reforms. We consider reforms that would alter in a simple or minimalistic way the existing rules, while capturing salient aspects of the policy prescriptions of section 2.<sup>22</sup> We consider, in particular, 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

<sup>22</sup>We emphasize reforms that are realistic from a policy perspective. In the appendix, we provide a numerical characterization of the first best allocation. Decentralizing such allocation through the pension system would require very large deviations from the current rule which would be difficult to implement, given the set of political constraints.

until period  $T$ . 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  $T$ .  $T$  is chosen optimally so as to maximize the welfare criterion discussed below. This reform entails a key aspect of the optimal policy in the two-period model of section 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: those who are already retired receive a lump-sum transfer equal to the present value of the benefits they would have received under the benchmark reform. Moreover, those still working in 2013 are compensated for their accumulated pension rights, scaled by the number of years they have contributed to the system. This reform entails a key 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 process, this system delivers high pensions to the earlier generations, and low pensions to the future ones – in line with the optimal policy in the two-period model of section 2.

We will also consider combinations of the different systems, in particular, a combinations of low taxes and declining replacement rates. Finally, we consider two reforms that extend the coverage of the pension system to rural workers. The *moderate* rural reform scenario offers a 20% replacement rate to rural retirees financed by a 6% social security tax on rural workers. Such a rural pension is similar to a scheme started recently by the government on a limited scale (see Appendix B for details). The *radical* rural reform scenario introduces a universal pension system with the same benefits and taxes in rural and urban areas.

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. In section 5.5, we show that the main results are robust to assuming, alternatively, that all reforms are perfectly anticipated

in year 2000.<sup>23</sup>

#### 4.1 The welfare criterion

We compare the welfare effects of alternative reforms by measuring, 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 would make agents in each cohort indifferent between the benchmark and the alternative reform.<sup>24</sup> We also 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  $\phi$  as in section 2. More formally, the planner's welfare function (evaluated in year 2013) is given by

$$U = \sum_{t=1935}^{\infty} \phi^t N_{t,t} \sum_{j=0}^J \beta^j u(c_{t,t+j}, h_{t,t+j}). \quad (12)$$

Then, the equivalent variation is given by the value  $\omega$  solving

$$\sum_{t=1935}^{\infty} \phi^t N_{t,t} \sum_{j=0}^J \beta^j u((1 + \omega) c_{t,t+j}^{BENCH}, h_{t,t+j}^{BENCH}) = \sum_{t=1923}^{\infty} \phi^t N_{t,t} \sum_{j=0}^J \beta^j u(c_{t,t+j}^*, h_{t,t+j}^*), \quad (13)$$

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

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,  $\phi$ . First,  $\phi = (1 + g)/R$ , which is the benchmark discount factor discussed in section 2 (see Proposition 1 and its Corollary) corresponding to a planner would not want to engage in any 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.<sup>26</sup> For this reason, we label a planner with  $\phi = (1 + g)/R$  as the *low-discount planner*. Second, following Nordhaus (2007),

<sup>23</sup>Conceptually, assuming that alternative reforms come as a surprise has the advantage that, when we derive the wage path from a model with endogenous capital accumulation (section 6), all macroeconomic trends which are the target of the calibration are identical until 2013. Moreover, from a policy perspective, it seems natural to study the effect of policy changes happening today without retrospectively affecting earlier expectations.

<sup>24</sup>Note 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.

<sup>25</sup>Note 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.

<sup>26</sup>Most macroeconomic studies assume discount rates in the range 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. Such a low discount rate would be largely inconsistent with the observation that governments typically run debt rather than accumulate surpluses, despite the fact that the interest rate is on average significantly above 0.1%. In this paper, we consider discount rates ranging between 0.5% to 2.5%, which we regard as rather conservative relative to the validity of our main message.

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.

#### 4.1.1 Delayed reform

We start by computing the optimal delay of the benefit cut. Namely, the current rules are maintained until time  $T-1$  and then a new (lower) replacement rate applies to those retiring at  $T$  or later so as to achieve financial balance. The tax rate remain constant at 20%.  $T$  is computed so as to maximize (12).

The optimal  $T$  for the low-discount planner turns out to be 2051. Namely, the current replacement rate continues to apply for all workers starting their employment before 2012, and the new lower replacement rate applies to worker starting their employment earliest 2013. This means that lower pensions will start being paid in 2051, and by 2090 all retirees will earn the new lower replacement rate.

Such delay has two main effects: on the one hand, the generations retiring before 2051 receive higher pensions. On the other hand, the fund accumulates a lower surplus between 2012 and the time of the reform, making necessary an even larger reduction of the replacement rate thereafter. Thus, the delay shifts the burden of the adjustment from the current (poorer) generations to (richer) future generations.

Figure 5 describes the positive effects of delaying the reform until 2051. Panel (a) shows that the post-reform replacement rate now falls to 36.7%, which is only 3.3 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 2066. Moreover, already in 2043 the system is running deficits. As a result, the government accumulates a smaller trust fund during the years in which the dependency ratio is low. The reason of small differences in the replacement rate is threefold. First, the urban working population continues to grow until 2052, due to internal migration. Second, wage growth is high between 2013 and 2051. Third, the trust fund earns an interest rate of only 2.5%, well below the average wage growth. The second and third factors, which are exogenous in this section, will be derived as the endogenous outcome of a calibrated general equilibrium model with credit market imperfections in section 6.

Figure 6 shows the equivalent variations, broken down by the year of retirement for each cohort. Panel (a) shows the case in which the reform is delayed until 2051. The consumption equivalent gains for agents retiring between 2013 and 2050 are large: on average over 15% of their lifetime consumption!

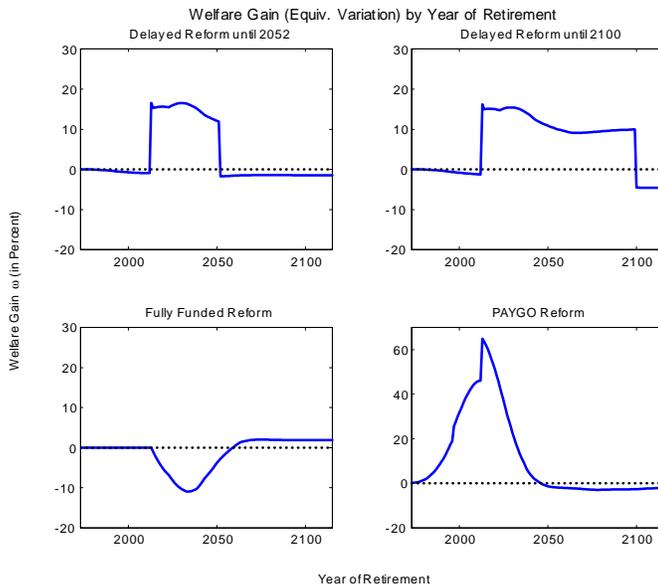


Figure 6: The four panels show welfare gains of alternative reforms relative to the benchmark reform for each cohort. The gains ( $\omega$ ) are expressed as percentage increases in consumption (see eq. 13).

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. The welfare gain declines over the year of cohort retirement, since wage growth slows down. Yet, the gains of all cohorts affected are large, being bounded from below by the 12% gains of the generation retiring in 2050. On the contrary, all generations retiring after 2051 lose, although their welfare losses are quantitatively small, being less than 1.8% of their lifetime consumption. The difference between the large welfare gains accruing to the first 38 cohorts and the small losses suffered by later cohorts is stark. For comparison, Panel (b) shows the distribution of losses and benefits for a case in which the reform is delayed until 2100. In this case, the losses accruing to the future generations are larger: all agents retiring after 2100 suffer a welfare loss of 4.6%.

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. Consider, first, delaying the reform until 2051. The delayed reform yields  $\omega = 6.4\%$  for the high-discount planner (i.e., the delayed reform is equivalent to a permanent 6.4% increase in consumption in the benchmark allocation). The gain is partly due to the fact that future generations are far richer and, hence, have a lower marginal utility of consumption. For instance, in the benchmark reform scenario, the average pension received by an agent retiring in 2051 is 5.2 times larger than that of an agent retiring in 2013. Thus, delaying the

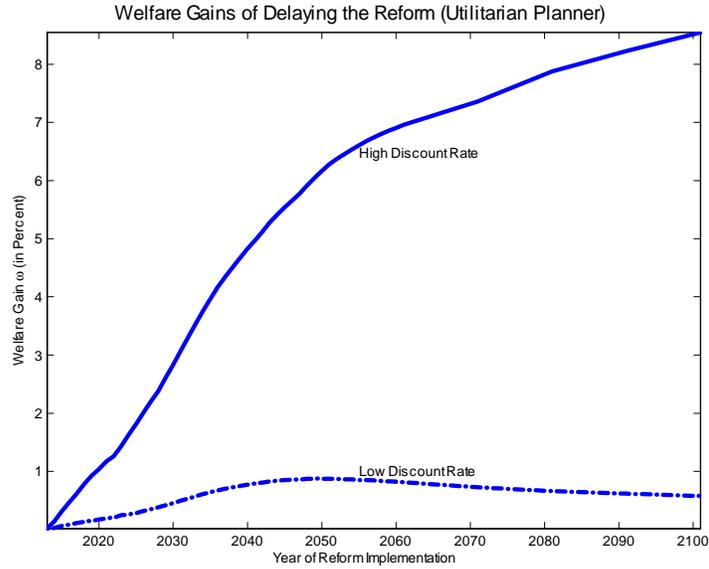


Figure 7: The figure shows the consumption equivalent gain/loss accruing to a high-discount planner (solid line) and to a low-discount planner (dashed line) of delaying the reform until time  $T$  relative to the benchmark reform. When  $\omega > 0$ , the planner strictly prefers the delayed reform over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

reform has a strong equalizing effect that increases the utilitarian planner's utility. The welfare gain of the low-discount planner is smaller,  $\omega = 0.9\%$ . The figure also shows that the high-discount planner would maximize her welfare gain by a long delay of the reform (the curve is uniformly increasing in the range shown in the figure).

#### 4.1.2 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 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. However, switching to a FF system does not cancel the outstanding liabilities (i.e., payments to current retirees and entitlements of workers who have already contributed to the system). We will therefore design a reform such that the government does not default on existing claims. In particular, we assume that all workers and retirees who have contributed to the pension system are refunded the present value of the pension rights they have accumulated.<sup>27</sup> Since the social security tax is abolished, the existing

<sup>27</sup>In 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.

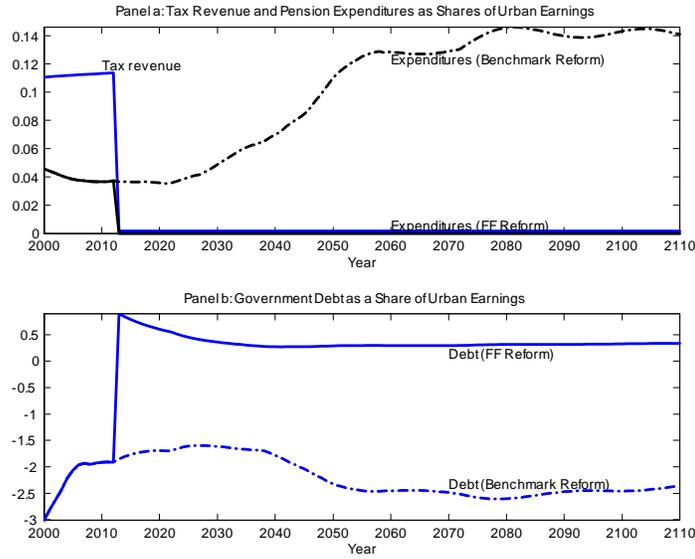


Figure 8: The figure shows outcomes for the fully funded reform (solid lines) versus the benchmark reform (dashed lines). Panel (a) shows the replacement rates. Panel (b) shows taxes and pension expenditures for the fully funded reform (solid lines) versus the benchmark reform (dashed lines) expressed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

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 89.5% of total labor earnings in 2012. A permanent 0.3% annual tax is needed to service such a 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 30% of labor earnings around 2040. Agents born after 2040 live in a low-tax society with no intergenerational transfers.

Panel (c) of Figure 6 shows the welfare effects of the FF reform relative to the benchmark. The welfare effects are now opposite to those of the delayed reforms. The cohorts retiring between 2013 and 2058 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

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People who are still working and have contributed to the system are compensated in proportion to the number of years of contributions.

later cohorts and become as large as 11% for those retiring in 2030-35. 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. The fact that generations retiring sufficiently far in the future gain is guaranteed by the assumption that the economy is dynamically efficient. 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 (see Proposition 1 and its Corollary). As the high-discount planner values intergenerational redistribution more than does the low-discount planner, the former strictly prefers the benchmark over the FF reform, with a consumption equivalent discounted loss of 3.3%.

### 4.1.3 Pay-as-you-go reform

The optimally delayed reform is 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. The optimal sequence of benefits would instead be a declining sequence with very high replacement rates for the initial generations (particularly, those already retired). A simple way to implement a system with a smooth declining replacement rate is a pure PAYGO. In this section, we consider the effect of switching to such a system.

To this end, 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:<sup>28</sup>

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

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 5, 8 and II); 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 under the benchmark reform.

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<sup>28</sup>Note that the pension system has accumulated some wealth before 2011. 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  $\delta$  in the labor income tax, in such a way that the present value of this tax subsidy equals the 2011 accumulated pension funds. In our calibration, we obtain  $\delta = 0.54\%$ .

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 2044. 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 them higher pensions than what they had been promised. This can clearly be seen in panel (b) of figure 9 and panel (d) of figure 6. Welfare gains are very pronounced for all cohorts retiring before 2045, especially so for those retiring in 2013 and in the few subsequent years, 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 and therefore would benefit the most from a pure PAYGO system. On the other hand, generations retiring after 2046 suffer a loss relative to the benchmark reform.

Due to the strong redistribution in favor of poorer early generations, 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, 12.8% and 1.7% for urban workers. These gains are larger than under all alternative reforms (including delayed and FF reform). These results underline that the gains for earlier generations come at the expense of only small losses for the future generations.

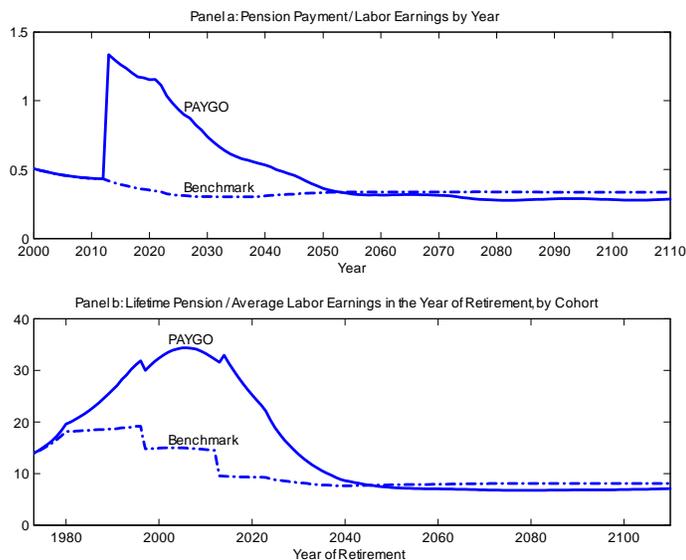


Figure 9: Panel (a) shows the average pension payments in year  $t$  as a share of average wages in year  $t$  for the PAYGO (solid) and the benchmark reform (dashed line). Panel (b) shows the ratio of the lifetime pensions (discounted to the year of retirement) to the average labor earnings just before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

## 4.2 Other reforms

In this section, we consider other reforms that have been discussed in the context of China: increasing retirement age and increasing the coverage of the pension system to rural workers.

### 4.2.1 Increasing retirement age

An alternative to reducing pension benefits would be to increase the retirement age. Our model allows us to calculate the increase in retirement age that would be required to balance the intertemporal budget, (11), given the current social security tax and replacement rate. We find such an increase to be equal to approximately six years (i.e., retirement age would have to increase from 60 to 66 years without any reduction in employment). This shows that a draconian reduction in pension entitlements may not be necessary if the retirement age can be increased. Since our model abstracts from an endogenous choice of retirement, we do not emphasize the welfare effects of policies affecting retirement age (there would obviously be a large welfare gain if the retirement age is increased exogenously).

### 4.2.2 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, we consider extending the system to rural workers.

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

$$A_0 + \sum_{t=0}^{\infty} R^{-t} \left( \sum_{j=0}^{J_W} \zeta_j [\tau_t N_{t-j,t} w_t h_{t-j,t} + \tau_t^r N_{t-j,t}^r w_t^r h_{t-j,t}^r] - \sum_{j=J_W+1}^J [N_{t-j,t} b_{t-j,t} + N_{t-j,t}^r b_{t-j,t}^r] \right) \geq 0, \quad (14)$$

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 III in Appendix C). This is consistent with the prediction of the general equilibrium model outlined in section 6.

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 B). Based on the current policies, we set the rural replacement rate ( $q_t^r$ ) and contribution rate ( $\tau_t^r$ ) 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 that the replacement rate of urban workers be cut to  $q_t = 38.7\%$ , 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 7.5%. When weighting rural and urban households by their respective population shares, one obtains an aggregate welfare gain of 1% relative to the benchmark reform.<sup>29</sup>

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 small: the replacement rate must be reduced to  $q_t = 38.5\%$  from 2013 onward, relative to 40% in the benchmark reform. The welfare loss for urban workers participating in the system is very limited – the high-discount planner would suffer a 0.6% loss relative to the benchmark (only marginally higher than in the low-scale reform). In contrast, the welfare gains for urban workers not participating in the system are very

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<sup>29</sup>A high-discount planner who only cares for urban households participating in the pension system would incur a welfare loss of less than 0.64% from expanding the pension system to rural inhabitants. A high-discount planner who only cares for rural households would incur a welfare gain of 12.4%. When weighting rural and urban households by their respective population shares, one obtains an aggregate welfare gain of 2% relative to the benchmark reform.

large (+13.2% if evaluated by the high-discount planner). Rural workers would also gain substantially (+6.8% if evaluated by the high-discount planner). The average effect (assessed from the standpoint of the high-discount planner weighting equally all inhabitants) is 5%.

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.

## 5 Sensitivity analysis

In this section, we study how the main results of the previous section depend on key assumptions about structural features of the model economy: wage growth, population dynamics, and interest rate. For simplicity, we focus on the urban pension system (no payments to rural workers). We refer to the calibration of the model used in the previous section as the *baseline economy*.

### 5.1 Lower wage growth

In the analysis above, Chinese wages grow fast over the next twenty-five years, and converge to 57% of the US level by 2039. Thereafter, the gap remains constant. In the theoretical model of section 2 we established that fast convergence followed by a growth slowdown is a key driver of the demand for intergenerational redistribution. In this section, we first consider a model where there is no convergence after 2013. Our analysis verifies that the results of the two-period analysis holds up, and that the model yields "conventional" predictions: delaying reform is harmful and an FF reform is preferred to a PAYGO reform insofar as it reduces tax distortions. This shows that our model bears standard prediction in an environment that is essentially identical to that of a mature economy.

We also ask an additional question. In the two-period model, we only considered, for simplicity, one initial period of transition with high growth. This begs the question of whether the speed of the transition matters – this is important since the future speed of convergence of China is uncertain. To address this question, we consider an alternative where wages converge more slowly to the same long-run gap (57% of the US level) as in the baseline scenario. The main results of the baseline economy now stand: delaying reform is good, and a PAYGO reform dominates an FF reform.

### 5.1.1 Scenario 1: Low wage growth (no convergence)

In this 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 40.3%. Note 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.

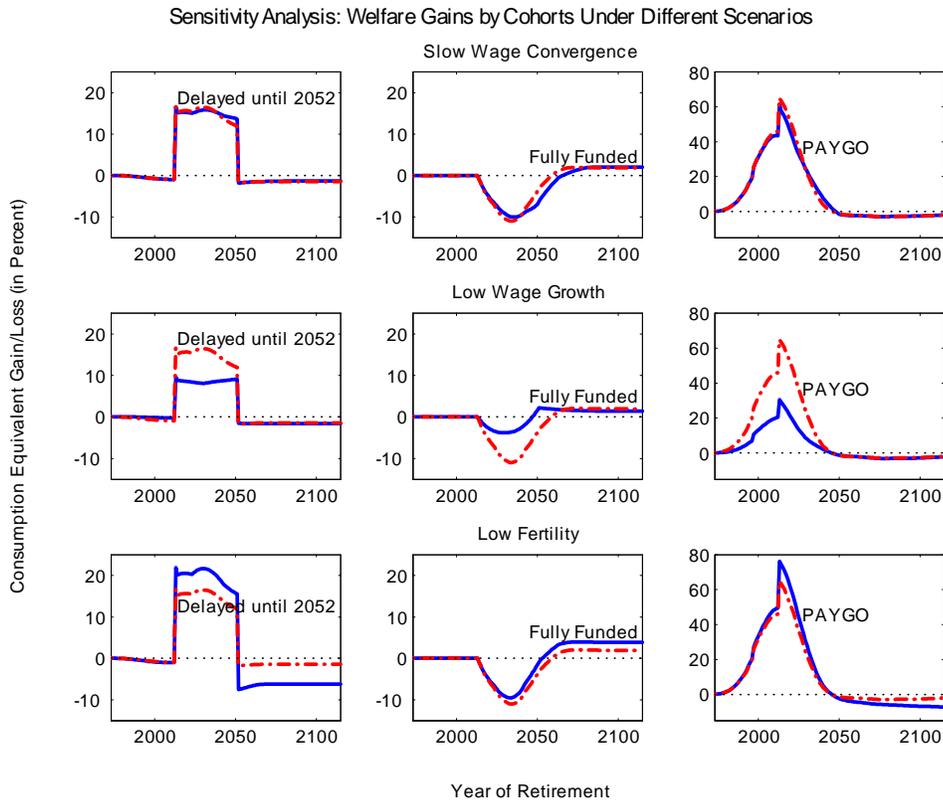


Figure 10: The figure shows consumption equivalent gains/losses accruing to different cohorts in three alternative scenarios. The top panels refer to the slow wage converge scenario of section 5.1.2. The middle panels refer to the low wage growth (no convergence) scenario of section 5.1.1. The bottom 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).

Delaying the reform until 2051 yields a replacement rate of 36.6% (29.6%). The welfare effects of the alternative reforms are displayed in the top row of Figure 10. 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 2051 the cohorts retiring between 2013 and 2050 experience a consumption equivalent welfare gain ranging between 8.1% and 9.6%. The cost imposed on the 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 (3.4%), albeit is 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 3.8% in the low wage growth economy, compared to a 11% loss in the baseline economy. Interestingly, the low-discount planner would now prefer the FF reform over any of the alternatives.<sup>30</sup>

Finally, the large welfare gains from the PAYGO alternative reform by and large vanish. The low-discount planner who has no built-in preference for transfers to the earlier generations at a given interest rate would now prefer the benchmark reform to the PAYGO reform. Thus, the welfare ranking order of the low discount planner is: FF reform first, then benchmark reform, and last PAYGO reform.

### 5.1.2 Scenario 2: Slower convergence

In this scenario, we assume an annual wage growth of 4% until 2049, and 2% thereafter. From 2049 and onward, the wage gap between China and the US is 57%, as in the baseline scenario.

The results of this experiment are similar to the baseline case. Delaying the reform until 2051 requires lowering the replacement rate (relative to the benchmark 2013 reform) by 3 percentage point, same as in the baseline wage growth scenario. The mid-centre 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 2052. Recall that gains and losses are expressed relative to the benchmark 2013 reform, and thus a cohort gains (loses) when the curve is above (below) zero. 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 till 2051 delivers a consumption-equivalent welfare gain to the low (high) discount planner of 0.9% (6.4%), approximately the same as in the baseline scenario.

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<sup>30</sup>The high-discount planner suffers a smaller welfare loss (0.6%) than in the baseline economy (3.3%). Thus, about 82% of the loss accruing to the utilitarian planner arises from the high implicit return of intergenerational transfers due to high wage growth in the baseline economy.

While for simplicity we have reported the welfare gain of delaying the reform until the same year as it was optimal in the baseline scenario, we should note that with slower convergence the low-discount planner would find it optimal to delay the reform somewhat longer. 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.

The mid-center and mid-right panels of Figure 10 yield the welfare gains/losses in the case of a FF reform (center) and PAYGO (right). The FF reform is now slightly less harmful for earlier generations than in the baseline scenario, but the losses extend to a larger number of cohorts. Similarly, the PAYGO reform yields slightly smaller benefits for the earlier generations and slightly larger gains for the intermediate ones. The PAYGO reform continues to dominate over all alternative options: a gain of 1.8% (12.6%) accrues the low (high) discount planner, compared to 1.7% (12.8%) in the baseline case.

Summing up, the differences relative to the baseline wage growth case are quantitatively very small. The reason is that, on the one hand, the pensions system earns a lower tax revenue (and pays lower benefits) in the earlier years (i.e., between 2013–2069). However, the return to the pension fund is low, and thus this temporary gain has little effect on the financial position of the pension fund. Thus, the reduction in welfare is small in absolute terms, and the comparison between alternative systems yields essentially the same results as in the case of faster wage convergence.

### 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 an 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 57% of the US level (an assumption that we regard as realistic, if conservative). In one case, convergence ends in 2039, in another it takes until 2069. The welfare implication 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. This requires a reform or a lenient implementation of the current one-child policy rules. 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 plot the welfare gains/losses of generations retiring between 2000 and 2110 in the case of a delayed, FF reform and PAYGO, respectively.

Under this low-fertility scenario, the benchmark reform requires an even more draconian adjustment. The replacement rate must be set equal to 35.5% as of 2013. Delaying the reform is now substantially more costly. A reform in 2051 requires a replacement rate of 21.9%. The trade-off between current and future generations becomes sharper than in the baseline economy. On the one 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 using a utilitarian welfare function yields a gain for the low-discount planner of 2.9%, which is 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 fully funded reform). Moreover, the PAYGO reform yields larger gains than in the benchmark reform (5.0% for the low-discount planner). Part of the reason is that with low population growth, the planner attaches a higher relative weight to the early generations, who are the winners in this scheme.

In summary, lower fertility increases the size of the adjustment required to restore the intertemporal balance of the pension system. It also widens the gap between the losses and gains of different generations in the alternative reforms.

### 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 55.5% of the baseline rates. This implies that the urban share of the total population is 67.7% in 2050, compared to 80.8% 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 under slow migration than in the baseline scenario (reduction of replacement rate to 40.2% vs. 40.0%). 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 (see Figure V 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 (cf. Auerbach and Kotlikoff, 1987). 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.

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 2051. 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, although both are dominated by the benchmark reform.

#### **5.5 Perfect foresight about alternative reforms**

In the main analysis, each alternative policy reform came as a “surprise” to agents in 2013. In this section, we show that the main insights are unchanged if one assumes, alternatively, that all reforms are perfectly anticipated in year 2000. The main difference is that the welfare gains of all alternative reforms are slightly larger, because households tailor their saving behavior prior to 2013 to the realized policy outcome. Figure (IV) in the appendix summarizes the results, showing how the welfare gains of each generation are affected by the different reforms. The results are very similar to those of Figure 6 – the difference being sizeable only in the case of a PAYGO reform. See also Table 1.

#### **5.6 Taking Stock**

Table 1 summarizes the results of the welfare analysis discussed in this section. Each pair of rows reports the welfare effects of different reforms accruing to the high- and low-discount planner relative

to a particular environment. All welfare effects are measured in consumption equivalent terms relative to the benchmark 2013 reform as in equation (13).

## WELFARE GAINS/LOSSES UNDER ALTERNATIVE REFORMS

discount	Delayed until 2052		Delayed until 2100		Fully Funded		PAYGO	
	high	low	high	low	high	low	high	low
Baseline parameterization	6.4%	0.9%	8.5%	0.6%	-3.3%	0.2%	12.8%	1.7%
Slow wage convergence	6.4%	0.9%	8.5%	0.6%	-3.6%	0.1%	12.6%	1.8%
Low wage growth	3.4%	0.0%	5.6%	-0.4%	-0.6%	0.8%	4.9%	-0.1%
Low fertility	8.0%	2.9%	10.3%	0.6%	-2.4%	-0.5%	15.7%	5%
Slow migration	6.5%	0.9%	8.4%	0.5%	-3.3%	0.2%	11.9%	1.6%
High interest rate	2.8%	0.0%	4.0%	-0.4%	0.5%	0.5%	8.7%	-0.1%
Perfect foresight	6.4%	0.9%	8.5%	0.6%	-3.3%	0.2%	14.7%	2.0%

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.

## 6 A dynamic general equilibrium model

Up to now, we have taken the wages and the rate of return on savings as exogenous. As we demonstrated in section 5, the normative predictions hinge on the assumed wage growth. 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 3 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. Therefore, the allocations and welfare analyses of the previous section carry over to the general equilibrium environment. The model is closely related to Song et al. (2011), augmented with the demographic model of section 3.2 and the pension system of section 3.

**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, 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 microfoundations of this assumption). However, they are subject to credit constraints that limit their size and 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  $\delta$  is the depreciation rate. The capital-labor ratio and the equilibrium are determined by  $r^l$ . Thus,

$$w_t \geq (1 - \alpha) \left( \frac{\alpha}{r_t^l + \delta} \right)^{\frac{\alpha}{1-\alpha}} A_t. \quad (15)$$

As long as there are active F firms in equilibrium ( $N_F > 0$ ), equation (15) 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  $\psi$  the share of the revenue accruing to managers.<sup>31</sup> Profit maximization yields, then, the following optimal labor hiring decision:

$$\begin{aligned} N_{Et} &= \arg \max_{\tilde{N}_t} \left\{ (1 - \psi) (K_{Et})^\alpha (\chi A_t \tilde{N}_t)^{1-\alpha} - w_t \tilde{N}_t \right\} \\ &= ((1 - \psi) \chi)^{\frac{1}{\alpha}} \left( \frac{r_t^l + \delta}{\alpha} \right)^{\frac{1}{1-\alpha}} \frac{K_{Et}}{\chi A_t}. \end{aligned} \quad (16)$$

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

$$\rho_{E,t} = \left( (1 - \psi) K_{Et}^\alpha (\chi A_t N_{Et})^{1-\alpha} - w_t N_{Et} + (1 - \delta) K_{Et} \right) / K_{E,t}. \quad (17)$$

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

<sup>31</sup>Managers have special skills that are in scarce supply. If a manager were paid less than a share  $\psi$  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.

the incentive-compatibility constraint of entrepreneurs implies that the share of investments financed externally must satisfy the following constraint:

$$K_E - \Omega_{E,t} \leq \frac{\sigma \rho_E}{1 + r^l} K_E, \quad (18)$$

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  $\sigma$  of next-period net profits.

Three regimes are possible: (i) during the first stage of the transition, the credit constraint (18) is binding and F firms are active (hence, the wage is pinned down by (15) holding with equality); (ii) during the mature stage of the transition, the credit constraint (18) is binding and F firms are inactive; (iii) eventually, the credit constraint (18) ceases to bind (F firms remain inactive). In regimes (ii) and (iii), (15) holds with strict inequality.

Consider, first, regime (i). Substituting  $N_{Et}$  and  $w_t$  into (17) by their equilibrium expressions, (15) and (16), 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,

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

Consider, next, regime (ii), where only E firms are active ( $N_{E,t} = N_t$ ) and the borrowing constraint is binding, so (18) 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

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

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*,  $\xi$ , which captures the operational costs, red tape, and so on, associated with granting loans. Thus,  $\xi$  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 3, 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 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  $R$  till  $J_E$ , 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  $\beta$  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 ( $\xi$ ) 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 ( $\chi$ ) implies a high rate of return in E firms, a high managerial compensation, and, hence, a high speed of transition; (iv) a high  $\sigma$  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 ( $\psi$ ) 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.

## 6.1 Calibration

In Song et al. (2011), 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,  $\xi$  and  $\sigma$ , and four technology parameters,  $\alpha$ ,  $\delta$ ,  $\chi$  and  $\psi$ . The parameters  $\alpha$  and  $\delta$  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  $\psi$  and  $\chi$  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 Song et al. (2011) 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.<sup>32</sup> 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.<sup>33</sup>

We set  $\xi$  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  $\xi$  is  $\xi_{2000} = 0.062$ . After year 2000, we assume that there is gradual financial improvement so  $\xi$  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  $\xi$  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  $\xi$  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  $\sigma$  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 urban GDP per capita is 20% of the US level in 2011. Moreover, we set the growth rate of  $A_t$  (i.e., the secular exogenous productivity growth) so that the model generates an aggregate growth in GDP per capita of 9.7% for China during 2000-2011. The resulting growth rate in  $A_t$  is 2% larger than the associated world growth rate during this period. After 2011, this excess growth in  $A_t$  falls linearly to zero until the TFP level in E firms is equal to that of US firms. This occurs in year 2022. Finally,  $\beta$  is calibrated to 1.0175 to match the average aggregate saving rate of 48.2% 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  $\chi_R$  is set to 0.75 to capture an observed urban-rural wage gap of 1.84 in 2000. The rural wage grows over time, due to the exogenous technology growth and to the decreasing

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<sup>32</sup>Song 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).

<sup>33</sup>Hsieh 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.

lending rate. The rural-urban wage gap implied by the model increases from 1.84 in 2000 to 3.47 in 2040 and stays constant thereafter (see Figure III in Appendix C).

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 1992 (1992 is the year when free-market reforms in China accelerated). Moreover, all managers are assumed to start with zero wealth in 1992. Initial wealth for workers and retirees is also set to zero in 1992. The 2000 distribution of wealth across individuals is then derived endogenously. Finally, the initial government wealth is set to 71% of GDP in 2000 so as to generate a net foreign surplus equal to 12% of GDP in 2000.<sup>34</sup>

## 6.2 Simulated output trajectories

The calibrated model yields growth forecasts that we view as plausible. Figure 11 shows the evolution of productivity and output per capita forecasted by our model. The growth rate of GDP per worker remains about 8.5% 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 6.9% 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 2015, 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 GDP per worker in China will be 73% of the US level by 2039, remaining broadly stable thereafter. 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 3 is now an endogenous outcome. Wages are forecasted to grow at an average of 5.1% until 2030 and to slow down thereafter. What keeps wage growth high after 2020 is mostly capital deepening.<sup>35</sup>

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<sup>34</sup>More 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.

<sup>35</sup>In 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.

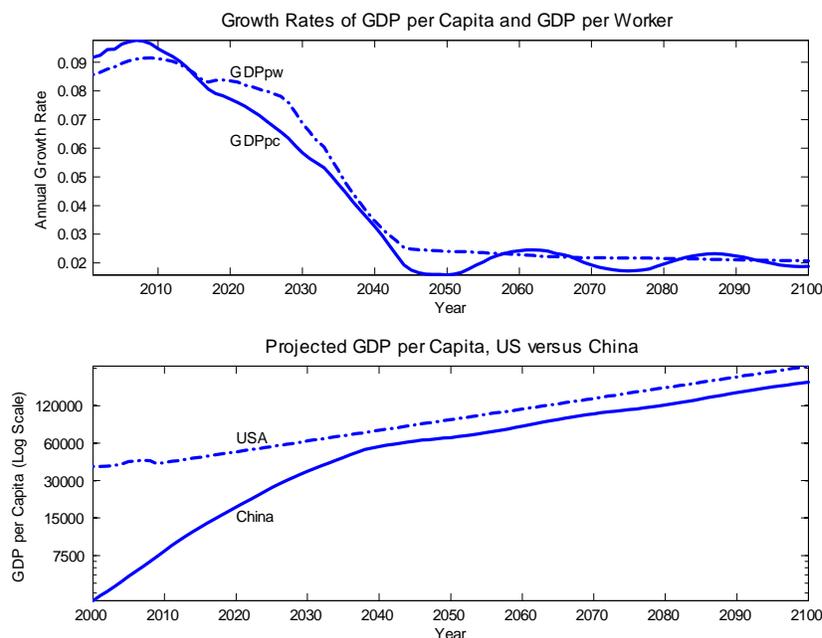


Figure 11: The upper panel shows projected annual growth rates in GDP per worker and GDP per capita in the calibrated economy. The lower panel shows projected GDP per capita in levels for China and the US.

### 6.2.1 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 2070 the economy has a wealth-GDP ratio equal to 1169%. This is because the model is calibrated to match aggregate savings during 2000-2010. In that period, China experienced high growth and yet a very high saving rate (48.2% on average).

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 ( $\beta = 1.0175$ ) in order to predict the empirical saving rate during the first decade of the 21st century. According to our model, the future saving rate will be even higher than today once the wage growth declines – provided that the discount factor remains constant. In our model, a high  $\beta$  is a stand-in for a number of institutional 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).<sup>36</sup>

Note that long-term wages and GDP do not hinge on the domestic propensity to save (although

<sup>36</sup>Chamon et al. (2010) 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  $\beta$ , their models would imply quantitatively too low savings for the young households.

the entrepreneurs' propensity to save determines the speed of the transition). The entrepreneurial firms grow out of their financial constraint by year 2039. Thereafter, domestic capital accumulation and wages are determined by the world interest rate. In the long run,  $\beta$  only determines the foreign position, which is predicted to reach 13.7 times GDP by 2070.

It seems implausible that China will accumulate such a large foreign surplus. One might also be concerned that the high discount factor could affect our quantitative welfare results. To address such concerns, 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 yields essentially the same results as in the high  $\beta$  economy. Thus, the calibration of  $\beta$  is unimportant for the effects of the welfare analysis, which is the main contribution of this paper.

### 6.2.2 Sensitivity: Financial development

The model borrows from Song et al. (2011) 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 2038, the financial constraint ceases to bind.

In our baseline calibration, the parameter  $\sigma$ , which regulates borrowing of private firms, is assumed to be constant over time. An exogenous increase in  $\sigma$  – 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 85%) due to the large capital deepening. In 2030, the wage level is still 15.8% above the baseline calibration. In 2038 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. The benchmark reform requires a slightly smaller reduction of the replacement rate: 40.7% instead of 40%. The delayed reform still entails gains for the transition cohorts, albeit these gains decline faster over time. For instance, delaying a reform until 2052 yields a 16.5% consumption equivalent gain for the cohort retiring in 2013, but only a 9.7% gain for the cohort retiring in 2051. The losses suffered by the cohorts retiring after 2051 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 (2059 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 reform considered. 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 equivalent gain of the low-discount planner relative to the benchmark reform is 1%, compared with 1.8% in the baseline scenario. Since the fully funded reform also entails a 0.6% gain relative to the benchmark reform, the consumption equivalent gain of the PAYGO relative to the FF reform is only 0.4% (although it remains significantly higher, 12.7%, for the high-discount planner).

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

## 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 have analyzed the positive and normative effects of alternative pension reforms with the aid of a dynamic general equilibrium model calibrated to China.

A number of studies before us have argued 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 adverse effects on inequality: it would significantly 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 generations. Under standard welfare criteria, a straight pay-as-you-go system would be preferred to both the draconian reform and to a reform that pre-funds the pension system.

Our study has abstracted from a number of features that can influence the welfare effects of alternative reforms. First, we did not consider uninsurable idiosyncratic risk nor intergenerational risk-sharing. Both sources of risk are important in the Chinese context, and would strengthen the case for a non-funded pension system (see, e.g., Krueger and Kuebler 2006, and Nishiyama and Smetters 2007). Second, we abstracted from within-cohort inequality. Its consideration would strengthen the welfare

gains of a transfer-based public pension system, to the extent to which, as it is the case in reality, public pensions provide some intragenerational redistribution. Third, the pension system could crowd out private transfers from children to elderly - which is not the case in our model since we have abstracted from altruism within families. This could in principle reduce the welfare gain of intergenerational transfers through the pension system. Indeed, Cai, Giles and Meng (2006) document that retirees in urban China receive private transfers from their children, and that these transfers respond to negative income shocks (e.g., pension arrears). However, such transfers appear to provide only very partial insurance. For instance, when income is close the poverty line, a one yuan temporary reduction in income leads to an increase in net transfers between 10 to 16 cents. The crowd out effect of *permanent* transfers is likely to be even smaller. In fact, their study concludes that improving the public pension system will not crowd out private transfers at all.<sup>37</sup>

While we focused mainly on China, our findings apply more broadly to emerging economies. In contrast, our model delivers very different predictions in a mature economy with low wage growth and perfect capital markets. In this case, a fully funded system outperforms a pay-as-you-go system. These contrasting results highlight the general principle (see, e.g., Acemoglu et al. 2006) that mechanically transposing policy advice from mature to developing or emerging economies may be misleading.

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<sup>37</sup>This conclusion is shared by Park *et al.* (2012) who argue, in addition, that the effectiveness of the informal private insurance system is set to decline in future, since elderly will have fewer children and more of them will live separately from their children. In their view, "*pension payments can significantly reduce the likelihood of the elderly being poor, providing some optimism that current policy initiatives will have a significant impact on elderly poverty. The shift from private to public transfer systems to support the elderly is a path that has been followed by many Latin American countries (Calvo and Williamson, 2008).*" In the same vein, Yang and Chen (2010) who document that pension entitlements reduce significantly poverty incidence among elderly, especially for people living alone and people without a son.

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# APPENDIX (not for publication)

## A 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 (19) and (20) are observable. The 2005 urban and rural population gender-age structure can thus be composed into three parts:

$$n_{2005}^{u,i,j} = \hat{n}_{2005}^{u,i,j} + m^{i,j} + \varepsilon^{u,i,j}, \quad (19)$$

$$n_{2005}^{r,i,j} = \hat{n}_{2005}^{r,i,j} - m^{i,j} + \varepsilon^{r,i,j}, \quad (20)$$

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

In the ideal case with no measurement errors, either (19) or (20) can back out  $m^{i,j}$ . The measurement error on the total population,  $\sum_{h,i,j} \varepsilon^{h,i,j}$ , is small. When  $\sum_{h,i,j} \varepsilon^{h,i,j} = 0$ , (19) and (20) 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%.<sup>38</sup> 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

$$\varepsilon^{i,j} \equiv \sum_h \varepsilon^{h,i,j} = \sum_h \left( n_{2005}^{h,i,j} - \hat{n}_{2005}^{h,i,j} \right). \quad (21)$$

Figure A-1 suggests  $\varepsilon^{i,j}$  to be quantitatively important.<sup>39</sup> 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  $\varepsilon^{i,j}$ :

$$\varepsilon^{u,i,j} = \pi \cdot \varepsilon^{i,j}, \quad (22)$$

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

$$\varepsilon^{r,i,j} = (1 - \pi) \cdot \varepsilon^{i,j}. \quad (23)$$

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<sup>38</sup>Despite the small discrepancy, to avoid biased estimates, we adjust  $n_{2000}^{h,i,j}$  by a scale of  $\kappa$ , where  $\kappa$  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%.

<sup>39</sup>If all the discrepancies are due to sampling errors in the 2005 survey, the comparison between the two lines in Figure A-1 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.

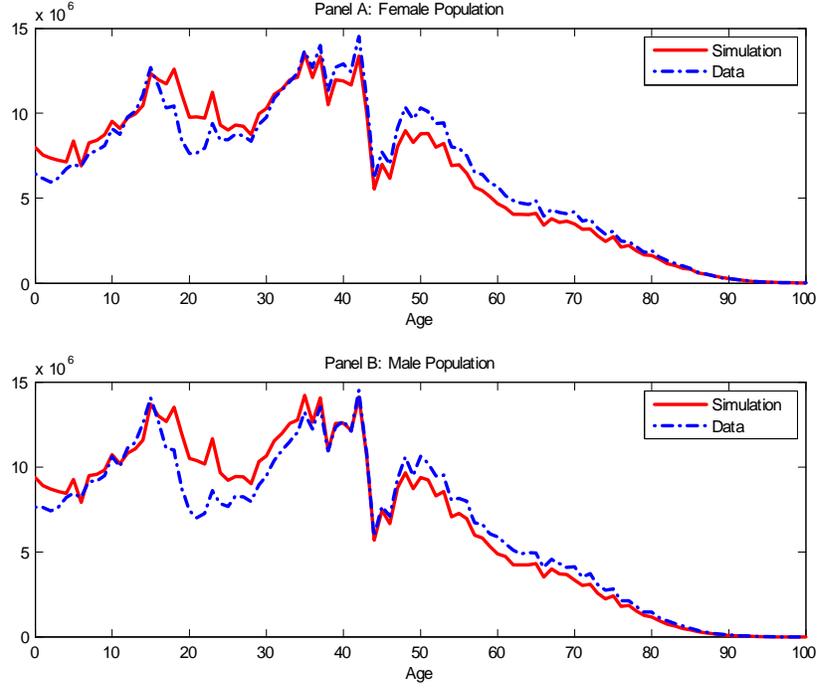


Figure 12: The upper panel shows the female population of different ages in 2005, in the survey data (solid line), and in our simulation (dashed line). The lower panel shows the male population in 2005.

Rearranging (19) gives the net flow of migration:

$$\begin{aligned}
 \sum_i \sum_j m^{i,j} &= \sum_i \sum_j \left( n_{2005}^{u,i,j} - \hat{n}_{2005}^{u,i,j} \right) - \pi \sum_i \sum_j \varepsilon^{i,j} \\
 &= \sum_i \sum_j \left( n_{2005}^{u,i,j} - \hat{n}_{2005}^{u,i,j} \right) - \pi \sum_h \sum_i \sum_j \left( n_{2005}^{h,i,j} - \hat{n}_{2005}^{h,i,j} \right).
 \end{aligned} \tag{24}$$

The second equality comes from (21). Let us consider two extreme cases of  $\pi$ . When  $\pi = 1$ , (24) 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  $\pi = 0$ , (24) 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  $\pi$  boils down to the choice of using rural or urban population to back out migration. It has been widely acknowledged that urban population survey tends to underestimate “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  $\pi = 1$ .<sup>40</sup>

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).

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  $j = J + 5$ :

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

<sup>40</sup>One 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.

⇒

$$mr^{i,J} = \frac{m^{i,J+5}}{n_{2000}^{r,i,J} \left(1 - d_{2000}^{r,i,J+4}\right) \cdots \left(1 - d_{2000}^{r,i,J}\right)}.$$

For  $j = J + 4$ :

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

⇒

$$mr^{i,J-1} = \frac{m^{i,J+4} - mr^{i,J} n_{2000}^{r,i,J-1} \left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}{\left(1 - mr^{i,J}\right) n_{2000}^{r,i,J-1} \left(1 - d_{2000}^{r,i,J+3}\right) \cdots \left(1 - d_{2000}^{r,i,J-1}\right)}.$$

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

## B 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.

### B.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 numbers 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 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% wage taxes 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. The targeted replacement rate of the system is 58.5%.<sup>41</sup>

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 wage taxes of 8% paid by workers only.<sup>42</sup>

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 enter into the labor market after 1997 (*Xinren*), cohorts retired 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 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.<sup>43</sup> 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.<sup>44</sup> 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

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<sup>41</sup>Suppose that the wage growth rate is equal to the interest rate. For a worker who contributes to the system for 35 years (from age 25 to 60), her pension benefits should be equal to 20% of the local average wages (the first pillar) plus 38.5% of her wage before retirement.

<sup>42</sup>The 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.

<sup>43</sup>Source: [http://www.ssf.gov.cn/xw/xw\\_gl/201205/t20120509\\_4619.html](http://www.ssf.gov.cn/xw/xw_gl/201205/t20120509_4619.html).

<sup>44</sup>The 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>

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.<sup>45</sup> 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:

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

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%.<sup>46</sup> So, we set the actual contribute 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 employees participating in the pension system as a share of the number of urban employees.<sup>47</sup> 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.

## B.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 pension from individual account. If a migrant worker who

<sup>45</sup>In addition, with a labor income share less than 20%, wages appear to be severely underreported.

<sup>46</sup>All 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*.

<sup>47</sup>Both numbers are obtained from *China Statistical Yearbook* 2010.

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.<sup>48</sup> 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.<sup>49</sup> 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%.<sup>50</sup> On the contribution side, rural residents in 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%.<sup>51</sup>

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 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%.

## REFERENCES

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<sup>48</sup>The 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.

<sup>49</sup>See “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.

<sup>50</sup>All rural residents above age 60 are entitled to 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, a recent 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%.

<sup>51</sup>Rural 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).

## C Additional figures

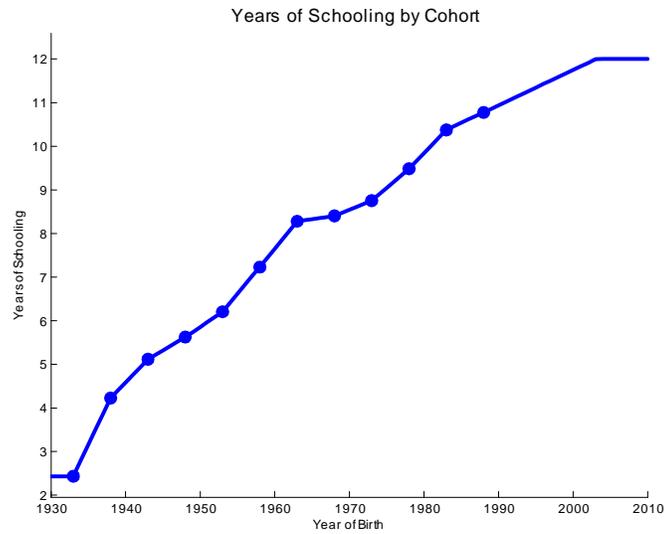


Figure I: The figure shows the average number of years of schooling for different age cohorts in China. Source: Barro and Lee data set. The values after 1990 are (linearly) extrapolated, assuming the growth in schooling accumulation stagnates at 12 years.

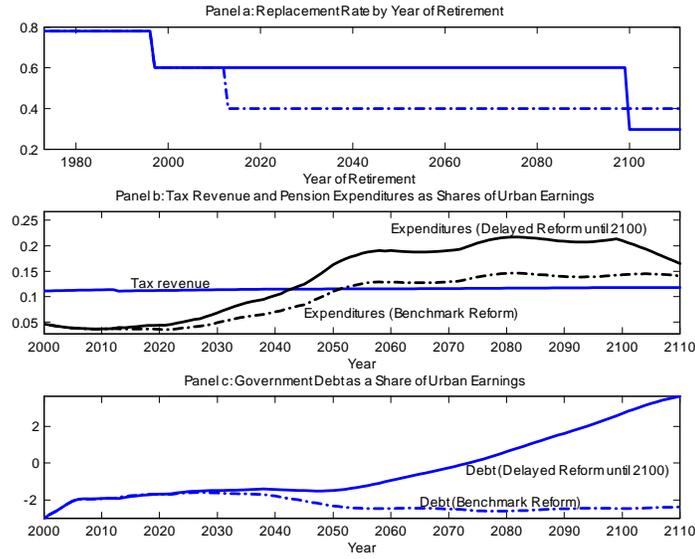


Figure II: Panel (a) shows the replacement rate  $q_t$  for the case when the reform is delayed until 2100 (solid line) versus the benchmark reform (dashed line). Panel (b) shows tax revenue and expenditures, expressed as a share of aggregate urban labor income (benchmark reform is dashed and the delay-until-2100 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.

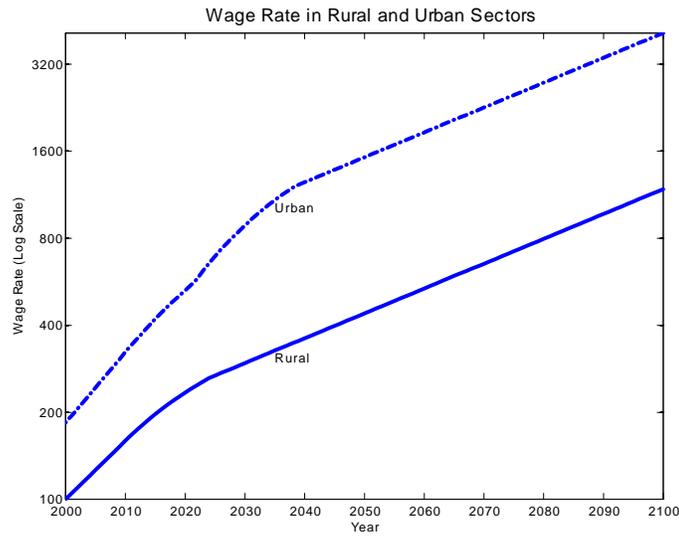


Figure III: The figure shows the projected hourly wage rate per unit of human capital in urban (dashed line) and rural (continuous line) areas, normalized to 100 in rural areas in 2000. The process is the endogenous outcome of the general equilibrium model of section 6.

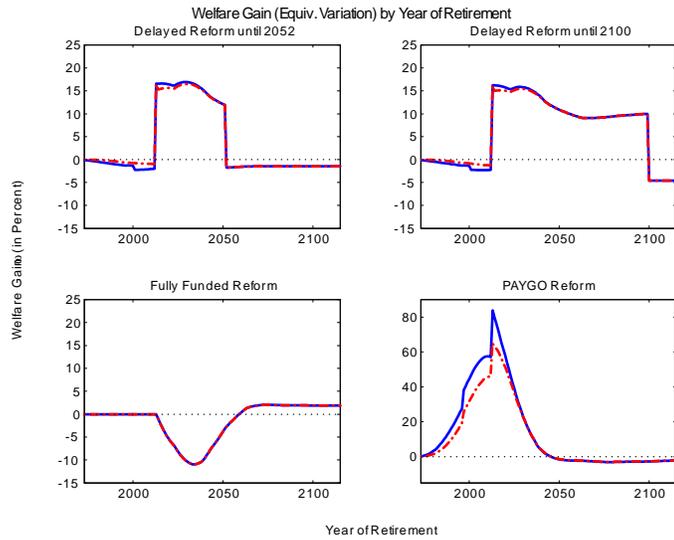


Figure IV: As in figure (6), the solid lines show welfare gains of alternative reforms relative to the benchmark reform for each cohort, but now under the assumption that all the reforms are perfectly anticipated at 2000. The dashed lines are the welfare gains in the baseline scenario, as in figure (6).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

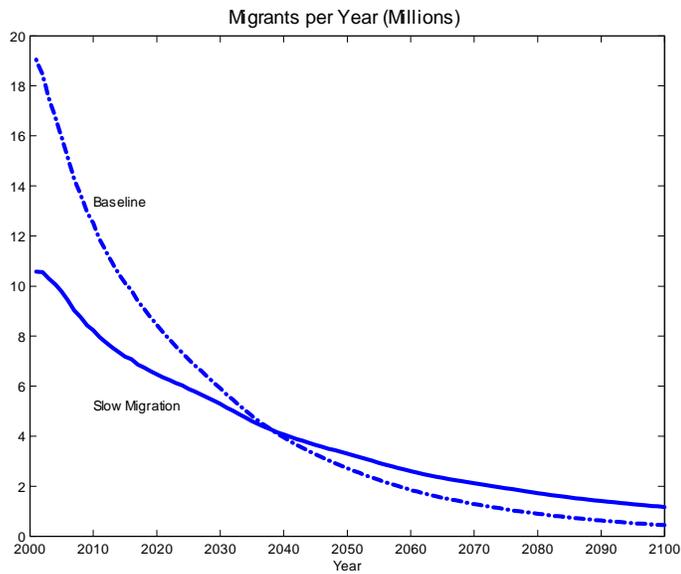


Figure V: The migration flow (i.e., the number of migrants per year) in the slow migration and baseline scenarios are shown with the solid and dashed lines, respectively. The migration flow is smaller in the slow migration scenario than in the baseline scenario before 2038, but larger afterwards.