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# Demographic Aging, Industrial Policy, and Chinese Economic Growth

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# Demographic Aging, Industrial Policy, and Chinese Economic Growth

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## Abstract

We examine the role of demographics and changing industrial policies in accounting for the rapid rise in household savings and in per capita output growth in China since the mid-1970s. The demographic changes come from reductions in the fertility rate and increases in the life expectancy, while the industrial policies take many forms. These policies cause important structural changes; first benefiting private labor-intensive firms by incentivizing them to increase their share of employment, and later on benefiting capital-intensive firms resulting in an increasing share of capital devoted to heavy industries. We conduct our analysis in a general equilibrium economy that also features endogenous human capital investment. We calibrate the model to match key economic variables of the Chinese economy and show that demographic changes and industrial policies both contributed to increases in savings and output growth but with differing intensities and at different horizons. We further demonstrate the importance of endogenous human capital investment in accounting for the economic growth in China.

Keywords: Aging; Credit policy; Household saving; Output growth; China

JEL classification: E21; J11, J13; L52

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# 1 Introduction

The Chinese economy has been growing rapidly over the last few decades. In 1980, per capita GDP in China was about 5 percent of that of the U.S. By 2012, the ratio had shot up to over 20 percent (Figure 1 panel a). In the meantime, the Chinese economy has undergone substantial structural changes. Over time, private firms have accounted for an increasing share of total employment. Additionally, the share of the capital stock in the capital-intensive industries relative to that in the labor-intensive industries has been trending up in recent years (Figure 1 panel b). Researchers have attributed these structural changes to government industrial policies. Specifically, a hallmark of the early industrial policy that began in the 1980s is the reduction of financial frictions that privately owned enterprises in the labor-intensive sector had endured.<sup>1</sup> Starting in the mid-1990s, the government started implementing preferential credit policies that favored firms in the capital-intensive sector.<sup>2</sup>

On the household side, China is aging rapidly due to declines in the fertility rate and increases in the life expectancy (Figure 2 panel a). The decline in the fertility rate started in the late 1960s but was exacerbated by the one-child policy enacted in 1979. The policy was intended to curb the population growth that the Mao-era pro-natality agenda had precipitated.<sup>3</sup> As a result of these changes, the young-age-dependency ratio, the ratio of people under the age of 15 to the population between 15 and 65, has declined significantly, from a high of 70 percent in 1975 to a low of 22 percent in 2012 (Figure 2 panel b).

In this paper, we build a unified growth model to capture all three aspects of the Chinese economy: the rapid output growth, the structural changes on the firm side, and the aging population. Households and firms interact through savings and investment decisions, as well as through labor supply and demand along both the quantity and quality margins. The model economy consists of three sectors: two intermediate goods sectors, one labor intensive and the other capital intensive, and one final goods sector.

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<sup>1</sup>See, among others, Brandt, Hsieh, and Zhu (2008), Brandt and Zhu (2010), Hsieh and Klenow (2009), and Song, Storesletten, and Zilibotti (2011, 2014).

<sup>2</sup>See Chang, Chen, Waggoner, and Zha (2015), and Bai, Lu, and Tian (2018).

<sup>3</sup>The Chinese government started to promote family planning as an effort to curb population growth in 1971. The tactics included initiatives that encouraged postponing marriage until a later age, lengthening birth spacing between children, and reducing their number. In the late 1970s, the government adopted a stricter approach and began imposing a limit on the number of children per couple: a two children limit implemented nationwide in 1978 followed by the one-child policy announced in 1979 and strictly enforced in urban areas after 1980 (Choukhmane, Coeurdacier, and Jin 2017).

The two intermediate goods sectors take capital and labor as their inputs but differ in capital intensity used in production. To capture the structural reforms of the 1980s, we allow for two types of firms in the labor-intensive sector, the state-owned firms and the private firms. While the state-owned firms are less productive than the private firms, they have access to cheaper credit. A final goods producing sector combines these intermediate goods into final goods that can be consumed or invested.

On the household side, the economy is depicted by an overlapping-generation model in which parents and children are connected by inter-vivos transfer. Specifically, households cannot borrow and they save for old age. We model the fertility decision exogenously. However, human capital investment is an important choice variable in the model.<sup>4</sup> While elementary and middle school education is mandatory, high school education and beyond is optional and determined by the parents. Grown children make transfer payments to their parents during the parents' old age and the payments are proportional to the children's labor earnings. In addition to the transfer payments from their children, retired parents receive a pension from the government. The government finances pensions through a wage tax and finances subsidies to firms through an income tax that applies to both labor income and pension income.

We use our model to conduct counterfactual exercises illustrating the contributions of these various channels to growth in output as well as in household savings.<sup>5</sup> We calibrate our parameters to match key aspects of the Chinese economy in the mid-1970s. Then we reduce the fertility rate, lengthen the life expectancy, and cut the retirement pension to match their data counterparts. Credit subsidies are chosen to match changes in employment shares by private firms and the ratio of assets in heavy industries relative to assets in light industries.

Our model matches aggregate output growth and the households savings rate between 1980 and 2012 reasonably well. All changes on the household side, the lower fertility rate, the lengthened life expectancy, and the reduction in pensions lead households to save more. Among the three factors, increases in longevity have the largest effect. The higher savings rate as well as the decline in the working age population affect firms and benefit the capital-intensive sector disproportionately. The same demographic changes, on the other hand, also encourage households to invest more in their children's human

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<sup>4</sup>Human capital accumulation has also accelerated over the last thirty years, with the average years of schooling increasing from 5.8 years to 8.9 for an adult aged 25 (Barro and Lee 2014, and Li, Liang, Fraumeni, Liu, and Wang 2013).

<sup>5</sup>We abstract from government savings, which remained under 5 percent through our model period. Instead, we assume that the government balances its budget each period.

capital because these transfer payments from children serve as an annuity in their old age. The resulting higher human capital leads to a more productive labor force and hence an increase in labor supply, which benefits the labor-intensive sector disproportionately. Thus, both higher savings and increased labor quality lead to higher output growth while the reduced quantity of labor restricts growth. Changing government subsidies initially benefit private firms in the labor-intensive sector as taxes on their credit are cut. This policy raises wages, which further encourages human capital investment. Subsidies to the capital-intensive sector, by contrast, increase capital demand and help raise the deposit rate received by households and encourage household savings. While the credit policies initially alleviate the capital misallocation between state firms and private firms and, hence, help raise output growth, they later lead to capital misallocation between heavy industries and light industries and, therefore, reduce output growth. Additionally, the initial promotion of private labor-intensive firms increases both labor demand and capital demand for the private firms. The resulting increase in interest rate, however, leads to reduced demand in capital from the capital-intensive sector. The net result is that households' savings rate moves down, albeit slightly. The later subsidies to capital-intensive firms have the opposite effect and greatly promote household savings through increased demand. With a multitude of competing channels and a wide range of policy changes, careful calibration is key to explaining what has economically transpired in China over three decades.

We quantify the findings concerning contributions from the different channels as follows. Among demographic changes, the rise in the life expectancy has the largest effect on the household savings rate resulting ultimately in a 10 percentage-point-increase in the rate. But that effect occurs gradually. Endogenous human capital investment, though it decreases savings slightly in the short run, also raises household savings significantly in the medium to long run. Investing in children's human capital serves as a substitute for investing in physical capital, but the resulting gains in income eventually contribute to additional savings of about 5 percentage points. Among industrial policies, subsidies to labor-intensive private firms decrease savings, but subsidies to the capital-intensive sector as well as reductions in intermediation cost raise savings significantly (by about 15 percentage points), and the effect takes place immediately after the policy is implemented.

Turning to output, demographic changes have a large effect on per capita output growth since the mid-1990s, raising it by 5 percentage points. Endogenous human

capital investment contributes significantly to per capita output growth especially after the mid-2000s (by about 3 percentage points). Output also increases when interest subsidies to the less productive state firms are reduced as more productive private firms take their place and when intermediation costs are reduced. Subsidies to capital-intensive industries, however, depress growth by about 1 percentage point because the subsidies result in a misallocation of capital.

In 2015, the Chinese government loosened the one-child policy to allow for two children per household. We thus conduct another analysis using a new path, where the fertility rate per adult gradually increases from 0.75 in 2015 to 1.25 in 2040. We show that the new policy will reduce aggregate savings by 3 percentage points after 2050 and will cut the per capita output growth rate by 1 percentage point starting from 2030.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the model. Section 4 calibrates the model for the initial steady state that matches the Chinese economy in the mid-1970s. Section 5 calibrates the steady state associated with the modern Chinese economy and solves the transition path of the model. Section 6 conducts various counter-factual government policies while Section 7 conducts alternative policy experiments. Section 8 concludes.

## 2 Related Literature

Our paper relates to three strands of literature that are not mutually exclusive. The first seeks to explain the fast growth of total output in China. The explanations explore the role of resource reallocation from agriculture to manufacturing and services (Brandt, Hsieh, and Zhu 2008, and papers cited therein), from state-owned enterprises to private enterprises (Brandt, Hsieh, and Zhu 2008, Hsieh and Klenow 2009, Song, Storesletten, and Zilibotti 2011, 2014, Chen and Irarrazabal 2015, and Liu, Spiegel, and Zhang 2018), or from the capital-intensive industrial sector to the labor-intensive industrial sector (Chang, Chen, Waggoner, and Zha 2015). This literature has mostly been growth accounting exercises with minimal or no modeling of the household side. Relative to this literature, our paper captures the resource allocation/misallocation of the latter two strands and models the household side explicitly.

The second literature focuses on the high savings rate China has experienced during this period, in particular high household savings. This strand of literature has attributed the high savings rate to the rising private burden of expenditure on education and health

care (Chamon and Prasad 2010), long-term care risk (Imrohoroglu and Zhao 2018a), an unbalanced sex ratio (Wei and Zhang 2011), the one-child policy (Banerjee, Meng, Porzio, and Qian 2014, Curtis, Lugauer, and Mark 2015, Choukhmane, Coeurdacier, and Jin 2017, and Ge, Yang, and Zhang 2018), precautionary savings (Chamon, Liu, and Prasad 2013, and He, Huang, Liu, and Zhu 2018), structural shifts in life-cycle earnings (Song and Yang 2010), housing prices (Wang and Wen 2012, and Wan 2015), and the constraints of the household registration system (Chen, Lu, and Zhong 2015). The analyses are generally conducted either in a partial equilibrium framework with the wage and/or interest rate given exogenously or in an environment that has largely ignored the complexity of the evolution of production. Our paper contributes to this literature by adding rich firm dynamics and changing government credit policies, although we do not model precautionary motives.

The third literature examines China’s current account and implications of capital control policies. This literature includes Song, Storesletten, and Zilibotti (2014), Imrohoroglu and Zhao (2018b), and Liu, Spiegel, and Zhang (2018). Song et al. (2014) explore the effects of capital controls and policies regulating interest rates and the exchange rate. The key feature of their paper is asymmetric productivity and financial constraints faced by state and private firms. Imrohoroglu and Zhao (2018b) add to Song et al. (2014) by adding declines in government as well as family insurance to elder households to account for increases in the current account. Liu et al. (2018) focus on the optimal capital account liberalization policies using a two-sector model that seeks to capture the same capital misallocation as those in Song et al. (2014) and Imrohoroglu and Zhao (2018b). Compared to these papers, our paper incorporates the recent government credit policy that favors heavy industry as documented in Chang et al. (2015). The modeling of the new credit policy is important as it helps account for the capital accumulation observed in more recent times. Furthermore, we add a detailed household sector to the model that complements those in Imrohoroglu and Zhao (2018b), yet differs in that we allow for endogenous human capital accumulation, which serves as an additional link between the household sector and the firms.<sup>6</sup>

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<sup>6</sup>Bairoliya, Miller, and Saxena (2018) study the impact of fertility changes on per capita output in an overlapping generations model that also features endogenous human capital investment. The model allows for uncertainty in survival probability, but abstract from any changes in industrial structure.

### 3 The Model

We consider an overlapping-generation model where households are connected through inter-vivo transfers. Production takes place in two industries, the capital-intensive industry and the labor-intensive industry. While the capital-intensive industry consists entirely of state-owned firms, the labor-intensive industry contains both state-owned and private firms. The government pays for government policies and the pay-as-you-go social security system through labor income taxes.

#### 3.1 Households

In each period  $t$ , a generation of households is born with human capital  $h$ . We assume that  $h$  grows at an exogenous rate of  $g_y$ . We denote a household's birth cohort by  $B$ . We thus have  $j = t - B$ , where  $j$  is the age of the household. A household begins to work at age  $j_1$ . It exits the economy at age  $J_B$  with a certain life span of  $J_B$ . The household gives birth to  $n_B$  ( $n_B > 0$ ) children at age  $j_f$  and retires at age  $j_r$ , where  $j_1 \leq j_f \leq j_r \leq J_B$ . At each age, the household makes consumption and savings decisions. When its children are between the age of 16 and 22, the household also makes human capital investment decisions for them. Labor supply is inelastic. Starting from retirement age  $j_r$ , the household also receives transfers from its children at which point the children would be  $j_r - j_f$  years of age and we assume that  $j_f + j_1 \leq j_r$  to ensure that when the household retires, its children have already entered the economy. Additionally, the household receives a social security/pension which is a fraction  $\varsigma_B$  of its earnings at the time of retirement. The demographic structure of our model endogenously determines population growth rate,  $g_t$ . We omit time  $t$  subscripts or the cohort  $B$  subscript in our description of the household's problem below.

Labor income is subject to a payroll tax  $\tau_{ss}$  with the revenue going towards pensions. Labor income as well as social security income are subject to an additional tax  $\tau$ , which is used to fund government credit subsidizing policies.

We denote the consumption of an age- $j$  household by  $c_j$ , savings by  $a_j$ , and children's human capital by  $h_{c,j}$ . The period utility function of a household of age  $j$  is

$$\frac{c_j^{1-\sigma}}{1-\sigma}, \tag{1}$$

where  $\sigma$  is the relative risk aversion parameter.

Labor productivity is deterministic and age dependent with all workers of the same age  $j$  facing the same exogenous profile  $e_j$ . Given the household's human capital  $h$ , the total productivity of the household is given by  $he_j$ . We impose an exogenous borrowing constraint: At any given period the household's financial asset must satisfy  $a_j \geq 0$ .

We assume that a household spends a fraction  $\Phi_1$  of its wage income on each child's consumption until their children turn  $j_1$  years of age. Children start receiving education at age 7. The first 9 years of education is mandatory and each child's education costs a fraction  $\Phi_2$  of the household's wage income. The next 7 years' education is optional and the level of investment  $i_h$  is chosen by the household (in terms of final goods). We assume the human capital production function follows  $h'_c = h_c + \eta_{j-j_f}(i^h)^\kappa h_c^{1-\kappa}$ , where  $0 \leq \kappa \leq 1$ , and the parameter  $\eta_{j-j_f}$  governs the child-age dependent efficiency in human capital accumulation. This functional form is a slight modification of that used in Manuelli and Seshadri (2014). The transfer to the household's parents is a fraction  $\mu_0 n_{B,s}^{\mu_1-1}$  of the wage income, where  $n_{B,s}$  is the number of siblings the household has. We assume  $0 \leq \mu_1 \leq 1$  to capture the decline of each child's transfer to parents with the number of siblings.<sup>7</sup>

### 3.1.1 Recursive Problems

Because we allow some parameters to vary by cohort, and also because during the transition path, wages, interest rates, and taxes differ over time, households at the same age but from different cohorts solve different problems. To summarize, a household's state space consists of its cohort  $B$ , age  $j$ , human capital  $h$ , and children's human capital  $h_c$ .<sup>8</sup> Table 1 describes a household's decisions at different ages. Define a household's after-tax labor income and pension

$$y_j = \begin{cases} (1 - \tau - \tau_{ss})he_jw, & \text{if } j < j_r, \\ (1 - \tau)\varsigma_B he_{j_r-1}w_{B,j_r-1}, & \text{if } j \geq j_r. \end{cases} \quad (2)$$

That is, a household receives wage earnings before retirement and a pension after retirement. Note the pension is taxed at rate  $\tau$ , labor income is taxed at rate  $\tau + \tau_{ss}$ . Let the symbol  $r_d$  represent the net deposit rate the household faces. The household then solves the following problem,

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<sup>7</sup>This part of our model also follows that of Choukhmane et al. (2017).

<sup>8</sup>Under our modeling structure, once cohort and age are given, the number of siblings and the number of children are determined and, thus, are not state variables.

1.  $j_1 \leq j < j_f + 7$ : the household either does not have children or has children under the age of 7 who do not require formal education yet;

$$\begin{aligned}
V_B(j, a, h, h_c) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(j+1, a', h, h_c) \right\} \\
s.t. \quad c + a' + n\Phi_1 h e_j w + 1_{(j_r - j_f \leq j < J - j_f)} \mu_0 n_{B,s}^{\mu_1 - 1} h e_j w &\leq (1 + r_d)a + y_j, \\
a', c &\geq 0.
\end{aligned} \tag{3}$$

The first term in the value function is the standard power period utility function. The parameter  $\beta$  is the discount factor. The left hand side of the budget constraint includes consumption, savings, basic living expense for the children, and the transfer the household makes to its parent when the parent is  $j_r$  years of age or older and hasn't exited the economy yet.<sup>9</sup> The right hand side of the budget constraint contains the household's asset plus interest income and after tax labor income.

2.  $j_f + 7 \leq j < j_f + 16$ : the household has children that must receive mandatory primary as well as middle school education;

$$\begin{aligned}
V_B(j, a, h, h_c) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(j+1, a', h, h_c) \right\} \\
s.t. \quad c + a' + n\Phi_1 h e_j w + n\Phi_2 h e_j w + 1_{(j_r - j_f \leq j < J - j_f)} \mu_0 n_{B,s}^{\mu_1 - 1} h e_j w &\leq (1 + r_d)a + y_j, \\
a', c &\geq 0.
\end{aligned} \tag{4}$$

Relative to households in the first age group, the household now needs to pay for its children's mandatory education captured by the fourth term in the budget constraint.

3.  $j_f + 16 \leq j < j_f + j_1$ : the household has children who are eligible for optional high

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<sup>9</sup>Since a parent gives birth at age  $j_f$ , an individual of age  $j$  has a parent of age  $j + j_f$ .

school as well as college education;

$$\begin{aligned}
V_B(j, a, h, h_c) &= \max_{\{c, a', i^h\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(j+1, a', h, h'_c) \right\} \\
s.t. \quad c + a' + n\Phi_1 h e_j w + n i_h + 1_{(j_r - j_f \leq j < J - j_f)} \mu_0 n_{B,s}^{\mu_1 - 1} h e_j w &\leq (1 + r_d) a + y_j, \\
h'_c &= h_c + \eta_{j-j_f} (i^h)^\kappa h_c^{1-\kappa}, \tag{5} \\
a', c &\geq 0, \quad h'_c \geq h_c. \tag{6}
\end{aligned}$$

The household now makes human capital investment decisions for its children, and the associated expenditure is captured by the fourth term in the budget constraint  $n i_h$ . The law of motion for the children's human capital is represented by equation (5), which combines the children's existing human capital with that of investment in a Cobb-Douglas functional form. As discussed earlier,  $\eta_{j-j_f}$  denotes efficiency in human capital accumulation, which is a function of the children's age.

4.  $j_1 + j_f \leq j < J_B$ : the household no longer has school-age children;

$$\begin{aligned}
V_B(j, a, h, h_c) &= \max_{\{c, a'\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(j+1, a', h, h_c) \right\} \\
s.t. \quad c + a' + 1_{(j_r - j_f \leq j < J - j_f)} \mu_0 n_{B,s}^{\mu_1 - 1} h e_j w &\leq (1 + r_d) a + y_j + 1_{(j \geq j_r)} \mu_0 n^{\mu_1} h_c e_{j_f, j-j_f} w, \\
a', c &\geq 0. \tag{7}
\end{aligned}$$

At this age group, as in age groups 1 and 2, the household makes only consumption and savings decisions. Its children have left the household and no longer cost anything. The household starts receiving transfer payments from the children after retirement as captured by the last term on the right hand side of the budget constraint.

### 3.2 The Firms

The economy consists of three sectors, two intermediate goods sectors and one final goods sector. The two intermediate goods sectors differ in their productivity, capital intensity, ownership structure, and importantly the subsidies they receive from the government. We term the sector that uses capital more intensively the capital-intensive sector or heavy-industry sector, and the sector that uses labor more intensively the labor-intensive sector or light-industry sector. This modeling choice, thus, combines the

two approaches adopted in the literature on the Chinese economy as represented by Song et al. (2011), and Chang et al. (2015) and researchers cited in their respective papers. It also captures important features of the Chinese economy: that the privatization of state-owned enterprises has been concentrated mostly in the labor-intensive sector; and the capital-intensive sector is dominated by state-owned enterprises that enjoy heavy subsidies from the government.

### 3.2.1 The Final Goods Sector

Following Chang et al. (2015), we denote final goods at time  $t$  by  $Y_t$ . It is a CES aggregate of the two intermediate goods:

$$Y_t = (\varphi Y_{k,t}^{\frac{\gamma-1}{\gamma}} + Y_{l,t}^{\frac{\gamma-1}{\gamma}})^{\frac{\gamma}{\gamma-1}}. \quad (8)$$

The subscripts  $k$  and  $l$  stand for capital- and labor-intensive intermediate goods, respectively, and  $\gamma$  denotes the elasticity of substitution between the two intermediate goods. We normalize the price of the final goods to be 1, and use  $P_{k,t}$  to denote the price of the capital-intensive intermediate goods, and  $P_{l,t}$  the price of the labor-intensive intermediate goods. The firm's optimization problem implies

$$\frac{Y_{k,t}}{Y_{l,t}} = \left(\frac{\varphi P_{l,t}}{P_{k,t}}\right)^{\gamma}. \quad (9)$$

The zero-profit condition for the final good further implies

$$[\varphi^{\gamma} P_{k,t}^{1-\gamma} + P_{l,t}^{1-\gamma}]^{\frac{1}{1-\gamma}} = 1. \quad (10)$$

### 3.2.2 The Capital-Intensive Intermediate Goods Sector

Motivated by the empirical evidence documented in, among others, Chang et al. (2015), we assume that the capital-intensive sector is populated entirely by state-subsidized enterprises. The production function takes the following Cobb-Douglas form:

$$Y_{k,t} = K_{k,t}^{\alpha_k} (A_{k,t} L_{k,t})^{1-\alpha_k}, \quad (11)$$

where  $K_{k,t}$  and  $L_{k,t}$  represent capital rented from households and efficient labor inputs, respectively, and  $A_{k,t}$  denotes labor augmented productivity. The parameter  $\alpha_k$  represents the capital income share in the production of the intermediate goods. The firms

in this sector solve the following problem,

$$\max_{K_{k,t}, L_{k,t}} \{P_{k,t} K_{k,t}^{\alpha_k} (A_{k,t} L_{k,t})^{1-\alpha_k} - (r_{f,t} + \delta)(1 - S_{k,t})K_{k,t} - w_t L_{k,t}\}, \quad (12)$$

where  $r_{f,t}$  denotes the gross interest rate that is common to both the capital-intensive and the labor-intensive sectors;  $S_{k,t}$  ( $0 \leq S_{k,t} < 1$ ) denotes the interest subsidy firms in the capital-intensive sector receive from the government;  $\delta$  represents the capital depreciation rate, and  $w_t$  is the wage rate that is also common to both sectors.<sup>10</sup> Profit maximization generates the following two first-order conditions,

$$(r_{f,t} + \delta)(1 - S_{k,t}) = \alpha_k P_{k,t} A_{k,t}^{1-\alpha_k} K_{k,t}^{\alpha_k - 1} L_{k,t}^{1-\alpha_k}, \quad (13)$$

$$w_t = (1 - \alpha_k) P_{k,t} A_{k,t}^{1-\alpha_k} K_{k,t}^{\alpha_k} L_{k,t}^{-\alpha_k}. \quad (14)$$

Note that we use different notation for the deposit rate and the rate of return to capital, where the difference  $\xi_t = r_{f,t} - r_{d,t}$  represents an intermediation cost.

### 3.2.3 The Labor-Intensive Intermediate Goods Sector

We assume that the labor-intensive sector consists of state-owned and privately owned enterprises. We wish to highlight some important differences between the two type of firms. First, state-owned firms are generally weaker in governance and offer fewer incentives to their managers than private firms. Second, compared to private firms, state-owned firms have better access to borrowing because of their close connection with state-owned banks. This second feature also motivated our modeling of the interest rate subsidy that we discussed regarding the capital-intensive firms. Thus, the key differences between these two types of firms are their labor productivity and costs of capital.

We assume that private enterprises have a higher labor productivity and are subject to higher cost of financing capital in the form of a tax, while the state-owned enterprises receive an interest rate subsidy. In order to capture the effects of a changing mix of firms in this sector, we employ an exogenous externality in production along with an operating cost measured in labor hours that is proportional to the number of  $i$  type firms in the sector, where  $i = s, p$  ( $s$  indicates state-owned firms and  $p$  indicates private firms). A zero profit condition allows us to pin down the number of firms  $N_{l,i,t}$  ( $i = s, p$ ) of each type and to endogenize the evolution of the relative share of private and state

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<sup>10</sup>We assume that the credit subsidy is proportional to the interest rate.

owned firms in this sector.

Let  $K_{l,i,j,t}$  and  $L_{l,i,j,t}$  ( $i = s, p, j = 1, 2, \dots, N_{l,i,t}$ ) denote the capital input and labor input, respectively, employed by firm  $j$  of type  $i$  at time  $t$  in the labor-intensive sector. We assume that firms in each type are symmetric. Let  $K_{l,i,t}$  and  $L_{l,i,t}$  denote the total capital and labor input, respectively, employed by type  $i$  firms, and let  $K_{l,t}$  and  $L_{l,t}$  denote total capital and labor inputs in the labor-intensive sector at time  $t$ . Given the symmetry assumption, we then have  $K_{l,i,j,t} = \frac{K_{l,i,t}}{N_{l,i,t}}$  and  $L_{l,i,j,t} = \frac{L_{l,i,t}}{N_{l,i,t}}$ . Additionally,  $K_{l,t} = K_{l,s,t} + K_{l,p,t}$  and  $L_{l,t} = L_{l,s,t} + L_{l,p,t}$ . The production function of firm  $j$  of type  $i$  in the labor-intensive sector at time  $t$  is as follows,

$$Y_{l,i,j,t} = (K_{l,i,j,t})^{\alpha_l} (A_{l,i,t} L_{l,i,j,t})^{\gamma_l} (K_{l,t})^{1-\alpha_l-\gamma_l}. \quad (15)$$

The parameter  $\alpha_l$  indicates capital income share,  $\gamma_l$  indicates labor income share, with  $0 < \alpha_l + \gamma_l < 1$ , and  $A_{l,i,t}$  indicates labor productivity. Note that the production function includes aggregate capital in the sector  $K_{l,t}$  as an additional input, which introduces an externality and is necessary to ensure balanced growth. The higher the total capital used in the sector, the more productive firms are. This setup allows both types of firms to coexist in the labor-intensive sector as the production function, without aggregate capital, exhibits decreasing return to scale. Finally, there is a cost of production,  $w_t f_{l,i}(N_{l,i,t})^\xi L_{l,i,t}$ , which is a function of the wage rate  $w_t$ , the total labor input  $L_{l,i,t}$ , and the number of same type firms  $N_{l,i,t}$  in the sector. The term  $f_{l,i}$  is a scaling factor.<sup>11</sup>

We can now write the firm's problem as follows,

$$\begin{aligned} \max_{\{K_{l,i,j,t}, L_{l,i,j,t}\}} \{ & P_{l,t} (K_{l,i,j,t})^{\alpha_l} (A_{l,i,t} L_{l,i,j,t})^{\gamma_l} (K_{l,t})^{1-\alpha_l-\gamma_l} - (r_{f,t} + \delta)(1 - S_{l,i,t}) K_{l,i,j,t} \\ & - w_t L_{l,i,j,t} - w_t f_{l,i}(N_{l,i,t})^\xi L_{l,i,t} \}, \end{aligned} \quad (16)$$

where  $S_{l,i,t}$  ( $i = s, p$ ) represent the interest subsidies if ( $0 \leq S_{l,i,t} < 1$ ) or a tax if  $S_{l,i,t}$  is

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<sup>11</sup>This particular functional form for production cost allows the cost to grow at the same rate as the wage rate while the total number of firms of the same type does not change and, thus, helps reserve balanced growth at steady state. Additionally, allowing the cost to depend on firm size exponentially ensures that firms receiving financing subsidies are larger when the exponent is positive. Having said that, our model is parsimonious in its modeling of firm sizes. We make no attempt to match the Chinese firm dynamics in this paper.

negative. The first order conditions from the profit-maximization problem are,

$$(r_{f,t} + \delta)(1 - S_{l,i,t}) = \alpha_l P_{l,t} (A_{l,i,t})^\gamma (K_{l,i,j,t})^{\alpha_l - 1} (L_{l,i,j,t})^\gamma (K_{l,t})^{1 - \alpha_l - \gamma}, \quad (17)$$

$$w_t = \gamma_l P_{l,t} (A_{l,i,t})^\gamma (K_{l,i,j,t})^{\alpha_l} (L_{l,i,j,t})^{\gamma_l - 1} (K_{l,t})^{1 - \alpha_l - \gamma_l}. \quad (18)$$

The profit for each firm is then,

$$\pi_{l,i,j,t} = (1 - \alpha_l - \gamma_l) P_{l,t} (K_{l,i,j,t})^{\alpha_l} (A_{l,i,t} L_{l,i,j,t})^\gamma (K_{l,t})^{1 - \alpha_l - \gamma_l} - w_t f_{l,i} (N_{l,i,t})^{-\xi} L_{l,i,t}. \quad (19)$$

In equilibrium, the fixed cost will be such that the profit for each firm is zero,  $\pi_{l,i,j,t} = 0$ .

### 3.3 The Government

The government chooses tax rates and interest subsidies  $\{\tau_t, \tau_{ss,t}, S_{k,t}, S_{l,s,t}, S_{l,p,t}\}$  in this economy. Let  $\Lambda_{j,t}$  denote the measure of households at age  $j$  and time  $t$ . We then have

$$\sum_{j=j_r}^{J_B-1} \Lambda_{j,t} \varsigma_B h_B e_{j_r-1} w_{B,j_r-1} = \tau_{ss,t} \sum_{j=j_1}^{j_r-1} \Lambda_{j,t} h_B e_j w_t, \quad (20)$$

$$(r_{f,t} + \delta) S_{k,t} K_{k,t} + \sum_{i=s,p} (r_{f,t} + \delta) S_{l,i,t} K_{l,i,t} = \tau_t \left[ \sum_{j=j_1}^{j_r-1} \Lambda_{j,t} h_B e_j w_t + \sum_{j=j_r}^{J_B-1} \Lambda_{j,t} \varsigma_B h_B e_{j-1} w_{B,j_r-1} \right]. \quad (21)$$

Note that  $B$  denotes cohort, or the year the household was born,  $B = t - j$ .

### 3.4 Equilibrium

The competitive equilibrium consists of prices  $\{P_{k,t}, P_{l,t}, w_t, r_{k,t}, r_{d,t}\}_{t=0}^\infty$ , government policies  $\{\tau_{ss,t}, \tau_t, S_{k,t}, S_{l,s,t}, S_{l,p,t}\}_{t=0}^\infty$ , allocations  $\{Y_{l,i,j,t}, K_{l,i,j,t}, L_{l,i,j,t}\}_{i=s,p; j=1, \dots, N_{l,i,t}; t=0, \dots, \infty}$ ,  $\{Y_{k,t}, Y_{l,t}, Y_{l,s,t}, Y_{l,p,t}, K_{k,t}, K_{l,s,t}, K_{l,p,t}, L_{k,t}, L_{l,s,t}, L_{l,p,t}, N_{l,s,t}, N_{l,p,t}\}_{t=0}^\infty$ ,  $\{c_{j,t}, a_{j,t}, i_{j,t}^h\}_{j=j_1, \dots, j; t=0, \dots, \infty}$ , and population measure  $\{\Lambda_{j,t}\}_{j=j_1, \dots, j, t=0, \dots, \infty}$  such that

1. Households maximize utility;
2. Firms maximize profits;
3. Markets clear,

- (a) Goods market: all goods produced by firms are purchased by households;
- (b) Capital market: firms rent capital from households.  $\sum_{j=j_1}^{J_B-1} \Lambda_{j,t} a_{j,t} = K_{k,t} + K_{l,s,t} + K_{l,p,t}$ ;
- (c) Labor market: households supply labor to firms.  $\sum_{j=j_1}^{j_r-1} \Lambda_{j,t} h_{j,t} e_j = L_{k,t} + L_{l,s,t} + L_{l,p,t}$ ;

4. Government balances budget.

## 4 Calibration

We calibrate our initial steady state benchmark to the Chinese economy in the mid-1970s, and accordingly the per capita GDP growth rate,  $g_y$ , to be 2 percent. The per capita GDP growth rate comes from the Penn World Tables where we first divide the output-side real GDP at chained purchasing power parity (PPPs) by population and then take the log difference. The series is subsequently HP filtered with a parameter of 1600. Table 2 presents the parameters and their sources or data moments that we seek to match. We discuss our choices below. For some of the economic indicators that are not available, we use their earliest available statistics, which are typically in the early 1990s and extrapolated back to 1975.

### 4.1 Households

We assume that a household enters the economy at age 23, gives birth to its children at age 25, and retires at age 55. We set the maximum life span to be 57 from World Bank data. We also obtain the population growth rate of 2.45 percent from the World Bank data. The implied births per woman was 3.6 which corresponds to 1.8 per single parent household in our model.

For preferences, we assume a 1.5 relative risk aversion parameter as is standard in the macro literature. The discount rate  $\beta$  is chosen to match the capital-output ratio in 1975. Because our overlapping generations framework abstracts from uncertainties in income, expenditure, and the pension, the model requires a discount factor that is significantly larger than 1 to get close to the observed savings rate.<sup>12</sup>

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<sup>12</sup>For the importance of these risks in explaining Chinese households' savings over time, see the papers cited in the related literature section.

We depict the labor efficiency profile in Figure 3, which we adopt from Choukhmane et al. (2017), who in turn obtained it from the 1992 Urban Household Survey. 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 in the state-owned enterprises. The coverage, however, was low in nonstate-owned enterprises. As a matter of fact, many nonstate-owned enterprises had no pension scheme for their employees (see, e.g., Sin 2005). For the benchmark analysis, we set our replacement rate at  $\varsigma_B = 0.70$ , which is the average national pension replacement rate calculated by He et al. (2018) (Figure 10 of the paper).

The parameters governing educational expenses, child living expenses, and transfers to parents mostly follow Choukhmane et al. (2017). In particular, we set the living expense of a child as a percent of its parents' labor income to 8 percent ( $\Phi_1$ ).<sup>13</sup> The mandatory education expense parameter  $\Phi_2$  is set to match the average 6 percent of income that urban households spend on their children's mandatory education (Figures 3 and 7 of Choukhmane et al. 2017). The parameters describing the transfer payments to parents ( $\mu_0, \mu_1$ ) follow exactly Choukhmane et al. (2017).

The age efficiency profile in human capital accumulation  $\eta_j (j = 16, \dots, 22)$  and parameter  $\kappa$  that describes the human capital production process are chosen to match the age profile of discretionary education expenditures as depicted in Figure 4.<sup>14</sup>

The deposit rate faced by households is taken from the International Financial Statistics Database of the International Monetary Fund. For the periods of our study, the vast majority of household financial savings takes the form of bank deposits and the deposit rate is set by the central bank.

## 4.2 Firms

Turning to firms, the capital income share of the capital-intensive and labor-intensive sectors,  $\alpha_k$  and  $\alpha_l$ , are calibrated to match the capital income share of the two industries

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<sup>13</sup>Assuming that households savings rate was 35 percent in 1980, a typical household with 3 children spent 65 percent of its income on consumption. Assuming that a child is equivalent to 0.5 of an adult in terms of consumption expenditure, we estimate an expenditure share of about 18.6 ( $=0.65/(2+3*0.5)$ )percent of household income per adult or 9.3 percent per child. Our 8 percent number, therefore, serves as a lower bound.

<sup>14</sup>To reduce the number of parameters, we estimate the efficiency function as a polynomial of degree 2 with respect to age.

using data provided by Chang et al. (2015).<sup>15,16</sup> The share of the capital-intensive sector output in final output production as well as the elasticity of substitution between capital-intensive and labor-intensive sector output are chosen according to Chang et al. (2015). Chang et al. (2015) estimate the parameters to match the dynamics of the ratio of output in the capital-intensive sector to that in the labor-intensive sector. The labor augmented TFP in the capital-intensive sector is chosen so that the ratio of capital employed in the capital-intensive sector to capital employed in the labor-intensive sector is 2.5. The relative labor augmented TFP of the private firms to the state firms in the labor-intensive sector, 2.2, is taken directly from Song et al. (2011).

As mentioned earlier, the adoption of a decreasing return to scales technology in the labor-intensive sector allows for the co-existence of the state and private enterprises when their outputs are perfect substitutes. We chose the share of income that pays the fixed cost, as well as the fixed cost parameters, to match the relative output and labor share of the state and the private enterprises reported in Song et al. (2011).<sup>17</sup>

The intermediation cost follows the logic of Song et al. (2011) to capture operational costs, red tape, etc. In other words, this cost is an inverse measure of the efficiency of intermediation. This initial intermediation cost is chosen so that the net rate of return to capital is roughly 16 percent in 1980s China (Bai, Hsieh, and Qian 2006) with a standard capital depreciation rate of 10 percent.<sup>18</sup>

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<sup>15</sup>Chang et al. (2015) collect their data from two databases: the CEIC (China Economic Information Center, now belonging to the Euromoney Institutional Investor Company) database – one of the most comprehensive macroeconomic data sources for China – and the WIND database – the data information system created by the Shanghai-based company called WIND Co. Ltd., the Chinese version of Bloomberg. The major sources of these two databases are the National Bureau of Statistics (NBS) and the People’s Bank of China (PBC) augmented with China Industrial Economy Statistical Yearbooks and China Labor Statistical Yearbooks.

<sup>16</sup>The heavy industry sector includes real estate, leasing and commercial service; electricity, heating and water production and supply; coking, coal gas and petroleum processing; wholesale, retail, accommodation and catering; banking and insurance; chemical; mining; transportation, information transmission and computer services and software. The light industry sector includes food, beverage and tobacco; other manufacturing; metal product; machinery equipment; construction material and nonmetallic mineral product; textile, garment and leather; construction; other services; and farming, forestry, animal husbandry and fishery (Table 11 of Chang et al. 2015).

<sup>17</sup>Their data, in turn, come from the China Industrial Economy Statistics Yearbook and China Statistical Yearbook.

<sup>18</sup>The estimated net aggregate return to capital from Bai et al. (2006) ranges from 12 percent to 22 percent between 1978 and 1983 depending on assumptions on depreciation rates, tax treatment, and the treatment of inventory capital.

### 4.3 Government

We normalize the interest subsidy received by the state-owned firms in the labor-intensive sector to zero, but choose the interest subsidy to the private enterprises to match the relative capital output ratio of the state-owned enterprises to private enterprises (2.65). We set the interest subsidy rate to the capital-intensive sector in 1975 to be zero. As Chang et al. (2015) discuss in detail, government subsidies to the capital-intensive sector did not start until the mid-1990s.

### 4.4 Results in the Initial Steady State

In the second and third columns of Table 3, we present data moments as well as their corresponding model moments. The return to capital and the aggregate capital-to-total output ratio are statistics that the paper is calibrated to match, the other moments are nontargeted moments. Note that in 1980, private enterprises were almost nonexistent. To capture that, we impose a large proportional credit tax that results in a small proportional income tax rebate of 0.1 percent.

Our model does a reasonably good job at matching most of the non-targeted data moments reported here. For example, the young age dependency ratio, defined as those under 15 to the population between the ages of 15 and 65, is close to the data. The social security tax needed to finance the pension payment amounts to 3.3 percent of wage income. This low number arises because in the mid-1970s, households had a life expectancy of only 57 years of age, only 2 years older than the retirement age of 55.

## 5 Final Steady State and Transition Dynamics

### 5.1 Final Steady State

We make the following assumptions about the final steady state. A one-parent household expects to live to 80 years of age and bears 0.75 child at age 25.<sup>19</sup> This is the average fertility rate between 2000 and 2010. The corresponding population growth rate is -0.89 percent. The pension replacement rate is assumed to be 20 percent of the households' wage income at retirement. No interest subsidies apply to any industry or any type of firm. We also set intermediation cost to zero.

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<sup>19</sup>Since our household consists of a single adult, we divide the average number of children per household 1.5 by 2 to obtain 0.75.

With these assumptions, we calculate the long run new steady state and report the results in the last column of Table 3. In the final steady state, the capital-output ratio rises to 4.30 from 1.68. Aggregate savings to total output goes from 24 percent to 46 percent. The equilibrium deposit rate drops from 5.4 percent to 1.6 percent. These results are mostly due to the demographic changes (fewer children to provide for old age, greater longevity, as well as the reduction of the safety net). The elimination of the credit tax on the private labor-intensive sector (there is no credit subsidy to the capital-intensive sector in the initial steady state) further increases demand for labor relative to capital. The decline of the intermediation cost from 10 percent to zero, however, boosts demand for capital. On net, in the final steady state, the net return to capital declines to 0.8 percent from 16 percent in the initial steady state. Finally, aggregate human capital investment as a fraction of income grows from 0.4 percent to 6.3 percent.

Though households also invest a substantially larger amount of their income in their children's human capital, the even larger demand for savings leads to a higher capital-to-labor ratio in the final steady state. The higher capital-to-labor ratio pushes up wages and the desire to invest in human capital. However, the longer life span and the decline in the pension replacement rate drive greater savings as well. Finally, despite the low pension replacement rate, the aging of the population requires a higher payroll tax rate to support the new pension system. At 13 percent, the new payroll tax rate is more than 4 times as large as it is in the initial steady state.

## 5.2 Exogenous Processes in Transition

We assume that in 1975 the Chinese economy was in steady state. We then solve the model for the period 1976-2300, assuming that the economy is hit by exogenous changes in fertility, life expectancy, and the pension replacement rate, and changes in interest subsidies and intermediation cost starting from 1976.

Figure 5 panel a depicts the exogenous processes on the household side. For the life expectancy series, the year on the x-axis indicates cohort year, i.e., the year when the household turns 23.<sup>20</sup> Note that life expectancy is discrete and can be only increased by integer numbers since the model period is one year. This introduces non-smoothness in

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<sup>20</sup>In our calculation, we assume that the life span of those who passed away before age 5 had a life span of 2 years and those who passed away between the ages of 6 and 14 had a life span of 9. Given the death rate for those who passed away under age 5  $x$ , and the death rate for those passed away between the ages of 6 and 14  $y$ , and assume the life span of those born at a particular year to be  $l$ , then the life span of those who survived to age 15,  $z$ , is the solution to  $2^*x+9*(1-x)*y+(1-x)*(1-y)*z=1$ .

aggregates as we discuss in the next section. According to the panel, life expectancy at 23 increases from 57 in 1975 to 80 shortly after 2040 and then stays there. The fertility rate drops from 1.8 per adult in 1975 to 0.75 in 2000. The pension replacement rate declines linearly from 70 percent in 1975 to 20 percent shortly before 2000.<sup>21</sup>

Figure 5 Panel b depicts the exogenous processes on the firm side. The credit subsidy rates, as government policy tools, are chosen to match the relative output as well as capital in the capital-intensive sector to those in the labor-intensive sector, and the changing employment share of private firms between 1980 and 2012 plotted in Figure 6.<sup>22</sup> According to panel b, credit taxes to private labor-intensive firms begin to decline in 1975 and reach zero by 2000. Credit subsidies to state-owned labor-intensive firms also start in 1975 and peak in 2000. Credit subsidies to capital-intensive firms start much more gradually and peak in 2025.

Panel c of Figure 5 charts the intermediation cost, that is, the wedge between the deposit rate and the capital rental rate faced by the firms absent credit subsidies. The calibration of the path of the intermediation cost is achieved by fitting the time path of the overall capital-output ratio in the economy. The intermediation cost starts at 10 percentage points and falls to zero by 2020.

To compute the transition dynamics, given all the exogenous processes discussed above, we find the equilibrium path with a guess on the sequence of interest rates, wages, prices of the intermediate goods, and government income taxes. Using this guess, we solve consumption, saving, and human capital investment in children for each cohort, and solve the firm's problem each year. We search over the sequences of interest rates, wages, prices of the intermediate goods, and government income taxes until we reach a fixed point. To simplify our computation, the payroll tax rate during transition is calculated each period using the ratio of retiree to working age population. Therefore, the government's pension expense doesn't always break even along the transition path. The remaining revenue, if there is any, is rebated back to the household resulting in a reduction in the labor income tax required so that government breaks even in implementing

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<sup>21</sup>The Chinese government provided widespread pension coverage before the 1980s. The reforms introduced since then have been incomplete and insufficient. Gu and Vlosky (2008) report that in 2002 and 2005, 40-50 percent of the elderly in cities and more than 90 percent of the elderly in rural areas did not have a pension. According to Song et al. (2014), and Sin (2005), the Chinese pension system provided a replacement rate of 60 percent to those retiring between 1997 and 2011 who were covered by the system. As the urban population was less than 40 percent of the Chinese population from 1980-2011, the pension coverage rate is calibrated to be 20 percent of the population.

<sup>22</sup>The data only go to 2012 so we extrapolate the processes to be consistent with the final steady state values that occur 200 years in the future.

credit policies.

The payroll tax initially declines due to reduction in the pension replacement rate. As the population ages, however, the economy needs to support a larger and larger share of elderly resulting in an increasing payroll tax rate, which reaches over 13 percent in the final steady state. The tax rate required to support credit policies peaks in 2020 at 35 percent, which corresponds to the time credit subsidies to capital-intensive industries peak. The small negative rate between 2075 and 2150 comes from the rebate from the pension expenses as discussed above. We don't plot the endogenously determined payroll as well as income tax rates during the transition to save space.

## 5.3 Transitional Dynamics

### 5.3.1 Household Transitional Dynamics

In Figure 6 panels a and b, we chart the life expectancy and birth rates per adult in the model against their counterparts in the data, respectively. To arrive at this series, we first obtain life expectancy at birth from the World Bank, and then adjust the rate by the mortality rate for those under 5 and the mortality rate for those between 6 and 14. After age 14, we assume the household's survival rate is 100 percent until it reaches the end of its life expectancy. Changes in the birth rates in the data are gradual. This is because the one-child policy was enforced at the provincial level and some provinces have more relaxed restrictions. There were also exceptions to the policy. For instance, families whose first child is disabled were allowed to have a second child. Families in the rural areas were also allowed to have a second child if the first born was a girl.

Figure 6 panel c presents both the model-implied and data regarding the young-age dependency ratio. Note that this is not a series that the model sets to match. Though the model series lies slightly above the data series, the overall trends match well. What is most striking about panel c is that the Chinese population is aging fast. In 1975, about 70 percent of the population are younger than 15 years of age. By 2010, only a bit over 20 percent of the population are under the age of 15.

In Figure 6 panel d, we chart the model-implied ratio of total human capital investment to income. In 1975, households in China barely spend any income on their children's human capital investment. Then the share starts to increase in 1991, the first year children born under China's birth planning program turned 16, the age when voluntary human capital investment is possible. By 2070, the share has reached 6.3

percent.

### 5.3.2 Firm Transitional Dynamics

In Figure 7, we chart model implications against data for the targeted moments on the firm's side including the ratio of output in the capital-intensive sector to the output in the labor-intensive sector, the ratio of capital input in the capital-intensive sector to that in the labor-intensive sector, private firms' employment share in total employment, and the overall capital-output ratio in the economy. The model does a good job fitting these targeted moments. Since the early 1990s, the capital-intensive heavy industry has become increasingly important both in terms of capital input and in terms of total output. Private firms have also become increasingly important. Their share of employment went from near zero in the early 1980s to over 50 percent by 2015. The economywide capital-output ratio has also been trending up during our sample period.

We now turn to the two aggregate series that are of particular interest to us: aggregate savings as a ratio of total output and per capita output growth. Figure 8 charts the two series. The model overpredicts the savings rate for the periods between 1995 and 2000. However, our model generates substantial output growth per capita as is observed in the data. Note that a feature of the model is it includes exogenous growth of 2 percent through the exogenous changes in the initial endowment of human capital. Finally, as mentioned earlier, due to the discreet change in life expectancy, the savings rate and per capita output growth exhibit zig-zag patterns. The pattern is particularly evident with per capita output growth.

## 6 Decomposing the Savings Rate and the Output Growth Rate

This section provides a decomposition of the impact of demographic changes represented by the one-child policy, the increase in longevity, and the reduction in the pension replacement rate. We also analyze in detail the effects of industrial policy changes characterized by credit subsidies to different industries and different enterprises in shaping the time-series path of the aggregate savings rate as well as the per capita output growth rate. We do this by running a sequence of counterfactual experiments where we allow demographic changes or industrial policy changes one by one. The interest rate, wage

rate, and relative prices are solved in the general equilibrium. The payroll tax rate is calculated as discussed above, that is, using the fraction of retirees. The income tax rate together with any possible rebate from the payroll tax revenue or shortfalls funds government credit subsidies.

## 6.1 The Role of Demographic Changes

In Figure 9, we investigate the role demographics play in shaping the time path of the aggregate savings rate and the per capita output growth rate absent of any change in credit policies. In panels a and b, we allow for only increased longevity. In panels c and d, we also introduce a gradual reduction in the pension replacement rate in addition to the increased longevity. Finally in panels e and f, we include a reduction in fertility completing the analysis of all the changes in demographics.

Increases in longevity monotonically raise aggregate savings from 25 percent of total output in 1975 to 29 percent in 2000 and to about 35 percent of total output in 2020. After that, as deposit rates begin to decline, and as households begin to invest more in their children's education, the aggregate savings rate starts to decline very gradually (Figure 9 panel a). Adding reductions in the replacement rate increases the time path of the savings rate. Specifically, in 2000, it raises the savings rate by about 1 percentage point to 30 percent. By 2020, the rate is increased by nearly 3 percentage points (Figure 9 panel c). The implementation of the one-child policy does not have any material impact on the savings rate (Figure 9 panel e). On the contrary, it actually decreases savings in the long run. This result arises because with fewer children, households find it more worthwhile to invest in their children's human capital in order to increase their old age transfer from the children.

Turning to the effects of demographic changes on per capita output growth as depicted in the right panels of Figure 9, increased longevity raises the per capita output growth rate substantially, but only after the mid-1990s (Figure 9 panel b). Given that the retirement age is kept at 55, the growth comes mostly from capital deepening as households need to save more for retirement given their longer life span. The reduced replacement rate raises the growth rate after the 1990s but only slightly (Figure 9 panel d). The reduced fertility rate raises the growth path in both the short run and the long run. The additional growth in the short run is largely mechanical as the fraction of young falls and a greater percent of the population is working. In the medium to longer term, per capita output growth further benefits from the supply of skilled labor

as human capital investment rises in concert with the lower fertility rate (Figure 9 panel f).

## 6.2 The Role of Industrial Policies

In this subsection, we investigate how credit policies and changes in intermediation cost help shape the time path of the aggregate savings rate as well as per capita output growth. The results are presented in Figure 10. We conduct four experiments here. First, we reduce the tax on credit to private firms in the labor-intensive sector. We present the results in panels a and b. Then we give subsidies to the entire labor-intensive sector. This includes the reduction in the credit tax on private labor-intensive firms and the initial increase and then decline in the credit subsidies to state-owned labor-intensive firms as described in Figure 5 panel b. The results are presented in panels c and d. In the third experiment, we add the effects due to the reduction in the intermediation cost (see Figure 5 panel c). The results are shown in panels e and f of Figure 10. Finally, we add interest rate subsidies to the capital-intensive industries and depict the results in panels g and h of Figure 10. All the experiments are conducted absent of any demographic changes.

With the reduction in credit taxes on the private firms in the labor-intensive industry, the demand for labor and capital both rise, but more so for labor due to its higher use in the labor-intensive industry. This leads to a rise in wage and, hence, a rise in households' desire to invest in their children's human capital. As a result, savings fall albeit very slightly (panel a). When the government gives subsidies to the state-owned firms in the labor-intensive sector, the short-run decline in the savings rate is reversed (panel c of Figure 5). This is due to lower productivity from these state-owned firms which shifts production to the now more productive capital-intensive sector and, hence, drives up the interest rate. The reduction in the intermediation cost leads to a surge in capital demand by firms, the deposit rate rises, and that drives up household savings substantially (panel e). The imposition of the credit subsidy to the capital-intensive industries further increases the demand for capital and results in even higher household savings, while its subsequent reduction after 2025 causes a decline in the household savings rate (panel g).

In terms of the per capita output growth rates, since the private labor-intensive firms are more productive than the other firms, the reduction in the credit tax on these firms should boost output growth. However, the associated lower savings discussed above

cancel out these positive effects and actually lead to slightly lower per capita output growth initially. The growth does pick up significantly after 1985 (Figure 10 panel b). The imposition of interest subsidies to state-owned labor-intensive firms mitigates the gains in output as the state firms are less productive than the private firms (Figure 10 panel d). The reduction in intermediation cost benefits firms in general as they now face a lower borrowing cost, and this benefits capital-intensive firms in particular. Output also rises in response (Figure 10 panel f). Finally, credit subsidies to the capital-intensive heavy industries boost growth initially when they correct the inefficiency caused by the intermediation cost. Later, however, the credit subsidies distort capital allocation and depress growth (Figure 10 panel h).

### 6.3 The Role of Endogenous Human Capital Investment

One unique feature of our model is the introduction of endogenous human capital investment. It allows households to save by investing in their children and affecting their expected old-age transfer payment from the children. In other words, with additional spending on children's education, a household can improve its children's labor efficiency and hence wage income. Since the old-age transfer from children to parents is proportional to the children's labor income, higher human capital investment means higher wages and hence higher transfer payments. At the aggregate level, human capital investment improves labor quality and drives growth. For savings, in the short run, households will save less for old age with endogenous human capital investment. In the long run, however, the additional income associated with human capital investment may lead them to save more with endogenous human capital investment than they would without endogenous human capital investment.

To quantitatively examine the importance of this margin, we conduct an experiment where we do not allow households to endogenously invest in human capital. Instead, we fix their human capital investment per child relative to income at the same ratio as in the initial steady state (which is shown in Figure 4) and solve the general equilibrium problem along the transition. In Figure 11, we report the new transition path for the aggregate savings rate (panel a) and per capita output growth rate (panel b) against their corresponding data and the benchmark counterparts. To understand this result, it is important to point out that human capital is a stock variable. It takes a whole cycle, 32 years (55-23) to be precise, for the whole working population to have benefited from the endogenous accumulation of human capital.

Without endogenous human capital investment, aggregate savings increase very slightly initially. After 2010, however, aggregate savings actually move down by almost 5 percentage points (Figure 11 panel a). The effect of endogenous human capital investment on per capita output growth exhibits a similar pattern (Figure 11 panel b). The initial effect is small and negative. After 1995, however, the effect becomes much larger. At its peak year of 2010, endogenous human capital investment raises per capita output growth by a large 2 percentage points compared to the per capita output growth without endogenous human capital accumulation. The difference is large even in 2070 and in the final steady state.

## 7 Reversing the One-Child Policy

In 2013, the one-child policy that had been in existence since the late 1970s was relaxed by the Chinese government. Under the new policy, families could have two children if one parent, rather than both parents, was an only child. This policy in practice affected mostly urban couples. In 2016, the Chinese government completely abolished the one-child policy. Starting in October 2015 all Chinese couples are allowed to have two children. In this section, we investigate the effect of this new fertility policy.

In Figure 12 panel a, we depict the new fertility rate path. Compared to the benchmark, we begin to raise the fertility rate gradually in 2015 and assume that the rate reaches 1.25 per woman in 2040 and then stays there. Figure 12 panel b graphs total human capital investment as a ratio of total income for the new economy and the benchmark economy. Figure 12 panel c presents the aggregate savings rate in the new economy together with the benchmark and the data. Figure 12 panel d likewise depicts the per capita output growth rate. With more children, households now spend a larger fraction of their income on their children's education. Per child, however, the fraction is much smaller, down by almost half compared to the benchmark economy. With more aggregate educational expenses and with more children now able to provide for their old age expenses, households reduce their savings, for example, by about 3 percentage points in 2050. The per capita output growth rate also falls especially in the longer run. By 2030, the growth rate is about 1 percentage point lower in the new economy than in the old. Total output growth, however, does increase by a little over 2 percentage points.

## 8 Conclusions

In this paper, we build a unified framework that brings together important changes on the households' as well as the firms' side of the Chinese economy to account for its rapid growth. On the household side, we focus on aging demographics arising from the one-child policy, increased life expectancy, and the reduced pension replacement rate. On the firm side, we focus on government credit policies that have favored different industries over time. Our model also features endogenous human capital investment that has been a prominent part of the Chinese growth experience.

Our analysis indicates both the demographic changes and the government policies played important roles in driving China's high rate of savings and fast growth. While the demographic changes did not take effect until the 1990s, the impact associated with government policies were much more immediate. This is particularly true for output growth. Importantly, though human capital investment in the short run crowds out capital investment and, hence, output growth, in the long run, it raises both savings and output growth substantially.

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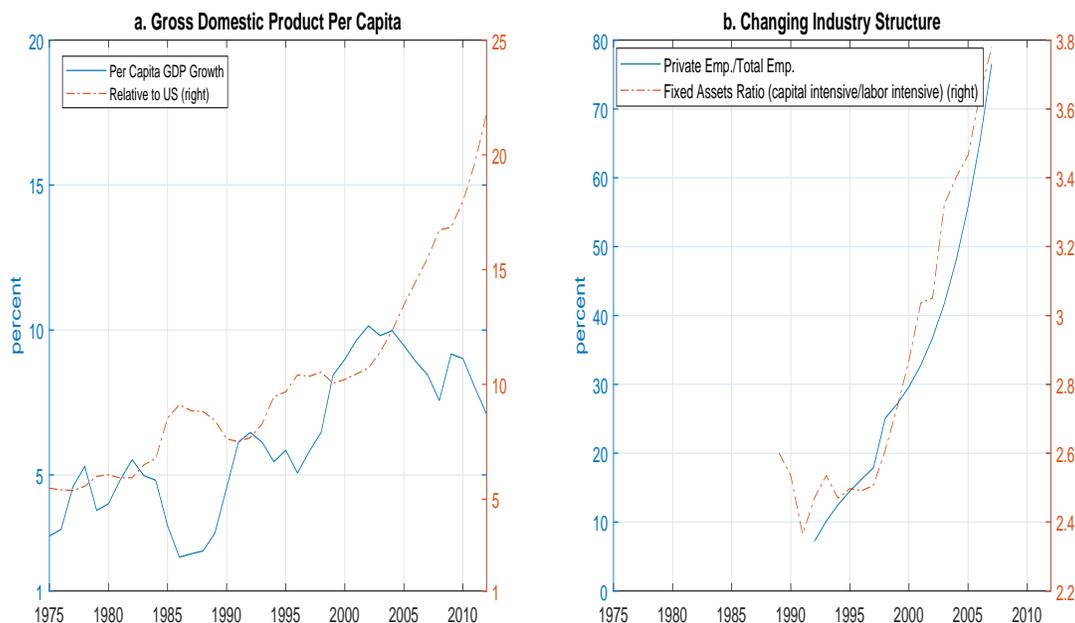


Figure 1: **The Growing Chinese Economy** This figure depicts the per capita GDP growth rate of the Chinese economy and the relative per capita GDP in China to that in U.S. (panel a) and the share of employment in private enterprises and the fixed assets of heavy versus light industry (panel b). Data for panel a come from the World Bank/Haver Analytics. To arrive at the per capita output growth, we first divide output-side real GDP at chained PPPs (2011 US\$) by total population, take the growth rates, and then HP filter the series. The employment share by private enterprises is from Song, Storesletten, and Zilibotti (2011). The relative size of fixed assets of heavy and light industry is from Chang, Chen, Waggoner, and Zha (2015). The heavy industry sector includes real estate, leasing and commercial service; electricity, heating and water production and supply; coking, coal gas and petroleum processing; wholesale, retail, accommodation and catering; banking and insurance; chemical; mining; transportation, information transmission and computer services and software. The light industry sector includes food, beverage and tobacco; other manufacturing; metal product; machinery equipment; construction material and nonmetallic mineral product; textile, garment and leather; construction; other services; and farming, forestry, animal husbandry and fishery (Table 11 of Chang, et al. 2015).

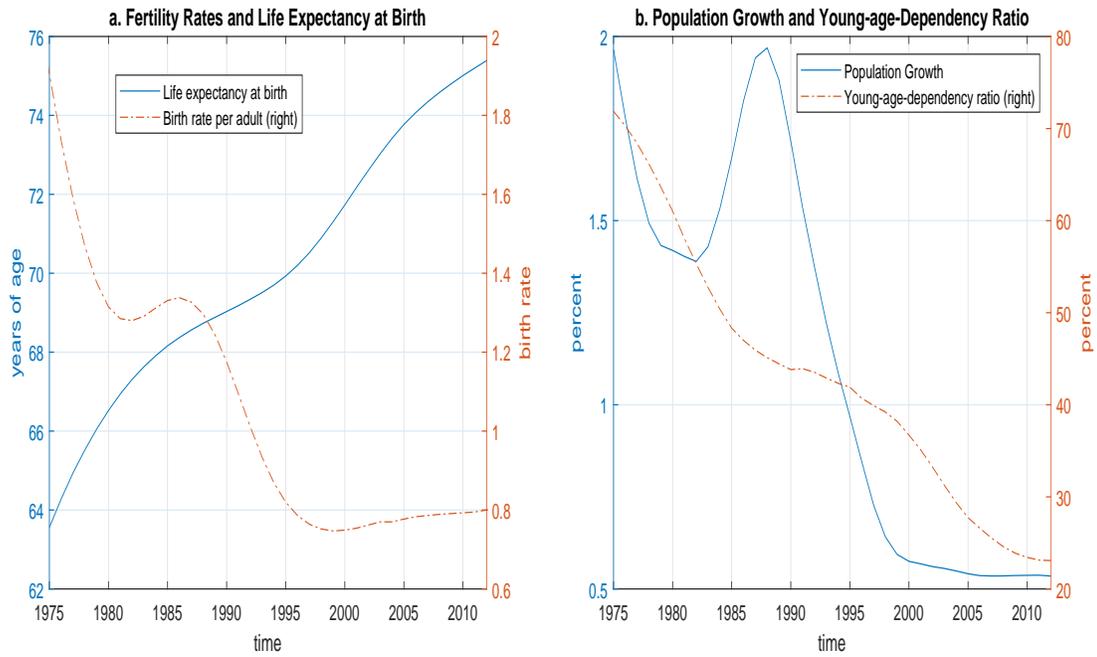


Figure 2: **The Aging Chinese Demographics** This figure describes the life expectancy and the fertility rate per adult (panel a); and population growth rate and young-age-dependency ratio (panel b). The young-age-dependency ratio is defined as the ratio of population aged 15 and below to the population between age 15 and 65. Data source: World Bank.

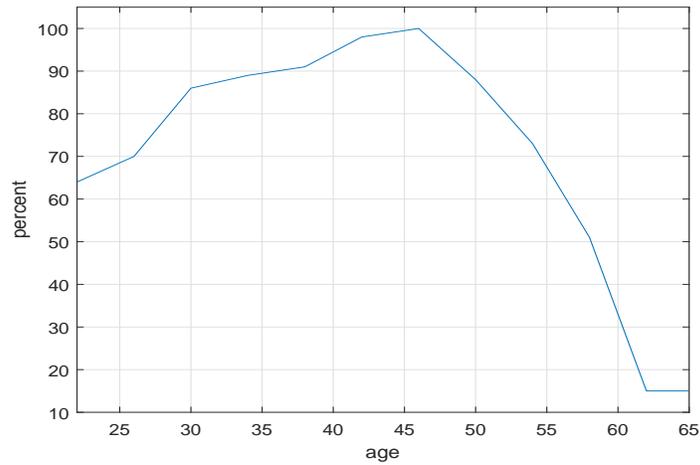


Figure 3: **Age-Income Profiles** This figure depicts the labor efficiency units by age for the Chinese economy. Data source: Urban Household Survey, 1992. Wages include wages plus self-business incomes.

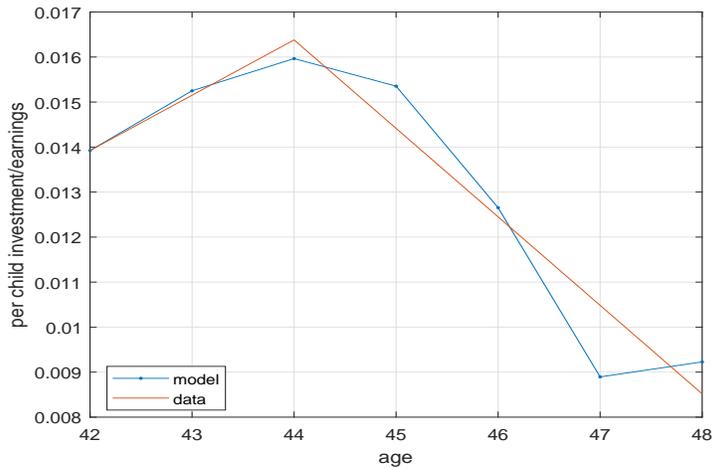


Figure 4: **Optional Education Expenditure Profiles** This figure depicts optional education expense per child as a fraction of parent earnings. The data come from Figure 3 in Choukhmane, et al. (2017) (the green area that corresponds to discretionary education expenditure. To arrive at the total expense of child education, we need to add an additional 8 percent of household earnings. See the main text of the paper.)

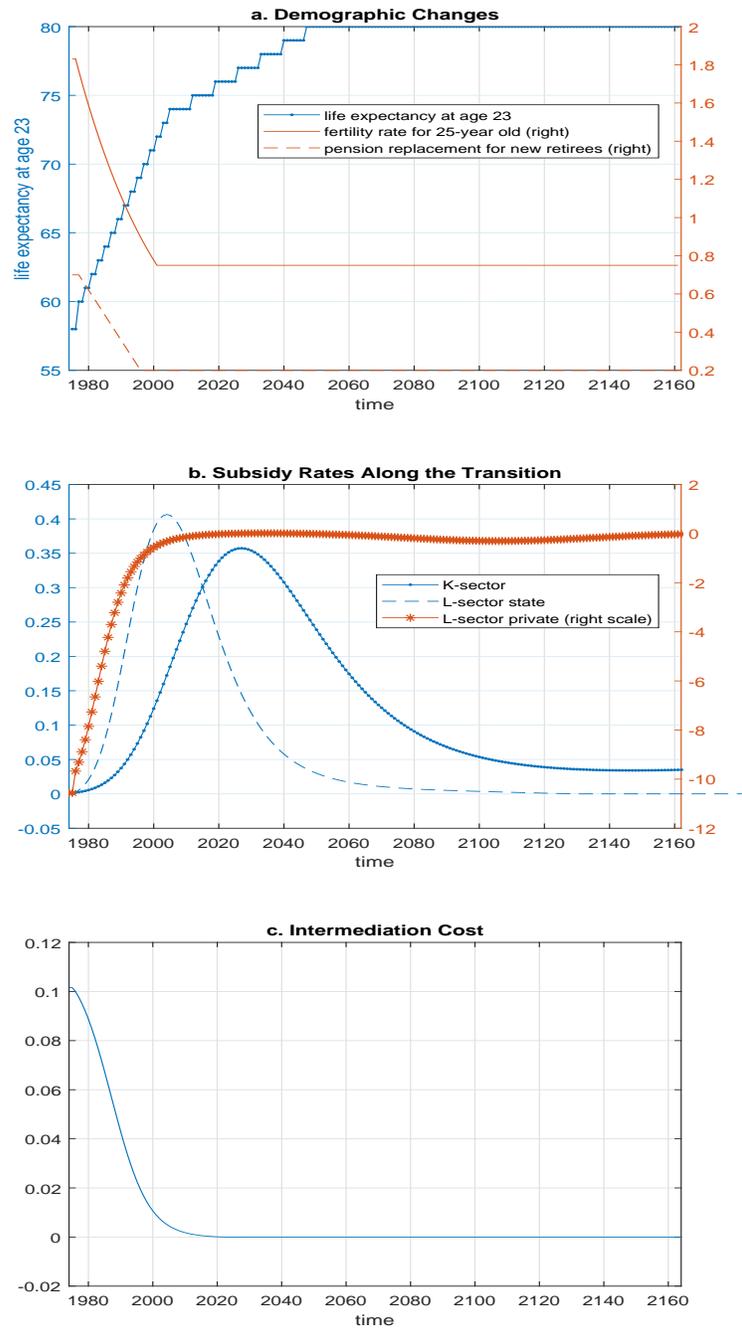


Figure 5: **Exogenous Processes Along the Transition** Panel a depicts exogenous demographic changes along the transition path. For life expectancy, the x-axis indicates birth cohort. Panel b depicts exogenous government interest subsidy changes along the transition path. Panel c describes the intermediation cost.

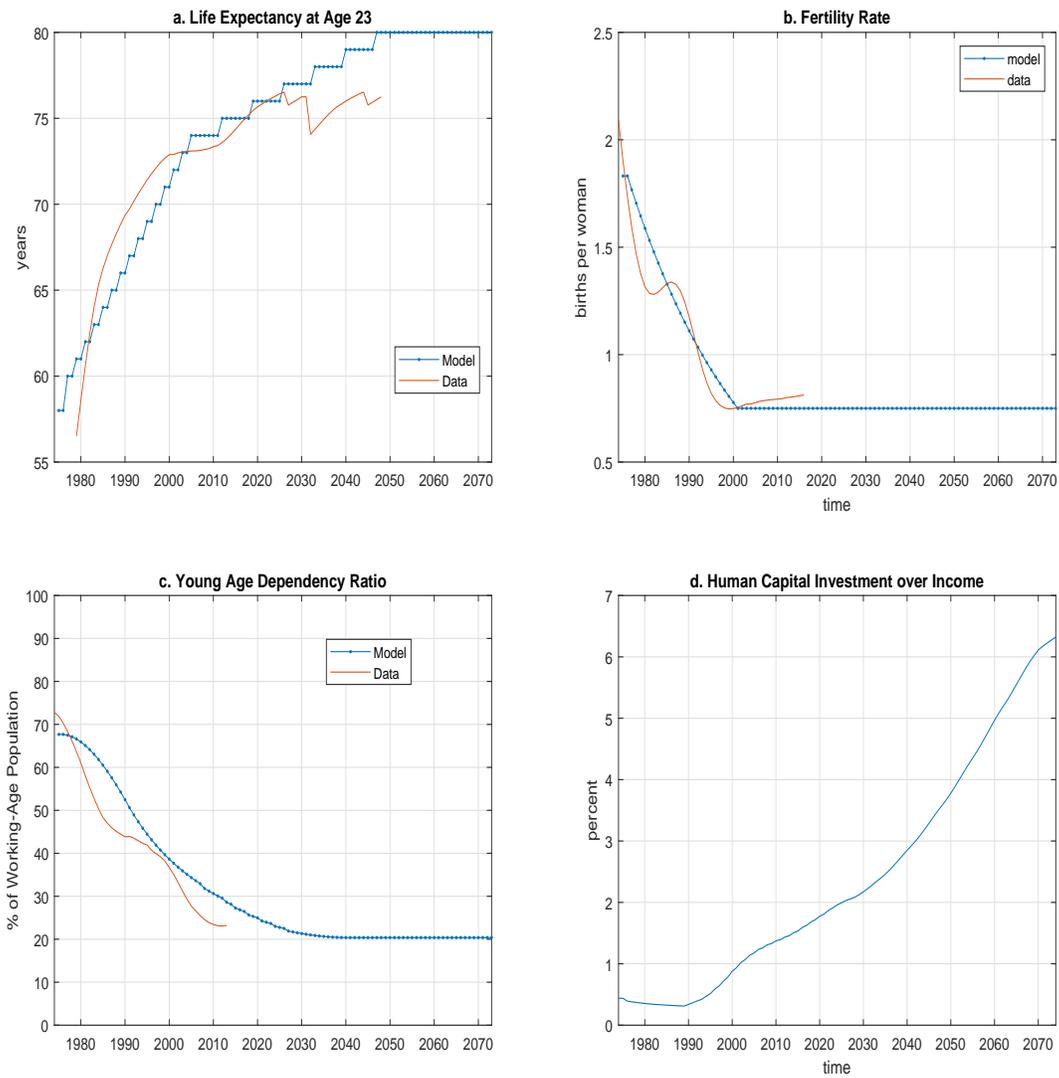


Figure 6: **Household Dynamics Along the Transition: Data versus Model**  
 Fertility rate is defined as the average number of births per adult. Life expectancy after 2012 is a projection by the World Bank. The life expectancy plotted here is the life expectancy for those at age 23, which is different from the life expectancy at birth plotted in Figure 2 panel a. The young dependency ratio is defined as those under age 15 to those between the ages 15 and 65. Data source: World Bank, Penn World Table.

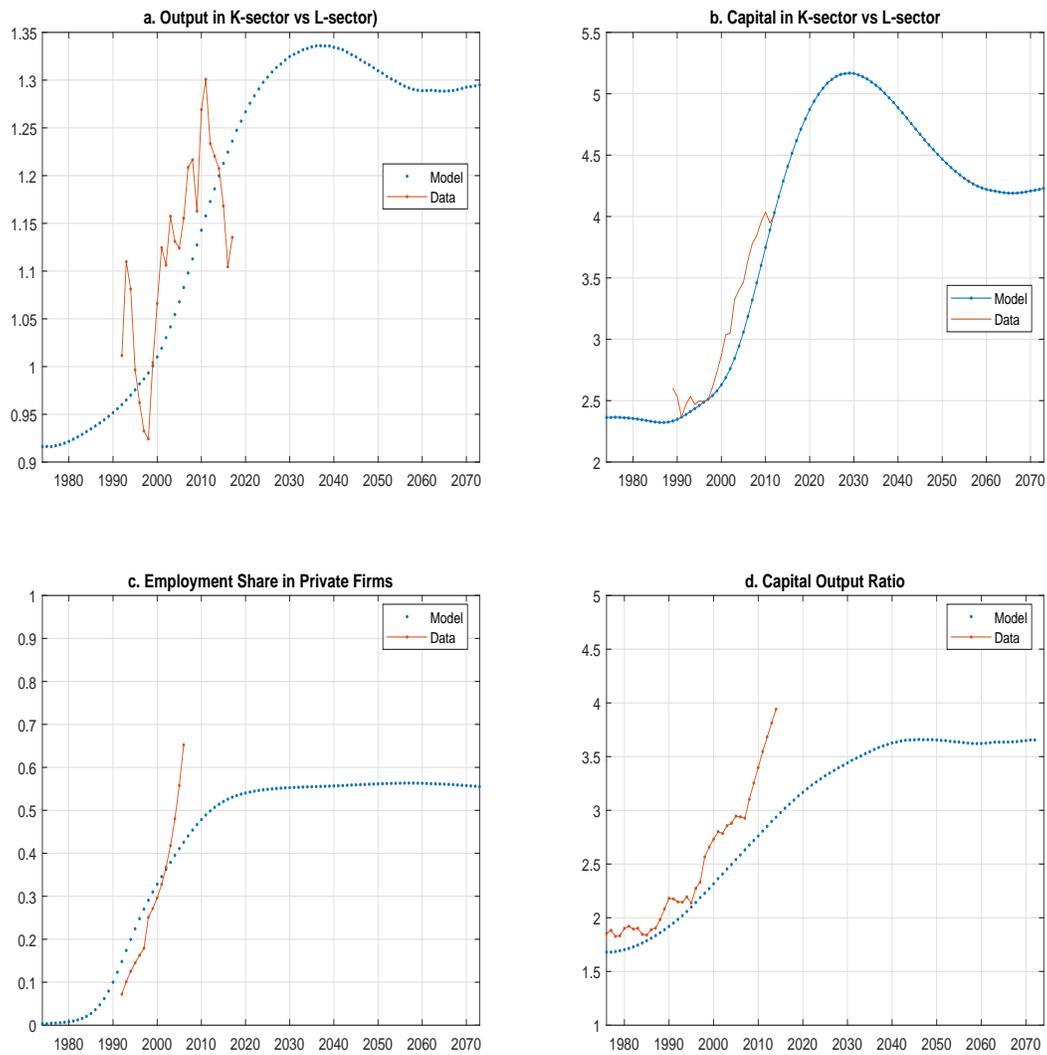


Figure 7: **Firm Dynamics Along the Transition: Data versus Model** Data source: Panels a and b: Chang et al. (2015); panel c: Song et al. (2011); panel d: World Bank, Penn World Table.

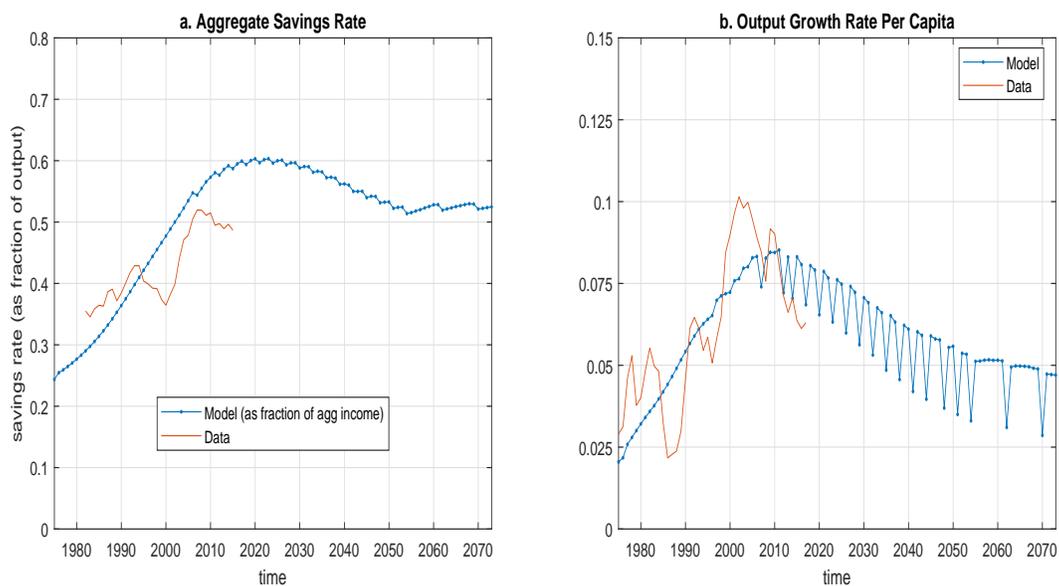


Figure 8: **Savings Rate and Per Capita Output Growth: Model versus Data**  
 Aggregate savings include household and corporate savings but exclude government savings. The data are provided by Chang et al. (2015). To arrive at the per capita output growth, we first divide output-side real GDP at chained PPPs (2011 US\$) by total population, take the growth rates, and then HP filter the series.

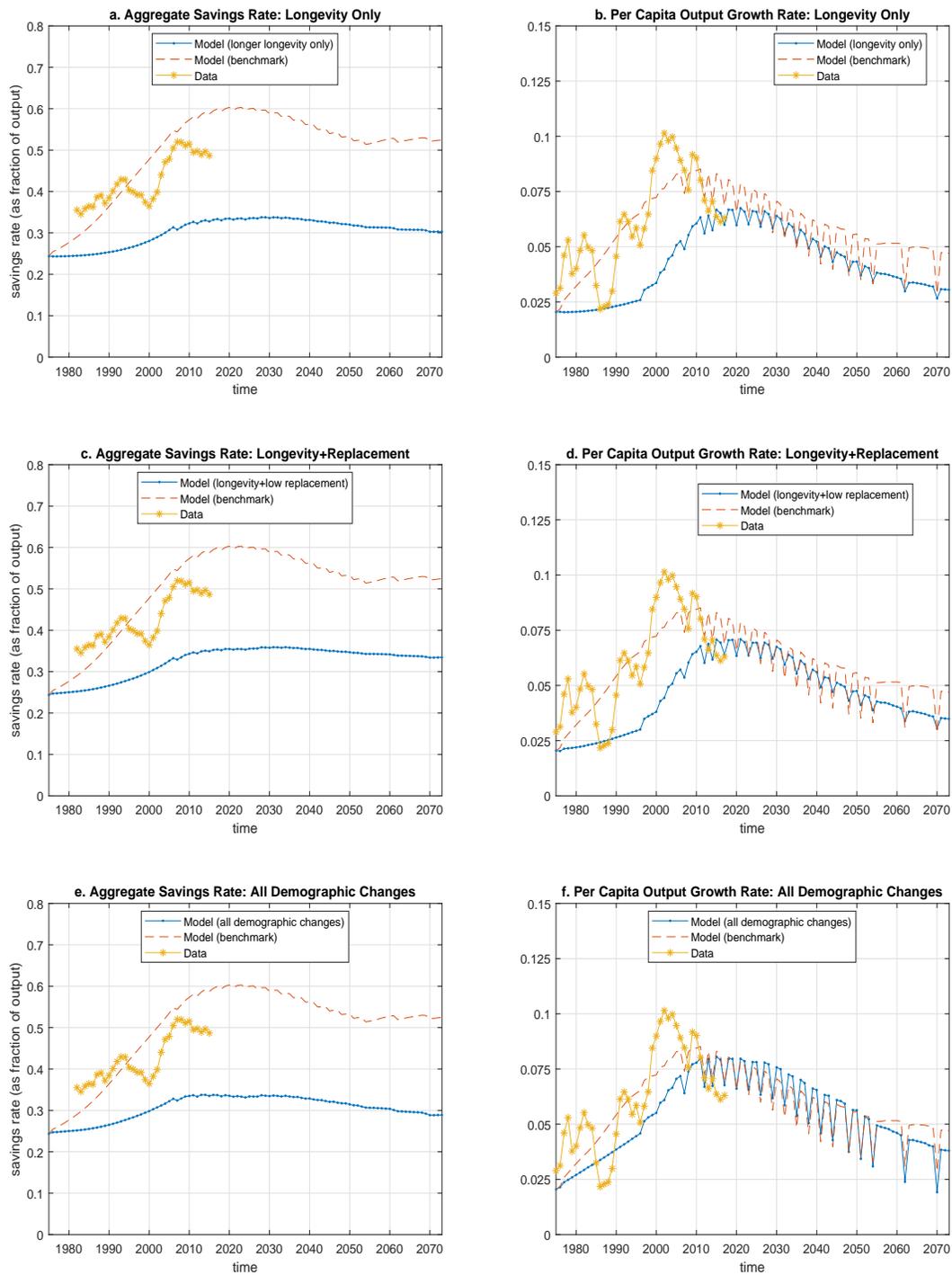


Figure 9: The Role of Demographic Changes in the Time Path of Savings Rate and Per Capita Output Growth Data source: Chang et al. (2015) and World Bank.

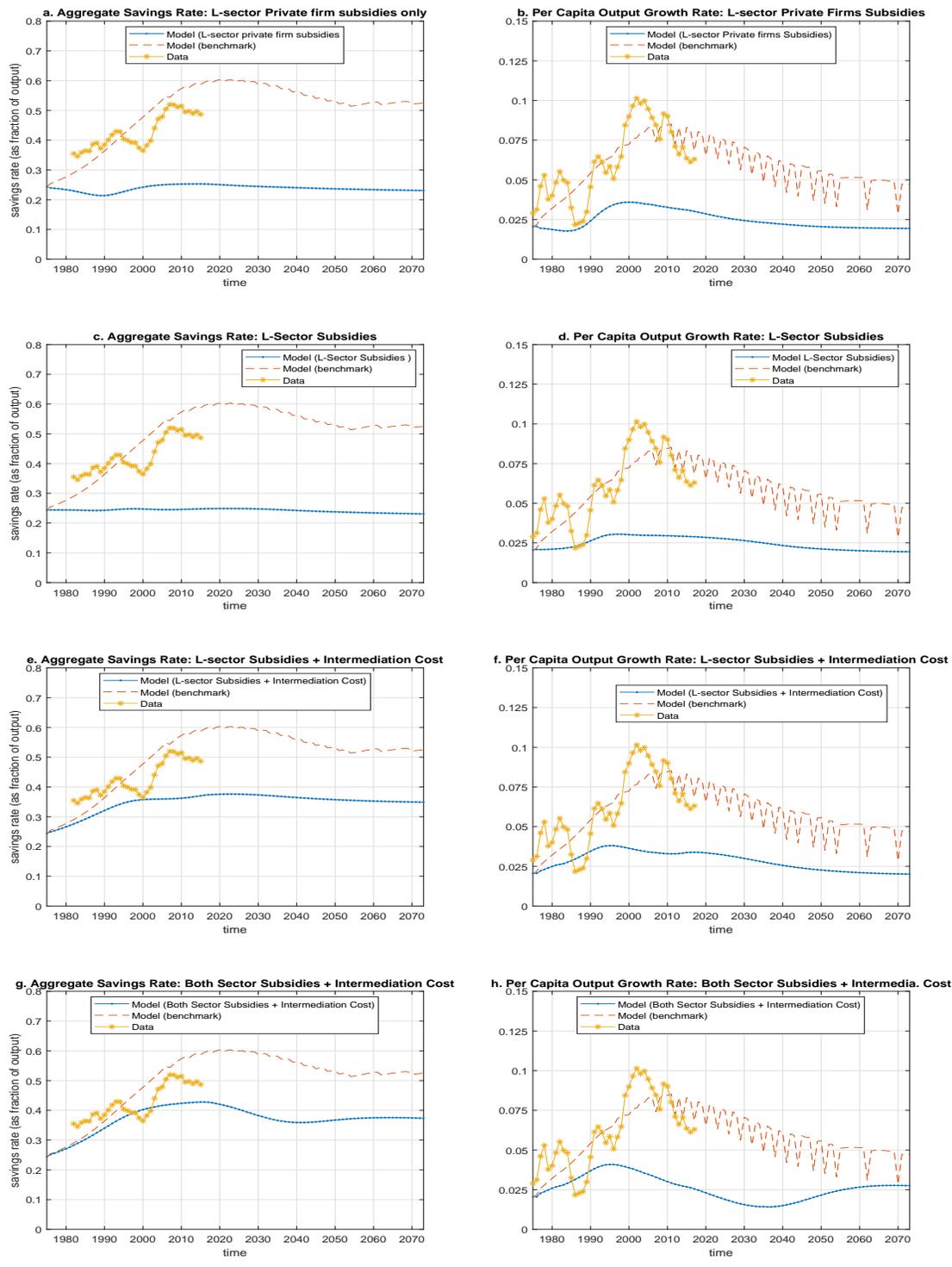
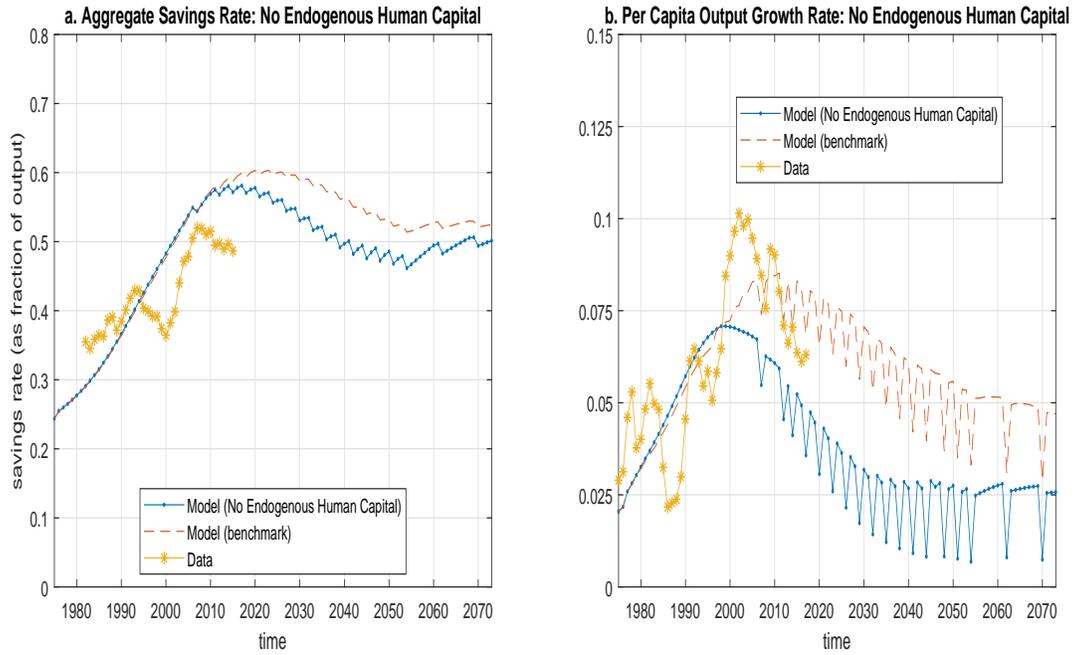


Figure 10: The Role of Industrial Policies in the Time Path of Savings Rate and Per Capita Output Growth Data Source: Chang et al. (2015) and World Bank.



**Figure 11: Savings Rate and Per Capita Output Growth: No Endogenous Human Capital Investment** In this experiment, we set the human capital investment exogenously so that relative to income it remains at the same level as in 1980. Data source: Chang et al. (2015) and World Bank.

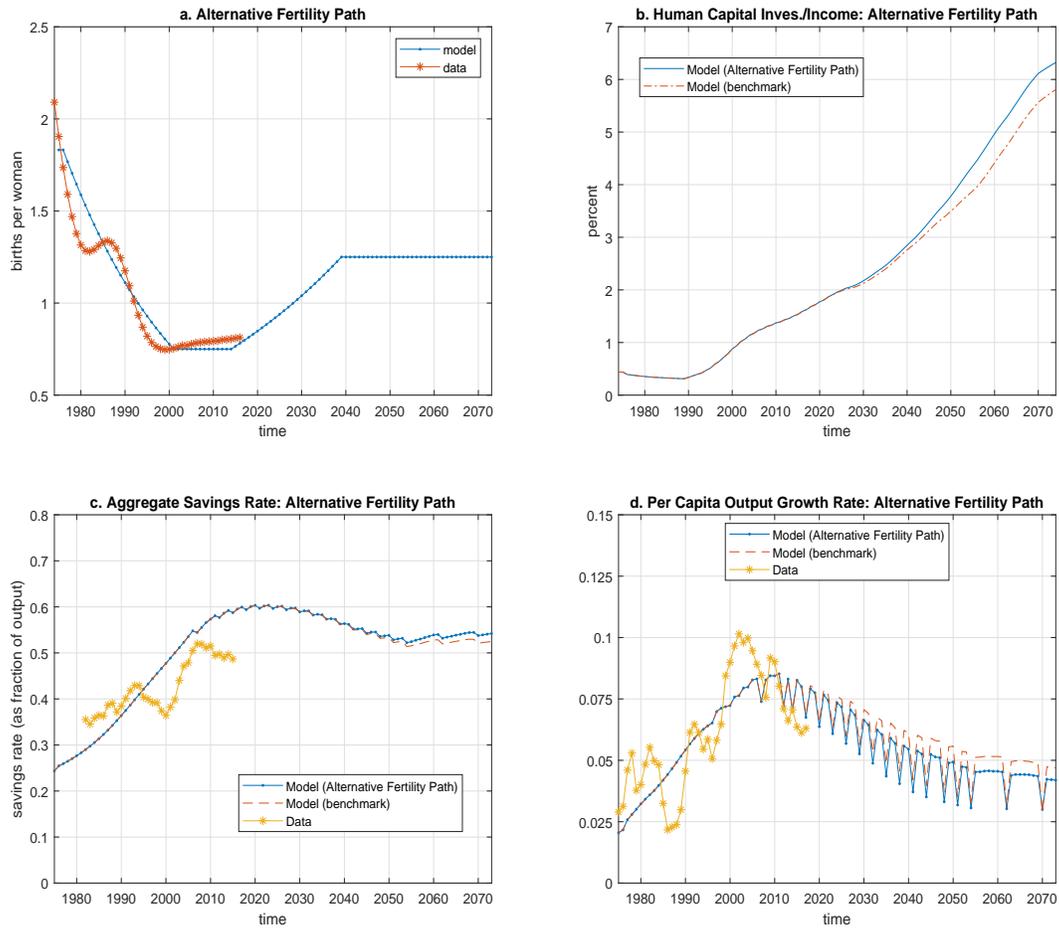


Figure 12: **Human Capital Investment, Savings Rate and Per Capita Output Growth: Alternative Fertility Path** The alternative fertility path captures the abolition of the one-child policy in 2015. Data source: Chang et al. (2015) and World Bank.

Table 1: Household Decisions

Age	$[j_1, j_f + 6]$	$[j_f + 7, j_f + 15]$	$[j_f + 16, j_f + 22]$	$[j_f + 23, j_r]$	$[j_r + 1, J_B]$
Consumption	yes	yes	yes	yes	yes
Savings	yes	yes	yes	yes	yes
Children's human capital investment	no	mandatory	optional	no	no
Make transfer			if $j_r - j_f \leq j \leq J_B - j_f$		
Receive transfer	no	no	no	no	yes
Receive pension	no	no	no	no	yes

Note. This table describes decisions that a household makes at different ages. The symbol  $j_1$  is the age at which the household enters the economy;  $j_f$  is the fertility age;  $j_r$  is the age at which they receive transfer from their children, which is also the retirement age; and  $J_B$  is the terminal age when the household exits the economy. Mandatory education is for children between the age 7 and 15. High school and college education between age 16 and 22 is optional.

Table 2: Calibration of the Initial Steady State

Parameter	Description	Value	Target (data source)
<i>Household: demographics</i>			
$\{j_1, J_B\}$	{Initial age, life expectancy}	{23, 57}	World Bank
$\{j_f, j_r\}$	{Fertility, retirement age}	{25, 55}	
$n$	Fertility rate per adult in mid-1970s	1.8315	World Bank
$g_t$	Population growth rate	0.0245	World Bank
<i>Household: preferences</i>			
$\beta$	Discount rate	1.0399	Capital-output ratio
$\sigma$	Relative risk aversion	1.5	Macro literature
<i>Household: others</i>			
$\{e_j\}_{j=j_1}^{j_r-1}$	Labor income by age	See Figure 3	Urban Household Survey
$\varsigma_B$	Pension replacement rate	0.700	See the text
$\{\Phi_1, \Phi_2\}$	Children living, required educ. exp.	{0.080, 0.060}	CHIP
$\{\mu_0, \mu_1\}$	Transfer to parents	{0.1512, 0.6500}	Choukhmane et al. (2017)
$\{\eta_j\}_{j=16}^{22}$	Human capital invest. efficiency	{4.81, 4.04, 3.06, 2.04, 1.17, 0.63, 0.62}	Choukhmane, et al. (2017)
$\kappa$	Weight on human capital invest.	0.12	Education exp. in 2002 (CHIP)
$r_d$	Deposit rate	0.054	IMF
<i>Firms</i>			
$g_y$	Per capita GDP growth rate	1.020	World Bank (Song, et al. 2011)
$\alpha_k$	Capital income share in k-sector	0.6312	Data, Chang, et al. (2015)
$\gamma_l$	Labor income share in l-sector	0.6839	Data, Chang, et al. (2015)
$\alpha_l$	Capital income share in l-sector	0.2459	Data, Chang, et al. (2015)
$\varphi$	Share of k-sector in final good prod.	0.85	Chang, et al. (2015)
$\gamma$	Elasticity of subst. bt. k- and l-goods	2	Chang, et al. (2015)
$\delta$	Capital depre. rate in k- and l-sectors	0.10	Standard
$A_k$	Labor augmented-TFP in k-sector	0.1884	$K_k/K_l = 2.5$ (Chang, et al. 2015)
$[A_{l,s}, A_{l,p}]$	Labor augmented-TFP in l-sector	[0.4065, 1.2875]	$TFP_{p,l} = 2.2TFP_{s,l}$
$\{f_{l,s}, f_{l,p}, \xi\}$	Fixed cost parameters	{0.0501, 0.2704, 0.786}	residual, see note below
$r_k - r_d$	Intermediation cost	0.1016	Net rate of return to capital Bai, et al. (2006)
<i>Government</i>			
$\{S_k, S_{l,s}, S_{l,p}\}$	Interest subsidy	{0,0, -10.5629}	$\frac{K_{s,l}/Y_{s,l}}{K_{p,l}/L_{p,l}} = 2.65$ (Song, et al. 2011)
$\{\tau_{ss}, \tau\}$	Tax rate (%)	{-0.0011, 3.3}	

Note. This initial steady state is calibrated to match the Chinese economy in the mid-1970s. Life expectancy  $J_B$  corresponds to the life expectancy of those at age 23, which is lower than the life expectancy of those born in that year. The model results are not sensitive to the choice of the parameter  $\xi$ , which is set at a low value so that the model has the property that the sector with more subsidies is larger.

Table 3: Steady State Properties

Moments	Initial SS	Data	Final SS
Capital output ratio	1.680	1.67 (1975 number) (Penn World Table)	4.298
Return to capital	0.156	[0.12, 0.22] (1975-1981) (Bai et al. 2006)	0.008
Aggregate savings to output	0.244	0.35 (1982 number) (World Bank)	0.465
Young-age-dependency ratio (under 15/15-65)	0.677	0.700 (1975 number) (World Bank)	0.398
Human capital invest./Income (%)	0.439		6.303
Capital/Labor supply	3.152		23.399
Interest rate (%)	5.400	5.000 (IMF)	1.600
Wage	1		2.750
Labor income tax (%)	-0.107		0
Social security tax rate (%)	3.298		13.419

Note. At the final steady state, we remove all the credit subsidies and reduce the pension replacement to 20 percent. Households now live until age 80 with certainty, the fertility rate per adult at age 25 is reduced to 0.75.