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Michael Dotsey, Wenli Li and Fang Yang

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Michael Dotsey†, Wenli Li‡ and Fang Yang§

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Abstract

We build a unified framework to quantitatively examine the demographic transition and industrial policies in contributing to China's economic growth between 1976 and 2015. We find that the demographic transition and industrial policy changes by themselves account for a large fraction of the rise in household and corporate savings relative to total output and the rise in the country's per capita output growth. Importantly, their interactions also lead to a sizable fraction of the increases in savings since the late 1980s and reduce growth after 2010. A novel and important factor that drives these dynamics is endogenous human capital accumulation, which depresses household savings between 1985 and 2010 but leads to substantial gains in per capita output growth after 2005.

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

JEL Classification: E21; J11; J13; L52

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†Michael Dotsey, Research Department, Federal Reserve Bank of Philadelphia, michael.dotsey@phil.frb.org.

‡Wenli Li, Research Department, Federal Reserve Bank of Philadelphia, wenli.li@phil.frb.org.

§Fang Yang, Research Department, Federal Reserve Bank of Dallas, fang.yang@dal.frb.org.

1 Introduction

In this paper, we build a framework that encompasses structural changes in both demographics and industrial policies to study the evolution of the Chinese economy between 1976 and 2015. The reason for undertaking such an exercise is two fold. First, the demographic changes, due in part to the implementation of the one-child policy and the increased life expectancy, and the industrial policies including privatization and preferential credit policies represent some of the most dramatic changes in the Chinese society over the last several decades. Second, there are strong reasons to believe that there exist important interactions between these two sets of changes. For example, a direct implication of household aging is increased savings. Limited resources, however, force households to trade off between savings in financial assets and investing in their children's human capital, and therefore affect the quantity of capital and labor supplied to firms. Preferential credit policies, on the other hand, affect returns to physical capital directly and wages indirectly, and hence household savings, investment, and consumption decisions. Understanding the Chinese growth experience, therefore, requires a model of households and firms that accounts for these complex interactions. To the best of our knowledge, our paper is the first to present such a unified framework.

To be more specific, the model we develop is depicted by an overlapping-generations model where parents and children are connected by inter-vivos transfer. While parents make human capital investment decisions for their school age children, grown children make transfer payments to their elderly parents. On the firm side, there exist two intermediate goods sectors, one final goods sector, and one education sector. Following Chang, Chen, Waggoner, and Zha (2015), we let the two intermediate goods sectors differ in capital and labor intensity and in their cost of capital due to government credit policies. The labor-intensive sector allows for two types of firms, state-owned firms and private firms, as in Song, Storesletten, and Zilibotti (2011). In addition to differences in their productivity, the state firms and the private firms also differ in that the private firms face a borrowing constraint tied to their internal capital. The government finances pensions through a payroll tax and finances credit market subsidies to firms through an income tax. Finally, we capture the financial market friction using intermediation costs.

We demonstrate that there exist important interactions between households and firms in response to these structural changes. Changes on the household side: the lower fertility rate, the lengthened life expectancy, and the reduction in pensions, lead households to save more. The same demographic changes also encourage households to invest more in their children's human capital as transfer payments from children serve as an annuity in parents' old age. The resulting higher human capital leads to a more productive labor force and hence an increase in the effective labor supply. Both higher savings and increased labor quality lead to higher output growth, while the reduced quantity of labor restricts growth. On the contrary, delaying the retirement age reduces saving, increases labor, and discourages households from investing in their children's human capital.

On the firm side, we incorporate the emergence of private firms, improved technology, reduction in financial intermediation cost, and government preferential credit policy to heavy industries. The growth of private firms in the labor-intensive sector raises wages, which encourages human capital investment, and encourages savings by private firms. Subsidies to the capital-intensive sector, by contrast, increase capital demand and help raise the deposit rate received by households, thus encouraging household savings but discouraging human capital investment. Credit policies also lead to capital allocation between heavy industries and light industries and, therefore, affect output growth.

Of particular importance is the increase in workers' human capital in response to the reduced fertility rate and increased life expectancy. Parents trade off the quantity of children with the quality of children to help maintain the transfer payments from the children during their old age. The increased human capital investment reduces household savings in the short run. In the medium to long run, output growth benefits significantly from the more productive labor force. Household savings also recover.

Using the calibrated model, we show quantitatively that,

- Changes in demographic factors and industrial policies can explain the rise of over 30 percentage points in total savings relative to output and the rise of over 5 percentage points in the growth of output per capita. The model, however, overpredicts household savings and underpredicts corporate savings.

- Changes in firm structure and industrial policies raise household savings as well as corporate savings by nearly 10 percentage points and over 12 percentage points, respectively, between 1976 and 2015. Thus, the national saving rate goes up by about 22 percentage points. These changes also raise per capita output growth by 1.3 percentage points between the two years.

- Demographic changes push up household savings by close to 9 percentage points between 1976 and 2015, and the effect on per capita output growth is a large 4 percentage points.

- The interactions between the firm side changes and the household side changes increase the total saving rate by about 2.5 percentage points and reduce the per capita output growth by close to one percentage point between 1976 and 2015.

- Finally, endogenous investment in human capital as opposed to a fixed proportional investment relative to income as in the initial balanced growth path reduces household savings by about 2 percentage points before 2010, but raises per capita output growth by two percentage points in 2015.

The rest of the paper is organized as follows. Section 2 presents the motivation and background of the paper. Section 3 discusses the related literature. Section 4 describes the model. Section 5 calibrates the model and presents the transition path between the two balanced growth paths. Section 6 investigates the role of endogenous human capital accumulation. Section 7 conducts various counter-factual experiments. Section 8 concludes.

2 Motivation and Background

In this section, we draw on the existing literature and numerous data sources to document changes in the Chinese economy since the end of Cultural Revolution in 1976. We first illustrate the rapid growth of the Chinese economy, and then describe the aging of the Chinese population and the contributing factors behind this phenomenon. Lastly, we provide evidence on the evolution of industrial policies and credit market frictions and their consequences.

2.1 The Rapid Growth of the Chinese Economy

The Chinese economy has been growing rapidly over the last few decades (Figure 1). Between 1976 and 1980, per capita GDP growth was under 5 percent. After a brief retreat in the mid-1980s, it jumped up to nearly 10 percent in the early 2000s, and hovered at around 7-8 percent afterwards. The growth is even more astounding in relative terms. For example, per capita GDP in China was about 5 percent of that of the U.S. before 1980. By 2012, the ratio had shot up to over 20 percent.

2.2 The Aging Population

The aging Chinese population is best depicted by the declining young-age dependency ratio, the ratio of people under the age of 15 to people between the ages of 15 and 64, and the declining trend in the population growth rate. According to Figure 2a, the young-age dependency ratio was close to 80 percent in 1976 but declined to 35 percent by 2012. The population growth rate began to decline in 1976 and reached a trough of 1.4 percent in the mid 1980s. Though the growth rate recovered to its 1976 level in 1987, it began another long decline after that. In 2010, the growth rate was only a tad above 0.5 percent.

There are two underlying causes behind the aging demographics, the reduced fertility rate and increased life expectancy (Figure 2b). According to the World Bank data, the birth rate fell gradually from 1.8 children per adult in 1976 to 0.75 in 2000 and 0.8 in 2015. The Chinese government started promoting family planning in 1971 as an effort to curb population growth. The tactics included initiatives that encouraged postponing marriage until a later age, lengthening birth spacing between children, and reducing the number of children. In the late 1970s, the government adopted a stricter approach and began imposing a limit on the number of children per couple: a two-child limit was implemented nationwide in 1978 followed by the one-child policy announced in 1979.[1] In 2015, the government abolished the one-child policy amid concerns over an aging population.

Between 1976 and 2015, Chinese life expectancy improved greatly, from a low of 57 years of age for a person at age 23 in 1979 to a high of 74 for the cohort at age 23 in 2015. For the life expectancy series, the year on the x-axis indicates cohort year, i.e., the year when the household turns 23.[2]

[1] The one-child policy was enforced at the provincial level but some provinces had more relaxed restrictions. There were also exceptions to the policy. For instance, families whose first child was 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.

[2] To arrive at the life expectancy at 23, 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. 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 $2*x+9*(1-x)*y+(1-x)*(1-y)*z=1$.

2.3 Industrial Policies and Credit Market Frictions

The Chinese economy experienced several major economic reforms since the late 1970s. The period between the late 1970s and the late 1990s is marked by the continued reallocation of labor from agriculture to nonagriculture sectors. Additionally, the Chinese government actively encouraged entrepreneurship across the country, by introducing the first patent law, allowing state-owned enterprises (SOEs) to go bankrupt, and creating a more investor-friendly environment for private entrepreneurs. As a result, entrepreneurship went from nearly nonexistent to almost 15 percent of the population between 1980 and 2015.[3]

In the late 1990s, the government started to implement credit policies that encouraged banks to favor state-owned enterprises, especially those in heavy industries. For example, Brandt and Zhu (2010) document that in 2007 more than half of all new capital formation went to the state sector. Bai, Lu, and Tian (2018) find that between 1997 and 2008 state-owned firms have higher leverage and pay much lower interest rates than non state-owned firms. Cong, Gao, Ponticelli, and Yang (2019) show that for manufacturing firms the stimulus-driven credit expansion disproportionately favored state-owned firms and firms with a lower average product of capital, reversing the process of capital reallocation towards private firms that characterized China's high growth before 2008. Chen, Gao, Higgins, Waggoner, and Zha (2019) also find that bank credit in the 2000s, especially between 2009Q1 and 2010Q4, was disproportionally allocated to finance investment in real estate and other heavy industries that were populated with state-owned firms.[4]

Besides these credit policies, during the last three decades the Chinese government has made considerable effort to improve the financial system. For example, the government deregulated the lending rate allowing for more competition and more flexibility in the pricing of loans. The increase in competition can be seen in the loan share of the four major state-owned banks, which fell from 61 percent in 1999 to 53 percent in 2004, and by the growing equity market (Podpiera 2006). There is some evidence, documented in the papers that we cited above, that some of these subsidies may have peaked as the economy recovered from the global financial crisis, but it is far from clear when these differential policies will be completely eliminated.

[3]Chinese Statistical Yearbook of various years.

[4]Chang, Chen, Waggoner, and Zha (2015) find that the share of SOEs in capital-intensive industries has increased steadily since the late 1990s.

3 Related Literature

As mentioned in the introduction, the contribution of our paper lies not just in accounting for the growth dynamics of per capita output and the household and corporate saving rates over the last three decades, but also demonstrating that there exist important interactions between the demographic transition and government industrial policies. As such, 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 et al. 2008, Hsieh and Klenow 2009, Song et al. 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 et al. 2015). This literature has mostly been a growth accounting exercise with little modeling of the household side. Relative to this literature, our paper intends to capture the resource allocation/misallocation in a model that explicitly considers the role of household saving and human capital investment on economic growth.[5]

The second strand of literature focuses on the high saving rate China has experienced during this period, in particular high household savings. This strand of literature has attributed the high saving 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 and thus allows us to decompose the impact of various sources. More importantly, our paper also makes an attempt to account for corporate savings in addition to household savings.

[5]To simplify our analysis, we classify agriculture as part of the light industry as in Chang et al. (2015).

The third literature examines China's current account and implications of capital control policies. This literature includes Song et al. (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 including 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 with these papers, our paper incorporates the recent government credit policy that favors heavy industry as documented in Chang et al. (2015). The modeling of 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 households and firms.

It is important to point out that our analysis is conducted in a general equilibrium framework with a balanced current account, i.e., we implement strict capital controls. We believe it is important to model the real interest rate in China as endogenous as during the period of our study, with the exception of the Great Recession when the Chinese government issued a rescue package worth over 4 trillion RMB, the current account balance as a share of total GDP remained under 4 percent and Chinese financial markets were not fully integrated into world financial markets. Importantly, the household saving rate and the investment rate have generally tracked each other and are on the order of 40-50 percent of GDP.

4 The Model

We consider an overlapping-generation model where parents and children are connected through inter-vivos transfers. Production takes place in industries that differ in important aspects including capital intensity, productivity, and financial constraints. The government pays for their subsidies to firms and the pay-as-you-go social security system through taxation.

4.1 Firms

The economy consists of four sectors: two intermediate goods sectors, one final goods sector, and one education sector. The two intermediate goods sectors differ in their productivity, capital intensity, and ownership structure. 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. While the capital-intensive industry consists entirely of state-owned firms, the labor-intensive industry contains potentially both state-owned and private firms. This modeling choice, thus, combines the two approaches adopted in the literature on the Chinese economy as represented by Song et al. (2011), Chang et al. (2015), and researchers cited in their papers. It also captures important features of the Chinese economy: that the privately owned enterprises have been concentrated mostly in the labor-intensive sector, including agriculture, and the capital-intensive sector is dominated by state-owned enterprises that enjoy subsidies from the government.

4.1.1 The Final Goods Sector

We denote final goods at time t by Y_t, which is a CES aggregate of the two intermediate goods:

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

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

$$\frac{Y_{k,t}}{Y_{l,t}} = (\frac{\varphi P_{l,t}}{P_{k,t}})^{\gamma}. \tag{2}$$

The zero-profit condition for the final good further implies

$$[\varphi^{\gamma} P_{k,t}^{1-\gamma} + P_{l,t}^{1-\gamma}]^{\frac{1}{1-\gamma}} = 1. \tag{3}$$

4.1.2 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-owned enterprises. The production function takes the following Cobb-Douglas form:

$$Y_{k,t} = K_{k,t}^{\alpha_k}(A_{k,t}L_{k,t})^{1-\alpha_k}, \tag{4}$$

where $K_{k,t}$ and $L_{k,t}$ represent capital rented from the financial intermediary and efficient labor inputs, respectively, and $A_{k,t}$ denotes labor augmenting technology. The parameter α_k represents the capital income share in the production of the intermediate goods. The firms in this sector solve the following problem,

$$max_{K_{k,t},L_{k,t}}\{P_{k,t}K_{k,t}^{\alpha_k}(A_{k,t}L_{k,t})^{1-\alpha_k} - (r_{k,t}+\delta)K_{k,t} - w_tL_{k,t}\}, \tag{5}$$

where $r_{k,t}$ denotes the net interest rate that is specific to the capital-intensive sector; δ represents the capital depreciation rate, and w_t is the wage rate per effective unit of labor that is common to all sectors. Profit maximization generates the following two first-order conditions,

$$r_{k,t} + \delta = \alpha_k P_{k,t} A_{k,t}^{1-\alpha_k} K_{k,t}^{\alpha_k-1} L_{k,t}^{1-\alpha_k}, \tag{6}$$

$$w_t = (1-\alpha_k) P_{k,t} A_{k,t}^{1-\alpha_k} K_{k,t}^{\alpha_k} L_{k,t}^{-\alpha_k}. \tag{7}$$

4.1.3 The Labor-Intensive Intermediate Goods Sector

We assume that the labor-intensive sector potentially consists of state-owned and privately owned enterprises. Compared with private firms, state-owned firms have better access to borrowing because of their close connection with state-owned banks. Thus, the key differences between the two types of firms are their labor productivity and access to capital. Particularly, we assume that private enterprises have higher labor productivity but are subject to borrowing constraints. Finally, we assume that goods produced by these two types of firms are perfect substitutes.

Let $K_{l,i,t}$ and $L_{l,i,t}$ $(i = s, p)$ denote the capital input and labor input, respectively, used by type i firms at time t in the labor-intensive sector. Let $K_{l,t}$ and $L_{l,t}$ denote total capital and labor inputs in the labor-intensive sector at time t. We then have $K_{l,t} = K_{l,s,t} + K_{l,p,t}$ and $L_{l,t} = L_{l,s,t} + L_{l,p,t}$. The production function of the state-owned firms in the labor-intensive sector at time t is as follows,

$$Y_{l,s,t} = (K_{l,s,t})^{\alpha_l}(A_{l,s,t}L_{l,s,t})^{1-\alpha_l}. \tag{8}$$

The parameter α_l indicates the capital income share, $1-\alpha_l$ indicates the labor income share, and $A_{l,s,t}$ indicates labor augmenting technology for the state-owned firms.

The private enterprises are owned and operated by entrepreneurs. We use small letters to denote the production function each entrepreneur operates as follows,

$$y_{l,p,t} = (k_{l,p,t})^{\alpha_l}(A_{l,p,t}l_{l,p,t})^{1-\alpha_l}, \tag{9}$$

where $A_{l,p,t}$ denotes labor augmenting technology which we assume to be the same among all private enterprises. The total output $Y_{l,p,t}$, capital $K_{l,p,t}$, and labor $Y_{l,p,t}$ for private firms are aggregates over all entrepreneurs. Let $Y_{l,t}$ denote the aggregate intermediate goods produced by this sector and we define

$$Y_{l,t} = Y_{l,s,t} + Y_{l,p,t}. \tag{10}$$

Problems of State-owned Enterprises We can now write the state-owned firm's problem as follows

$$max_{\{K_{l,s,t},L_{l,s,t}\}}\{P_{l,t}(K_{l,s,t})^{\alpha_l}(A_{l,s,t}L_{l,s,t})^{1-\alpha_l} - (r_{l,t}+\delta)K_{l,s,t} - w_tL_{l,s,t}\}, \tag{11}$$

where $r_{l,t}$ denotes the net interest rate faced by firms in the light-industry sector. The first-order conditions from the profit-maximization problem are,

$$r_{l,t} + \delta = \alpha_l P_{l,t}(A_{l,s,t})^{1-\alpha_l}(K_{l,s,t})^{\alpha_l-1}(L_{l,s,t})^{1-\alpha_l}, \tag{12}$$
$$w_t = (1-\alpha_l)P_{l,t}(A_{l,s,t})^{1-\alpha_l}(K_{l,s,t})^{\alpha_l}(L_{l,s,t})^{-\alpha_l}. \tag{13}$$

These two first-order conditions lead to

$$w_t = (1-\alpha_l)(P_{l,t})^{\frac{1}{1-\alpha_l}}A_{l,s,t}(\frac{\alpha_l}{r_{l,t}+\delta})^{\frac{\alpha_l}{1-\alpha_l}}. \tag{14}$$

Problems of Private Enterprises Our modeling of privately owned labor-intensive enterprises follows Song et al. (2011). Specifically, they are owned and operated by entrepreneurs who invest their own capital in the firm and borrow part of the capital from the financial intermediary at the net interest rate of $r_{l,t}$. But entrepreneurs can pledge to repay only a share η of profits, which then leads to a borrowing constraint that we explain below. An entrepreneur with physical capital $a_{l,p,t}$ solves the following problem

$$max_{\{b_{l,p,t},l_{l,p,t}\}}\{P_{l,t}(a_{l,p,t}+b_{l,p,t})^{\alpha_t}(A_{l,p,t}l_{l,p,t})^{1-\alpha_l}-w_t l_{l,p,t}-(r_{l,t}+1)b_{l,p,t}+(1-\delta)(a_{l,p,t}+b_{l,p,t})\}$$

where $b_{l,p,t}$ is the amount of capital the entrepreneur borrows from the bank and $k_{l,p,t}{\equiv}a_{l,p,t}+b_{l,p,t}$. The first-order conditions from the profit-maximization problem for labor choice is

$$w_t=(1-\alpha_l)P_{l,t}(A_{l,p,t})^{1-\alpha_l}(k_{l,p,t})^{\alpha_l}(l_{l,p,t})^{-\alpha_l}. \tag{15}$$

Rearranging the terms, we have $l_{l,p,t}=[\frac{(1-\alpha_l)P_{l,t}}{w_t}]^{\frac{1}{\alpha_l}}(A_{l,p,t})^{\frac{1-\alpha_l}{\alpha_l}}k_{l,p,t}$. The value of the firm before the loan payment is then

$$\begin{aligned} vf_{l,p,t} &= \alpha_l P_{l,t}(k_{l,p,t})^{\alpha_t}(A_{l,p,t}l_{l,p,t})^{1-\alpha_l}+(1-\delta)k_{l,p,t} \\ &= [\alpha_l(P_{l,t})^{\frac{1}{\alpha_l}}(\frac{(1-\alpha_l)A_{l,p,t}}{w_t})^{\frac{1-\alpha_l}{\alpha_l}}+(1-\delta)]k_{l,p,t}. \end{aligned} \tag{16}$$

Turning to the bank loan borrowing decision by entrepreneurs, given the borrowing rate, for the entrepreneurs to borrow, we require that the return on their capital is larger than or equal to the borrowing rate, $\chi-1\geq r_{l,t}$, where $\chi\equiv\alpha_l(P_{l,t})^{\frac{1}{\alpha_l}}(\frac{(1-\alpha_l)A_{l,p,t}}{w_t})^{\frac{1-\alpha_l}{\alpha_l}}+(1-\delta)$. Further simplification leads to

$$\frac{A_{l,p,t}}{A_{l,s,t}}\geq 1. \tag{17}$$

The incentive compatible constraint for the entrepreneur is

$$(r_{l,t}+1)b_{l,p,t}\leq\eta\chi(a_{l,p,t}+b_{l,p,t}). \tag{18}$$

Assuming that the incentive constraint for the entrepreneur binds, the level of loan for any given amount of capital is,

$$b_{l,p,t}=\frac{\eta\chi}{r_{l,t}+1-\eta\chi}a_{l,p,t}. \tag{19}$$

The net profit of the firm is

$$
\begin{aligned}
\pi_{l,p,t} &= \chi k_{l,p,t} - (r_{l,t}+1)b_{l,p,t} - a_{l,p,t} \\
&= \chi(a_{l,p,t}+b_{l,p,t}) - (r_{l,t}+1)b_{l,p,t} - a_{l,p,t} \\
&= [(\chi-1)+(\chi-r_{l,t}-1)\frac{\eta\chi}{r_{l,t}+1-\eta\chi}]a_{l,p,t},
\end{aligned}
$$

and thus the net rate of return to the entrepreneurs' assets is

$$
\Gamma_{l,p,t} \equiv [(\chi-1)+(\chi-r_{l,t}-1)\frac{\eta\chi}{r_{l,t}+1-\eta\chi}]. \tag{20}
$$

4.1.4 The Education Sector

For simplicity, we assume a linear technology that transforms one unit of efficiency labor input into one unit of human capital investment. As such, i_h units human capital investment will cost the equivalent of $i_h w$ units of final goods.

4.2 Households

In each period, a generation of individuals is born. Let B denote their birth year/cohort. The age of an individual of cohort B at time t is then $j = t - B$. The individual starts working and forms a household upon turning age J_1. The household gives birth to n_B ($n_B > 0$) children at age J_f, retires at age $J_{r,B}$, and exits the economy at age J_B, where $J_1 \leq J_f \leq J_{r,B} < J_B$. Following Song et al. (2011), we assume that a fraction of the households are also endowed with entrepreneurial skills and use Λ to indicate whether a household is endowed with entrepreneurial skills or not.[6]

At each age, the household makes consumption and savings decisions. When its children are between the ages of 7 and 22, the parent makes the human capital investment decisions for them. Labor supply is inelastic. Starting from retirement age, $J_{r,B}$, the household also receives transfers from its children, at which point the children would be $J_{r,B} - J_f$ years of age, and we assume that $J_f + J_1 \leq J_{r,B}$ to ensure that when the household retires, its children have already entered the economy. Finally, a retired household receives a social security pension, which is a fraction ς_B of its earnings at the time of retirement for workers which is $J_{r,B} - 1$.

[6]Throughout the paper, we use households and individuals interchangeably.

4.2.1 Labor Income

Labor is supplied inelastically before retirement. Labor productivity is deterministic and age dependent, with all workers of the same age j facing the same exogenous profile e_j. For a household with human capital h, the total productivity of the household is given by he_j. Define the household's labor income as

$$E_{B,j} = h_B e_j w_t, \quad \text{if } j < J_{r,B},$$

where $t = j + B$.

4.2.2 Transfer Payments to Parents

Let $T_{B,j}$ denote the transfer payment a household of cohort B and age j makes to its retired parent. The transfer payment is a fraction $\mu_0 n_{B-J_f}^{\mu_1 - 1}$ of the labor earnings, where n_{B-J_f} is the number of kids the household's parents have.[7] We assume $0 \leq \mu_1 < 1$ to capture the decline of each child's parental transfer with the number of siblings following Choukhmane et al. (2017). Specifically,

$$T_{B,j} = \begin{cases} \mu_0 n_{B-J_f}^{\mu_1 - 1} E_{B,j}, & \text{if } J_{r,B-J_f} - J_f \leq j < J_{B-J_f} - J_f, \\ 0, & \text{otherwise.} \end{cases} \tag{21}$$

4.2.3 Children's Living Expense

We assume that a household spends a fraction Φ_1 of its labor earnings on each child's consumption until the child turns J_1 years of age and leaves the household. Let $F_{B,j}$ denote the living expense of the child; we then have,

$$F_{B,j} = \begin{cases} \Phi_1 E_{B,j}, & \text{if } J_f \leq j < J_f + J_1, \\ 0, & \text{otherwise.} \end{cases} \tag{22}$$

4.2.4 Human Capital Investment

Let h_c denote the human capital of the child. We assume that the human capital accumulation 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 η_{j-J_f} governs the child-age dependent efficiency in human capital production,

[7] Since a parent gives birth at age J_f, an individual of cohort B has a parent of cohort $B - J_f$.

and i_h denotes the investment level in efficiency units of labor. This functional form is a slight modification of that used in Manuelli and Seshadri (2014). As noted before, i_h units human capital investment will cost the equivalent of $i_h w$ units of final goods.

Human capital investment occurs in two phases, the mandatory phase and the voluntary phase. Specifically, children start receiving education at age 7. The first 9 years of education is mandatory, and each child's education costs a fraction Φ_2 of the household's labor earnings, thus the amount of investment is

$$i_h = \Phi_2 E_{B,j}/w. \tag{23}$$

From age 16, the next 7 years' education is optional (3 years of high school and 4 years of college education), and the level of investment is chosen by the household.

4.2.5 Income

A household receives labor earnings before retirement and a pension after retirement. Labor income is subject to a payroll tax $\tau_{ss,t}$ with the revenue going towards the provision of pensions. Income is subject to an additional tax τ_t. The income structure is quite different for workers and for entrepreneurs and we discuss them separately below.

Worker Households Workers supply their labor inelastically in return for a wage and they deposit their savings in banks and earn interest income at the net deposit rate $r_{d,t}$. In addition to their labor income, workers also receive interest payment from savings which is taxed at rate τ_t. Let a denote the savings; we then have after-tax income as

$$y_{\Lambda=0,B,j} = \begin{cases} (1-\tau_t-\tau_{ss,t})E_{B,j} + (1-\tau)r_{d,t}a, & \text{if } j < J_{r,B}, \\ \varsigma_B E_{B,J_{r,B}-1} + (1-\tau)r_{d,t}a, & \text{if } j \geq J_{r,B}, \end{cases} \tag{24}$$

where ς_B is the pension replacement rate for cohort B.

Entrepreneurial Households Before they run their own businesses, entrepreneurial households first work as workers, they receive wages, deposit their savings in the bank and earn interest income. After they become entrepreneurs at age $J_c = J_1 + 1$, they work and at the same time invest their accumulated wealth in the firms they own. Their income, therefore, consists of the wage they receive as well as profits of the firm they own. After retirement, entrepreneurs receive a pension as well as interest income from their savings in the bank. The after tax income of an entrepreneur is then

$$y_{\Lambda=1,B,j} = \begin{cases} (1-\tau_t-\tau_{ss,t})E_{B,j} + (1-\tau_t)r_{d,t}a, & \text{if } j < J_c, \\ (1-\tau_t-\tau_{ss,t})E_{B,j} + (1-\tau_t)\Gamma a, & \text{if } J_c \leq j < J_{r,B}, \\ \varsigma_B E_{B,J_{r,B}-1} + (1-\tau_t)r_{d,t}a, & \text{if } j \geq J_{r,B}. \end{cases} \tag{25}$$

4.2.6 Recursive Problems

Entrepreneurs and workers solve similar problems after we take into consideration the differences in their income structure as just described. 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

$$\frac{c_j^{1-\sigma}}{1-\sigma}, \tag{26}$$

where σ is the relative risk aversion parameter. The discount factor is denoted by β.

Because we allow some parameters to vary by cohort, and because wages, interest rates, and taxes vary over the transition path, households at the same age but from different cohorts solve different problems. To summarize, a household's state space consists of its cohort B, whether it is endowed with entrepreneurial skills or not indicated by Λ, age j, assets a, human capital h, and children's human capital h_c.[8] Table 1 describes a household's decisions at different ages. We impose an exogenous borrowing constraint: At any given period, the household's financial asset must satisfy $a_j \geq 0$.

A household solves the following problem,

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;

$$\begin{aligned} & V_B(\Lambda, j, a, h, h_c) = max_{\{c,a'\}}\{\frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(\Lambda, j+1, a', h, h_c)\} \\ s.t.\quad & c + a' + n_B F_{B,j} + T_{B,j} \leq a + y_{\Lambda,B,j}, \\ & a' \geq 0. \end{aligned} \tag{27}$$

The left hand side of the budget constraint includes consumption, savings, basic living expense for the children if the household is J_f years of age or older, and the

[8] 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.

transfer the household makes to its parent when the parent is $J_{r,B-J_f}$ years of age or older and hasn't exited the economy yet.[9] The right hand side of the budget constraint contains the household's asset and after tax income.

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

$$V_B(\Lambda, j, a, h, h_c) = max_{\{c,a'\}}\{\frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(\Lambda, j+1, a', h, h_c)\}$$

$$s.t. \quad c + a' + n_B F_{B,j} + n_B i_h w + T_{B,j} \leq a + y_{\Lambda,B,j},$$

$$h'_c = h_c + \eta_{j-J_f}(i_h)^\kappa h_c^{1-\kappa}, \tag{28}$$

$$a' \geq 0. \tag{29}$$

Relative to households in the first age group, the household now needs to pay for its children's mandatory education, captured by $n_B i_h w$ in the budget constraint. Note that human capital investment decision is mandatory in this case and is defined in equation (23). The law of motion for the children's human capital is represented by equation (28).

3. $J_f + 16 \leq j < J_f + J_1$: the household has children who are eligible for optional high school as well as college education;

$$V_B(\Lambda, j, a, h, h_c) = max_{\{c,a',i_h\}}\{\frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(\Lambda, j+1, a', h, h'_c)\}$$

$$s.t. \quad c + a' + n_B F_{B,j} + n_B i_h w + T_{B,j} \leq a + y_{\Lambda,B,j},$$

$$h'_c = h_c + \eta_{j-J_f}(i_h)^\kappa h_c^{1-\kappa}, \tag{30}$$

$$a' \geq 0, \quad i_h \geq 0. \tag{31}$$

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 $n_B i_h w$. The law of motion for the children's human capital is represented by equation (30).

[9] Since a parent gives birth at age J_f, an individual of age j has a parent of age $j + J_f$.

4. $J_1 + J_f \leq j < J_B$: the household no longer has school-age children;

$$
\begin{aligned}
& V_B(\Lambda, j, a, h, h_c) = max_{\{c,a'\}}\{\frac{c^{1-\sigma}}{1-\sigma} + \beta V_B(\Lambda, j+1, a', h, h_c)\} \\
s.t. \quad & c + a' + T_{B,j} \leq a + y_{\Lambda,B,j} + 1_{(j \geq J_{r,B})} T_{B+J_f, j-J_f}, \\
& a' \geq 0. \qquad (32)
\end{aligned}
$$

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.

4.3 The Government

Banks pay deposit at the rate $r_{d,t}$, and incur an intermediation cost when making loans denoted by ξ_t. Define $r^*_{d,t} \equiv r_{d,t} + \xi$ to be the prime lending rate. Banks charge $r_{k,t}$ for loans to the capital-intensive firms, and $r_{l,t}$ for loans to the labor-intensive firms. The term $s_{k,t} \equiv r_{k,t} - r^*_{d,t}$, if positive (negative), represents the government's credit tax (subsidies) to banks on loans to the capital-intensive sector. We assume zero government subsidies or credit tax to the labor-intensive industry, thus $r_{l,t} = r^*_{d,t}$. To balance the budget on loan subsidies, the government relies on an income tax. Let $\Pi_{j,t}$ denote the measure of households at age j and time t, and let $\Lambda_{j,t}$ denote the fraction of households that operates private firms at age j and time t. We then have

$$
\begin{aligned}
s_{k,t} K_{k,t} = \tau_t [& \sum_{j=J_1}^{J_B-1} \Pi_{j,t} r_{d,t} a_{j,t} + \sum_{j=J_c}^{J_{r,B}-1} \Lambda_{j,t} \Pi_{j,t} (\Gamma_{j,t} - r_{d,t}) a_{j,t}] \\
& + \tau_t \sum_{j=J_1}^{J_{r,B}} \Pi_{j,t} E_{B,j,t}. \qquad (33)
\end{aligned}
$$

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

As discussed earlier, the government taxes labor income at rate $\tau_{ss,t}$ to fund pensions. We also assume that government balances the Social Security system,

$$
\sum_{j=J_{r,B}}^{J_B-1} \Pi_{j,t} \varsigma_B E_{B,J_r-1,t} = \tau_{ss,t} \sum_{j=J_1}^{J_{r,B}} \Pi_{j,t} E_{B,j,t}. \qquad (34)
$$

Finally, in each period, the government also specifies the fraction of entrepreneurs that can operate for each birth cohort B among households with entrepreneurial ability.

4.4 Equilibrium

Let $B_{l,p,t}$ denote total loans for private firms aggregated over all entrepreneurs. The competitive equilibrium consists of prices $\{P_{k,t}, P_{l,t}, w_t, r_{d,t}, r_{k,t}, r_{l,t}\}_{t=0}^{\infty}$, government policies $\{\tau_{ss,t}, \tau_t, s_{k,t}, \varsigma_B, J_{r,B}\}_{t=0}^{\infty}$, allocations $\{Y_t, Y_{k,t}, Y_{l,t}, Y_{l,s,t}, Y_{l,p,t}, K_{k,t}, K_{l,s,t}, K_{l,p,t}, L_{k,t}, L_{l,s,t}, L_{l,p,t}, B_{l,p,t}\}_{t=0}^{\infty}$, $\{c(.), a(.), i(.)\}$, $\{l_{l,p,t}(.), b_{l,p,t}(.), k_{l,p,t}(.)\}$, and population measure $\{\Pi_{j,t}, \Lambda_{j,t}\}_{j=J_{1,..,J_B},t=0,..,\infty}$ such that, for given exogenous processes that govern the evolution of technology of all firms, intermediation cost, household life expectancy, fertility rate, retirement age,

1. Households maximize utility;
2. Firms maximize profits;
3. Markets clear,
    (a) Goods market: all goods produced by firms are consumed by households or turned into investment;
    (b) Capital market: firms rent capital from households, $(1-\Lambda_{j,t})\sum_{j=J_1}^{J_B-1}\Pi_{j,t}a_{j,t} + \Lambda_{j,t}(\sum_{j=J_1}^{J_c-1}\Pi_{j,t}a_{j,t} + \sum_{j=J_{r,B}}^{J_B-1}\Pi_{j,t}a_{j,t}) = K_{k,t} + K_{l,s,t} + B_{l,p,t}$;
    (c) Labor market: households supply labor to firms, $\sum_{j=J_1}^{J_{r,B}-1}\Pi_{j,t}h_{j,t}e_j = L_{k,t} + L_{l,s,t} + L_{l,p,t} + \sum_{j=J_f+7}^{J_f+22}\Pi_{j,t}i_{h,j,t}n_B$;
4. Government balances the budget.

4.5 Balanced Growth Rates Along the Balanced Growth Path

Assuming that along the balanced growth path, the population grows at rate g_{pop} and labor augmenting technology at all firms grows at rate g_A, then the other variables in the economy will grow at rates as specified in Table 2. Given that human capital investment is specified in terms of efficiency units of labor, in the balanced growth path, i_h will remain constant. The growth rates of the other variables are straightforward.

We assume that the economy stays on a balanced growth path until 1976 and transits to another balanced growth path after 800 years.

5 Calibration of the Model

We set our initial balanced growth path to be the average of 1970-1976. 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 and social security taxes. Using this guess, we solve for 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 taxes until we reach a fixed point.

The model contains parameters that are fixed over time and stochastic processes that vary over time. We calibrate our fixed parameters and time-varying processes in two stages. In the first stage, we choose some fixed parameters either from the literature or from the data. In the second stage, we jointly calibrate the remaining fixed parameters and exogenous time-varying processes to match certain moments and time-series along the transition path. We do so for fixed parameters because data are limited for some of the earlier years that correspond to our initial balanced growth path, making it infeasible to identify fixed parameters from the initial stationary state alone.

5.1 First-Stage Calibration

The first-stage calibration choices are reported in Table 3.

5.1.1 Households

We assume that a household enters the economy at age 23, gives birth to its children at age 25. For preferences, we assume a relative risk aversion parameter of 1, so that utility is logarithmic. 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 at 4 percent of a parent's labor income (Φ_1). The mandatory education expense parameter Φ_2 is set to match the average 3 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 ($\mu_{0,} \mu_1$) are also taken from Choukhmane et al. (2017).

5.1.2 Firms

The capital income share of the capital-intensive and labor-intensive sectors, α_k and α_l, are calibrated to match the respective capital income and labor income shares of the two industries using data provided by Chang et al. (2015).[10] We make a slight modification in this classification. Particularly, we reclassify the two industries with the highest labor income share in total output in the heavy sector, mining and transportation, into the light sector. The reason for this reclassification is to better capture corporate savings, which we assume is done entirely by private firms in the labor-intensive sector.[11] The share of capital-intensive sector output in final output as well as the elasticity of substitution between the capital-intensive and labor-intensive sector are chosen according to Chang et al. (2015). The depreciation rate δ is set at a standard 6 percent. We choose the initial g_A so that the growth of GDP in our initial balanced growth path matches per capita GDP growth rate of 2 percent before 1976.

5.2 Second-Stage Calibration

The second-stage calibration includes a set of fixed parameters and all exogenous processes are chosen to match certain moments and time-series along the transition path.

5.2.1 Parameters Fixed Over Time

For the household, these fixed parameters include the discount rate β, the labor efficiency profiles $\{e_j\}_{j=23}^{J_{r,B}-1}$, the efficiency of human capital investment by children's age

[10]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. Chang et al. (2015) classify industries into heavy industry and light industry according to their labor income shares in total output. In their paper, 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)

[11]This reclassification doesn't lead to significant changes in the two industries' relative output nor relative capital over time.

$\{\eta_j\}_{j=7}^{22}$, and the weight on human capital investment in the human capital accumulation technology κ. On the firm's side, the parameters include the initial levels of labor augmenting technology in the capital-intensive sector $\{A_k\}$ and in the labor-intensive sector $\{A_{l,s}, A_{l,p}\}$, as well as the parameter η that governs the stringency of the collateral constraint for entrepreneurs.[12] The targeted moments include the age profile of earnings in 1986, the age profile of discretionary education expenditures in 2002,[13] the deposit rate faced by households, the average relative capital-output ratio of state and private enterprises during the period of 1998-2005, and finally the loan to asset ratio of 0.5 for private firms as in Song et al. (2011). We normalize the wage rate in 1976 to be 1.

We report parameters calibrated in the second stage in Table 4 and the target moments in Table 5. Note that because our overlapping generations framework abstracts from uncertainties in income and health expenditure, the model requires a discount factor that is slightly larger than 1 to be consistent with the observed savings rate.[14]

To reduce the number of parameters, we estimate the efficiency function as a polynomial of degree 3 with respect to age as is commonly done in the literature. In terms of human capital investment, our estimate indicates that the efficiency $\{\eta_j\}_{j=7}^{22}$ is hump-shaped with respect to age.[15] In Figure 3, we depict the model-generated earnings profile in 1986 and the data counterpart from the Urban Household Survey.[16] We present the age-specific educational expenditure data versus model generated moments in 2002 in Figure 4. The model matches both sets of data moments quite well.

5.2.2 Exogenous Processes

We now describe the calibration of the exogenous processes in the model. To facilitate our discussion, we classify these processes into two groups, those that affect mainly households and those that affect mainly firms. On the household side, we have the

[12] The $A's$ will change during the transition as we introduce differential sectoral growth rates (see detailed discussion in the next subsection), but we keep the ratio of A_{lp}/A_{ls} constant as in the initial balance growth path.

[13] We obtained the 2002 discretionary education expenditures from Choukhmane et al. (2017), as mentioned earlier. This is the only year we have information on private education expenditures.

[14] For example, Chamon et al. (2013) argue that rising income uncertainty induces younger households to raise their saving rate significantly. Imrohoroglu and Zhao (2018a) find that the combination of the risks faced by the elderly and the deterioration of family insurance due to the one-child policy may account for approximately half of the increase in the saving rate between 1980 and 2010. He et al. (2018) finds that precautionary savings account for about 30 percent of the wealth accumulation of SOE workers between 1995 and 2002.

[15] We assume that $\{\eta_j\}_{j=7}^{15} = \eta_{16}$.

[16] We thank Fang and Qiu (2021) for providing us with the data profiles.

reduction in the fertility rate, the increase in life expectancy, the delay in retirement age, and the reduction in pensions. On the firm side, we have government policies that control for the speed of the growth of entrepreneurship and hence the growth of private firms; credit policy that benefits capital-intensive heavy industry; the decline in intermediation cost, which benefits all firms, and time-varying labor augmenting technology.

Exogenous Processes on the Household Side In Figure 5, we chart the exogenous processes including life expectancy at birth for a household who is age 23 at the year plotted and birth rate per adult over time. Note that life expectancy in the model is discrete and can be increased only by integer numbers since the model period is one year. According to data we obtained from the World Bank, life expectancy at birth increases from 57 for a person who was 23 in 1976 to 75 for a person who was 23 in 2020. We assume that in the final balanced growth path households expect to live to 80 years of age.

The fertility rate in the initial balanced growth path is chosen to match the population growth rate of 2.05 percent between 1970 and 1976 (World Bank). In 2013, the one-child policy that had been in place 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. Starting in October 2015, the Chinese government completely abolished the one-child policy and all Chinese couples are allowed to have two children. We raise the fertility rate gradually starting from 2015 and assume that the rate reaches 1.25 per adult in 2040 and then stays there. We then fit a gradual change of birth rate in the model to match the data.[17] The implied growth rate of the population is 0.9 percent in the final balanced growth path.

In response to the aging population due to the increase of life expectancy and the decline in fertility, we incorporate two government policies: the delay in retirement age, and the reduction in pensions. In Figure 6, we chart the retirement age for a 23-year old and the current pension replacement ratio over time. Since the 1950s, China has implemented a compulsory scheme to regulate the retirement age, 60 for men, 55 for female professionals such as teachers, medical personnel, other professionals, and administrators, and 50 for the rest of the female work force. In reality, however, many people take early retirement as evidenced in the decline of cross section income over the

[17] Since fertility is fixed at age 25, to generate a gradual change of population distribution, the change of fertility has to follow a constant rate and to stop in 25 years.

years starting at age 50.[18] According to the Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035, China will take small steps to raise the retirement age. To account for these developments, we set the retirement age for the initial balanced growth path at 50. We then begin to raise the retirement age in 2017, which corresponds to the retirement age a 23 year old in 1990 faces, by 1 year every four years. A 23 year old from 2042 and onward will thus face a retirement age of 64 ((2042-1990)/4=13).

Turning to pension replacement rate, 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 state-owned enterprises. The coverage, however, was low in private enterprises, especially in rural areas (see, e.g., Sin 2005). Given that 75 percent of the population lived in the rural areas in 1980, we chose a pension replacement rate of 45 percent for the general population for our baseline calibration ς_B. The pension replacement rate declines linearly from 45 percent in 1977 to 20 percent shortly before 2000 and stays there afterwards.[19]

Exogenous Processes on the Firm Side Figure 7 depicts the five exogenous processes on the firm side: the respective growth rates of labor augmenting technology for the capital-intensive firms as well as the labor-intensive firms; the interest subsidy rate to the capital-intensive sector; the financial intermediation cost, and the fraction of entrepreneurs allowed to operate in each cohort of 23-year olds in the economy. We assume that in the labor-intensive sector, labor augmenting technology in the state-owned firms grows at the same rate as that in the privately owned firms. These processes are chosen jointly to match five sets of moments: the overall capital-output ratio in the economy, the relative output as well as the relative capital in the capital-intensive sector to that in the economy, the changing employment share of private firms, and the fraction of the labor force that is self employed. The aggregate capital-output ratios over time are constructed from the Penn World Table. The data on relative output and relative

[18] See Appendix D in Choukhmane et al. (2017) for a discussion.

[19] 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.

capital are constructed using data from Chang et al. (2015) and from the China Statistical Yearbook of various years. The private employment share is constructed as follows. Using the 2012 China Statistical Yearbook Table 4-2 ("Number of Employed Persons at Year-end in Urban and Rural Areas"), we count individuals as working in private firms if they are self-employed, or work in private enterprise.[20]

Credit subsidies to capital-intensive firms are instituted in 2000, which is roughly consistent with the narrative given in section 2.3. Although the large fiscal stimulus plan ended in 2010, the data show that the bank loan-to-GDP ratio remains elevated well into 2016 (Chen et al. 2019). We assume that the subsidies to the capital-intensive firms $s_{k,t}$ peak in 2020 at 1.5 percentage points and declines to zero by 2040. For simplicity, and to reduce parameter dimensions, we assume a linear transition path in the subsidy rate leading to the peak and also returning to zero.

The intermediation cost ξ_t follows the logic of Song et al. (2011) and captures operational costs, red tape, etc. In other words, this cost is an inverse measure of the efficiency of intermediation. We estimate the initial intermediation cost to be 9.5 percent. The intermediation cost is assumed to come down to zero in 2005, four years after China joined the World Trade Organization and began to open up its financial market. Finally, we assume the transition in the intermediation cost is linear.

Figure 7c charts the fraction of entrepreneurs allowed to operate in each cohort of 23-year olds in the economy, which is chosen by the government and directly governs the growth of private firms in the labor-intensive sector. Note that in our setup, as a departure from that in Song et al. (2011), entrepreneurs receive an efficiency wage in addition to a higher return on capital. As a result, entrepreneurs will always operate their businesses if allowed by the government. Our initial balanced growth path is an economy with no private enterprises. The fraction of entrepreneurs is thus set to zero. During the transition, the series is chosen to roughly match the fraction of self-employed in the data.[21] Mechanically, we set 25 percent as the upper bound of entrepreneurship in the economy, a level that is currently seen in more developed Asian economies such as South Korea's.[22] We then adjust the fraction of households that can operate as entrepreneurs starting in 1990, along with other parameters, to roughly match self employment in

[20] We count employment in township enterprises in rural areas also as private employment (note this series was discontinued after 2010).

[21] We construct the fraction of workers that are self-employed from the China Statistical Yearbook of various years, for example, Table 4-1 in the 2021 Statistical Yearbook, by adding the urban self-employed and the rural self-employed and dividing the sum by total labor force.

[22] See https://data.oecd.org/korea.htm.

the economy without deviating too far from several other economic statistics along the transition such as the private employment share.

In Figure 8, we chart model implications against data for targeted statistics on the firm's side: the ratio of output in the capital-intensive sector to total output, the ratio of capital input in the capital-intensive sector to total capital in the economy, private firms' employment share in total employment, the overall capital-output ratio in the economy, and the fraction of the labor force that are self employed. For the most part the model does a reasonable job fitting the data. Since the 1990s, the capital-intensive heavy industry has become increasingly important in both output and capital. Private firms have also become increasingly important. Their share of employment went from near zero in the early 1980s to over 60 percent by 2015. With a maximum of 25 percent of the workforce being allowed to be entrepreneurs, private sector firms have also grown in size. The economy-wide capital-output ratio has also been trending up during our sample period. Our model does not capture the fast rise in entrepreneurship in 1990 and then the dramatic decline in the late 1990s that we see in the data. That data trajectory was entirely due to changes in self-employment in rural areas with no consensus on the underlying driving forces.

5.3 Non-targeted Data Moments versus Model Implied Moments

We now describe the model's fit of some key data moments that were not used in parameterizing the model. How well the model accounts for these data represents a test of the model's capabilities.

5.3.1 Labor Market Outcome and Return to Human Capital

To validate the modeling of endogenous human capital accumulation, we now evaluate the model's performance on various dimensions of human capital accumulation and the returns to human capital. One important empirical observation is that cross-sectional age-earning profiles in China have been changing over time (Fang and Qiu 2021). Our model does a reasonably good job at matching age-earnings profiles over time from the household survey data, as shown on the Figure 9a. Note that for each given year, the difference in wage earnings by age or cohort is a product of the life-cycle efficiency profile and the efficiency units coming from human capital investment. The life-cycle efficiency profile is fixed over time.

To further decompose the forces that attribute to changes in cross-sectional age-earning profiles, and isolate the effect of human capital investment on earnings, we next follow Fang and Qiu (2021) and construct the cohort effects as well as time effects on earnings and contrast them with their data counterparts (Fang and Qiu 2021 Figure 4) in Figures 9b and 9c. The cohort effect is defined as inter-cohort human capital growth and reflects human capital investment, and the time effect is defined as changes in the price of human capital, which is the efficiency wage rate in our model. We normalize the first data points for both series, data as well as model, to 1. Our model captures the salient feature found in the data, that is, the increase in the price of human capital (time effects) is more important than the increase in the quantity of human capital (cohort effects). In terms of fit, our model matches the time effects well, but somewhat under-predicts the cohort effects starting with the mid-1970s cohort .

One popular way to measure returns to human capital in the literature is to run a Mincerian regression, where wage is regressed on years of schooling. In China, a high school education takes three years to complete whereas a college education typically takes four years to complete. In our model, as in Manuelli and Seshadri (2014), human capital investment is entirely on the intensive margin with years of investment fixed.[23] There is no obvious mapping of human capital investment expenditure to years of schooling. We nevertheless conduct an analysis where we define, for each individual, the return to high school as his human capital at age 19 divided by his human capital at age 16, and the return to college as his human capital at age 23 divided by his human capital at age 16.[24] We then take the average of these returns for each year to arrive at an economy wide return to high school and return to college, respectively. We take log of our measures of the returns to human capital and chart them against their data counterparts from Figure 1 in Ge and Yang (2014) in Figure 9d. Our model captures the data moments in the early 1990s but underestimates both returns in later years. This is somewhat expected since our model doesn't feature any skill biased technological change that is typically needed to explain these premium.[25]

[23]The Cobb-Douglas functional form for human capital accumulation implies an infinite return to human capital investment at zero. As a result, parents make positive human capital investment for their children in all periods.

[24]Manuelli and Seshadri (2014) use a similar approach to measure return to human capital.

[25]See Violante (2008) for an overview of this literature.

5.3.2 Capital Market Outcome

In Section 5.2, we showed that our model matches the sectoral capital allocation, output shares, and the aggregate capital output ratio quite well (Figure 8). As an additional validation of our model, we chart in Figure 10 the dynamics of the return to capital net of depreciation. The model-implied marginal product of capital exhibits a downward trend, consistent with the data (Figure 7 in Bai et al. 2006).

5.3.3 Growth and Savings

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. Note that we follow Imrohoroglu and Zhao (2018b) and treat savings by entrepreneurs as corporate savings.

Figure 11 graphs the two series. The aggregate saving rate is provided by Chang et al. (2015). To arrive at the per capita output growth, we first divide real GDP at chained PPPs (2011 US $) by total population, take the growth rates, and then HP filter the series. The model captures the increasing pattern of the aggregate national savings rate reasonably well, although it overpredicts the saving rate for the periods between 2007 and 2015, a period that was marked by the Great Recession. The model overpredicts household savings, particularly between 1992 and 2010 and, as a result, the model underpredicts the corporate saving rate.

Turning to the growth rates of output per capita, the model generates growth that is substantially greater than the assumed 2 percent exogenous growth rate in the initial balanced growth path due to the endogenous behavioral responses to changes in demographics and industrial policies. Since the model abstracts from business cycle fluctuations, it is not designed to match the cyclical fluctuations in the growth rate of GDP per capita. As with the savings rate, our model overpredicts the per capita output growth after 2005, likely because we don't explicitly model the Great Recession.

6 The Role of Endogenous Human Capital Accumulation

One unique feature of our model is the joint modeling of physical as well as human capital accumulation. To support retirement, households rely on transfers from their children as well as their own savings to supplement their government pension. Transfers from children increase with the number of children as well as with children's labor earnings, while the return on savings is governed by the return to capital net of intermediation costs for worker households and by the return to capital in their own project for entrepreneur households. For a given amount of resources, households, therefore, face a trade-off between investing in their children's human capital and saving on their own.

To quantitatively examine the importance of this interaction between human capital investment and savings, 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 by age at the same ratio as in the initial balanced growth path. Although no private firms are allowed in the initial balanced growth path, we can still compute human capital investment per child relative to income by age for entrepreneurs. Note that in our setup entrepreneurs have access to higher returns to capital, implying that their incentive to save (and invest in their own projects) is stronger than worker households. As a result, entrepreneurial parents will always invest less in their children's human capital than worker parents holding everything else the same. We thus expect this counter-factual to have a larger impact on workers behavior than on entrepreneurs.

We first chart the resulting human capital investment relative to earnings for workers and entrepreneurs for 2002 in Figure 12a. As expected, the rates fixed at the initial balanced growth path are much lower than in the benchmark for all the ages at which parents are eligible to make voluntary investment in their children's human capital. We plot in Figure 12b the amount of human capital for each individual at age 23. Since we fix their human capital investment per child relative to income by age at the same ratio as in the initial balanced growth path, human capital for worker individuals barely change over time. Entrepreneurs' human capital decreases over time since their parents now invest less than what they do in 1976 when everyone is a worker.

In this new economy, relative to the benchmark, given that parents are much more restricted in their ability to increase their old age support through investment in their children's human capital, they will respond with more of their own savings. On the labor side, lower human capital investment means lower labor efficiencies, which in turn implies lower household earnings and lower total output. However, it is important to point out that human capital investment takes time and human capital is a stock variable. It takes a whole cycle, 27 years (50-23) to be precise, for the entire working age population to have benefited from the endogenous accumulation of human capital. We expect its full impact on output growth to materialize much later than on savings.

We present our simulation results for the new economy together with those for the benchmark economy in Figures 12c to 12f and for the remainder of the discussion, we will focus on the comparison with the benchmark economy. Indeed as discussed, with less human capital investment, households now save more relative to the benchmark economy. Between 1980 and 2005, as shown in Figure 12c, our simulation suggests that the household saving rate would have gone up by another 2 percentage points had it not been for the additional expenditure on human capital. There is little difference in corporate savings as entrepreneurs have less incentive for investing in human capital due to their higher return to savings. The greater physical saving and the lower stock of human capital in the alternative experiment lead to a higher capital output ratio as indicated in Figure 12d. The lower labor efficiency leads to lower wage income relative to the benchmark particularly in later years as seen in Figure 12e. Despite the increased physical savings, the lower labor efficiency significantly lowers per capita output growth starting in 1996 as can be seen in Figure 12f. In 2015, the per capita GDP growth rate is 2 percentage points higher with endogenous human capital accumulation.[26]

7 Additional Counterfactual Experiments

In addition to endogenous human capital investment, our model contains many other structural features as well as important government policies. There are countless combinations of these policy changes and we do not intend to isolate the effects of each of them here. Instead we sort these changes roughly into two groups, those that affect mainly firms and those that affect mainly households. On the firm side, we have government policies that control for the speed of the growth of entrepreneurship and hence the growth of private firms; credit policy that benefits the capital-intensive heavy industry sector; time-varying technology growth; and the decline in intermediation cost, which benefits all firms. On the household side, we have the reduction in the fertility rate, the increase in life expectancy, the delay in retirement age, and the reduction in pensions. We conduct two important counterfactual experiments, one where we implement changes we classify as firm side only and the other where we implement changes we classify as household side only. We are fully aware that many of the changes, for example, the reduction in intermediation cost, affect both households and firms directly and all of the

[26]The industrial composition in terms of relative output and relative capital change little in this experiment though the capital-intensive sector benefits slightly more from the increased savings when human capital accumulation is exogenous (not shown).

changes affect households and firms indirectly. We will highlight the interaction of firm structure and policy changes with demographic transitions on the various saving rates in our model and with respect to per capita output growth in section 7.3.

7.1 The Effects of Firm Structure and Policy Changes

In order to ascertain the combined contributions that the many firm side changes have on the behavior of the economy, we consider an economy that experienced only the firm side policy changes including technology changes, growth of private firms through entrepreneurial activities, government credit policy that favors firms in the capital intensive sector, and finally the reduction in intermediation cost.

Intuitively, relative to the initial balanced growth path, the reduction in intermediation cost increases the effective return on savings for households and firms, and, as a result, will increase their incentive to save in physical assets and crowd out their investment in their children's human capital. The increase in physical assets will lead to higher output growth. The reduction in human capital investment will in turn lead to lower labor efficiency and reduce output growth. The increase of entrepreneurial households operating their own firms, on the other hand, will increase total output as private firms are more productive than state-owned firms. Relative to the benchmark economy, firm side changes alone will lead to less savings and less investment in children's human capital without demographic aging as households have less incentive to save.

We chart the various economic statistics in this counterfactual economy along with their benchmark counterparts in Figure 13. The dynamics of the counterfactual economy directly measure the effects of firm structure and policy changes. Their respective differences with the benchmark counterparts reflect the effect from demographic changes and their interactions with firm structure and the policy changes.

In the counterfactual economy, as seen in Figure 13a, starting from the initial balance growth path in 1976 as displayed by the dashed lines, the result confirms our intuition that the reduction in intermediation cost together with government preferential credit policy lead to higher household savings. Corporate savings also rise, a result of higher profit due to lower cost of financing as well as an increasing number of entrepreneurs operating their own firms. The stock of human capital increases slowly relative to the initial balance growth path for workers and actually declines over time for entrepreneurs who have strong incentive to save (and invest in their own projects) instead (Figure 13b). For the economy as a whole, the capital labor ratio moves up (Figure 13c), wages also rise (Figure 13d), while the interest rate fluctuates over time but remains on an upward trajectory (Figure 13e). Relative to 1976, output per capita consistently increases (Figure 13f). Quantitatively, due to firm structure and policy changes alone, in the years between 1976 and 2015, the household savings rate goes up by close to 10 percentage points, the corporate savings rate goes up by over 12 percentage points, and per capita output growth rises by 1.3 percentage points.

Relative to the benchmark, the alternative economy has a much lower households saving rate throughout the simulation period (Figure 13a) as households have less reason to save. Growth in output per capita is also significantly lower in the counterfactual, due to a lower physical capital stock and a lower human capital stock (Figures 13a, 13b and 13f). All of these differences demonstrate the importance of the effects of demographic factors and their interaction with firm structure and policy changes, which we investigate next.

7.2 The Effects of Demographic Changes

Turning to the contributions that all the demographic factors have on the behavior of the economy, we investigate an economy that experienced only the demographic changes including the increase in life expectancy, the one-child policy, the reduction in pensions, and an increase in the retirement age.

Intuitively, relative to the initial balanced growth path in 1976, the lower fertility rate, the lengthened life expectancy, and the reduction in pensions all push households to save more and to invest in their children's human capital. However, the one-child policy reduces the aggregate labor supply. On the other hand, delaying the retirement age reduces savings, increases labor, and discourages households from investing in their children's human capital. Endogenously increased human capital investment causes savings to go down but increases effective labor supply. Relative to the benchmark economy, no private firms means no corporate savings, thus national saving equals household saving. Firms in the labor-intensive sector will be less productive.

We report the various economic statistics in this alternative economy along with their respective benchmark dynamics in Figure 14. To reiterate, the dynamics of the alternative economy directly measure the effects of the demographic transition that starts in 1977, and their differences with the benchmark reflect the effects of the missing firm structure and policy changes, and their interactions with demographic transitions.

As can be seen in Figure 14a, starting in 1976, the combined effect of the various demographic changes on savings is that household savings go up consistently over time. Between 1976 and 2015, the household saving rate increases by about 8.5 percentage points. The stock of human capital of individuals upon entering the economy at age 23 also moves up over time especially after 2005 when the whole population has benefited from the investment in human capital (Figure 14b). On balance, capital increases faster than labor and the economy wide capital output ratio increases over time particularly after 1995 as seen in Figure 14c. As a result, the wage rate goes up and the interest rate comes down noticeably after 1995 as seen in Figures 14d and 14e. Finally, growth in output per capita moves up steadily as seen in Figure 14f. Quantitatively, from 1976 to 2015, the per capita output growth rate rises by an appreciable 4 percentage points.

In contrast to the benchmark, the counterfactual economy experiences much lower household savings, no corporate savings (Figure 14a), roughly the same human capital investment for workers (Figure 14b), and both a much lower capital labor ratio and a capital output ratio (Figure 14c). In terms of prices, wages are also much lower than the benchmark and beginning in 1995 interest rates actually start to decline (Figures 14d and 14e). Finally, per capita output also grows much more slowly (Figure 14f) in part reflecting the absence of private entrepreneurs. All of these differences point to the significance of the effects associated with firm side structure and policy changes, and their interactions with the demographic transition.

7.3 The Interaction of Firm Structure and Policy Changes with Demographic Changes

In this subsection, we wish to highlight the interaction of firm structure and policy changes with demographic transitions on the various saving rates in our model and with respect to per capita output growth. The interaction effects arise from the general equilibrium effects coming from wages and interest rates.

We obtain our numerical estimates of the interaction effects by combining the analysis in the preceding two subsections. One observes that the benchmark economy is driven by firm side changes plus household side changes along with the interaction of both types of changes. To derive the interaction term, we subtract the household side changes in section 7.2 from the benchmark, leaving us with the effects from firm side changes plus the interaction term. These are displayed by the solid lines in Figures 15a and 15b. If we subtract the 1976 balance growth path from the firm side changes only in section

7.1 we are left with the effect of firm side changes without the interaction term, and these are displayed by the dashed lines in Figures 15a and 15b. If we then subtract the dashed lines from the solid lines we arrive at the effects of the interaction term, which are displayed in Figures 15c and 15d.[27]

As shown in Figure 15c, the interaction term contributes roughly 2.5 percentage points to the aggregate saving rate between 1976 and 2015. While the interaction term positively influences household saving, it initially has little effect on corporate savings and in the medium term it actually reduces corporate savings. It is only at the end of the sample that it has a positive effect on the savings of entrepreneurs. Regarding per capita output growth, Figure 15d indicates that for much of the sample, the interaction term has little effect and the effect turns negative toward the end of the sample period.

8 Conclusions

In this paper, we build a unified framework that brings together important changes on the household side as well as the firm side of the Chinese economy to account for its rapid growth and elevated saving rate. On the household side, we focus on demographic transition arising from the one-child policy, increased life expectancy, as well as government policies that reduce the pension replacement rate and delay the retirement age. On the firm side, we analyze government policies that have controlled the growth of private firms, credit policies that have favored different industries, financial development, as well as sectoral TFP changes over time. Our model also features endogenous human capital investment that has been a prominent part of the Chinese growth experience.

Our model does a reasonable job of accounting for the time trend of the aggregate saving rate as well as the growth rate of per capita output. Our analysis indicates that both the demographic transition and the government policies played important roles in driving China's high rate of savings and rapid growth. The effects on savings from the interaction of the two sets of changes are also nontrivial. Finally, endogenous human capital investment suppresses household savings prior to 2010. Growth in per capita output rises significantly due to human capital investment after 2005. The paper

[27] One can also construct the interaction effects by working through the household side changes. That is, we subtract from the benchmark economy results from section 7.1 to arrive at estimated effects due to household side changes and the interaction. Then we subtract the 1976 balance growth path from results in section 7.2 to arrive at estimated effects due to demographic transition only. Lastly, we subtract the second constructed series from the first constructed series; we obtain the same interaction effects.

thus links important insights from the literature that explains the fast growth in China and from the literature that focuses on the high saving rate, and shows that there are important reasons to consider these various avenues in tandem.

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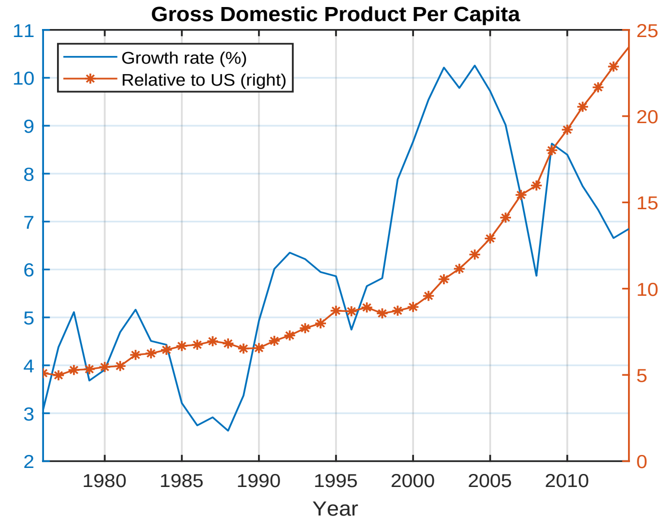

Figure 1: **The Growing Chinese Economy** This figure depicts the per capita GDP growth rate of the Chinese economy and the relative per capita GDP in China to that in U.S. Data come from the World Bank/Haver Analytics. To arrive at the per capita output growth, we first divide output-side real GDP at chained PPPs (2011 US$) by total population, take the growth rates, and then HP filter the series.

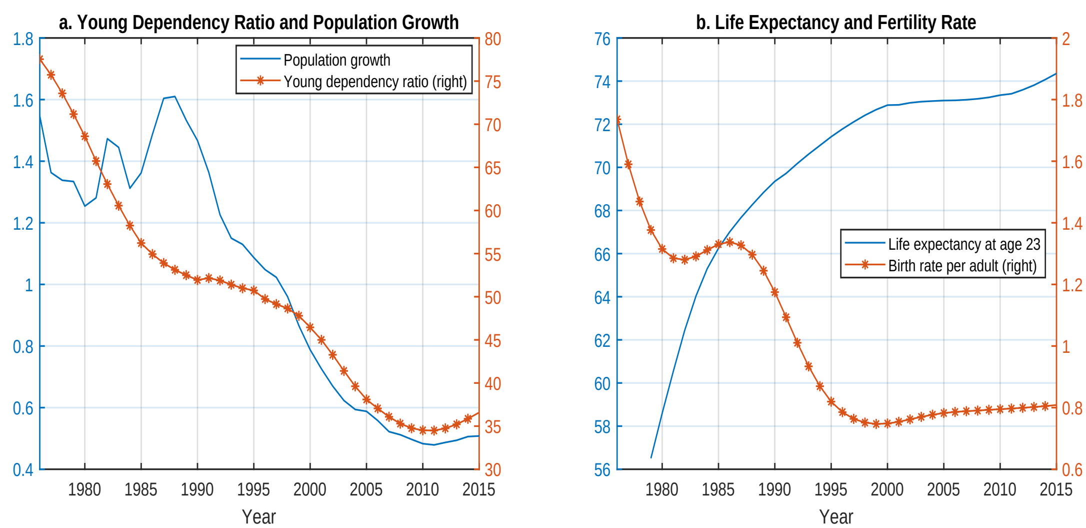

Figure 2: **The Aging Chinese Demographics** This figure describes population growth rate and young-age-dependency ratio (Panel a), and the life expectancy and the fertility rate per adult (Panel b). The young-age-dependency ratio is defined as the ratio of people younger than 15 to people between the age of 15 and 64. Data source: World Bank.

Figure 3: **Age-Income Profiles** This figure depicts the labor earnings by age for Chinese households in 1986. Data source: Urban Household Survey, Fang and Qiu (2021).

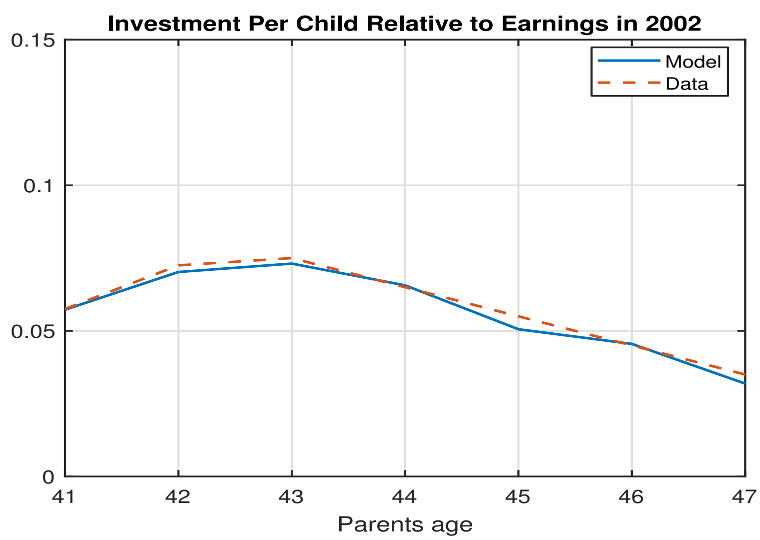

Figure 4: **Optional Education Expenditure Profiles** This figure depicts optional education expense per child as a fraction of parent earnings. The data come from Figure 3 in Choukhmane et al. (2017) (the green area that corresponds to discretionary education expenditure. See the main text of the paper.)

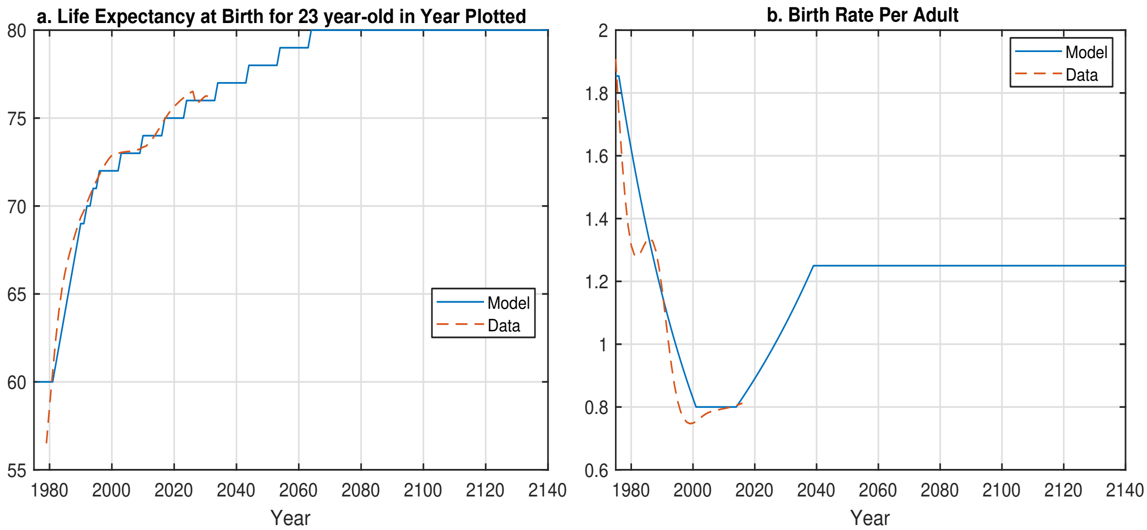

Figure 5: **Exogenous Processes Along the Transition: Demographics** Life expectancy is defined as life expectancy at birth for a person at age 23 in the year plotted. Fertility rate is defined as the average number of births per adult. Data source: World Bank.

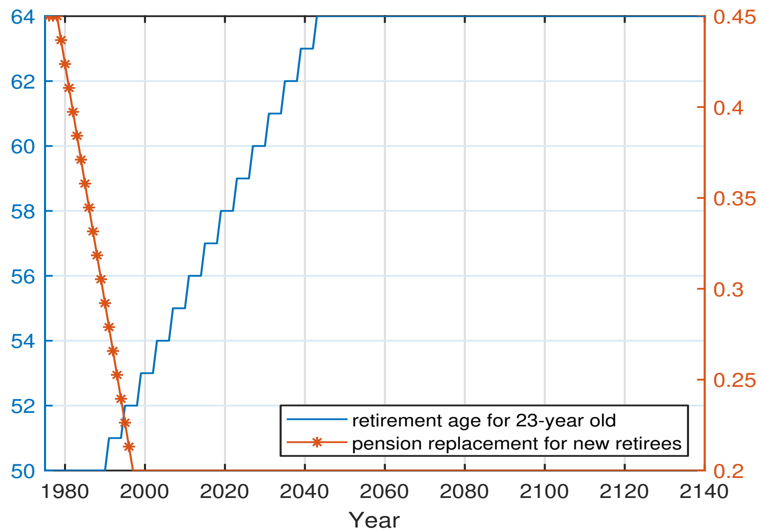

Figure 6: **Exogenous Processes Along the Transition: Retirement** Pension replacement rate uses right y-axis. See the main text of the paper for data construction.

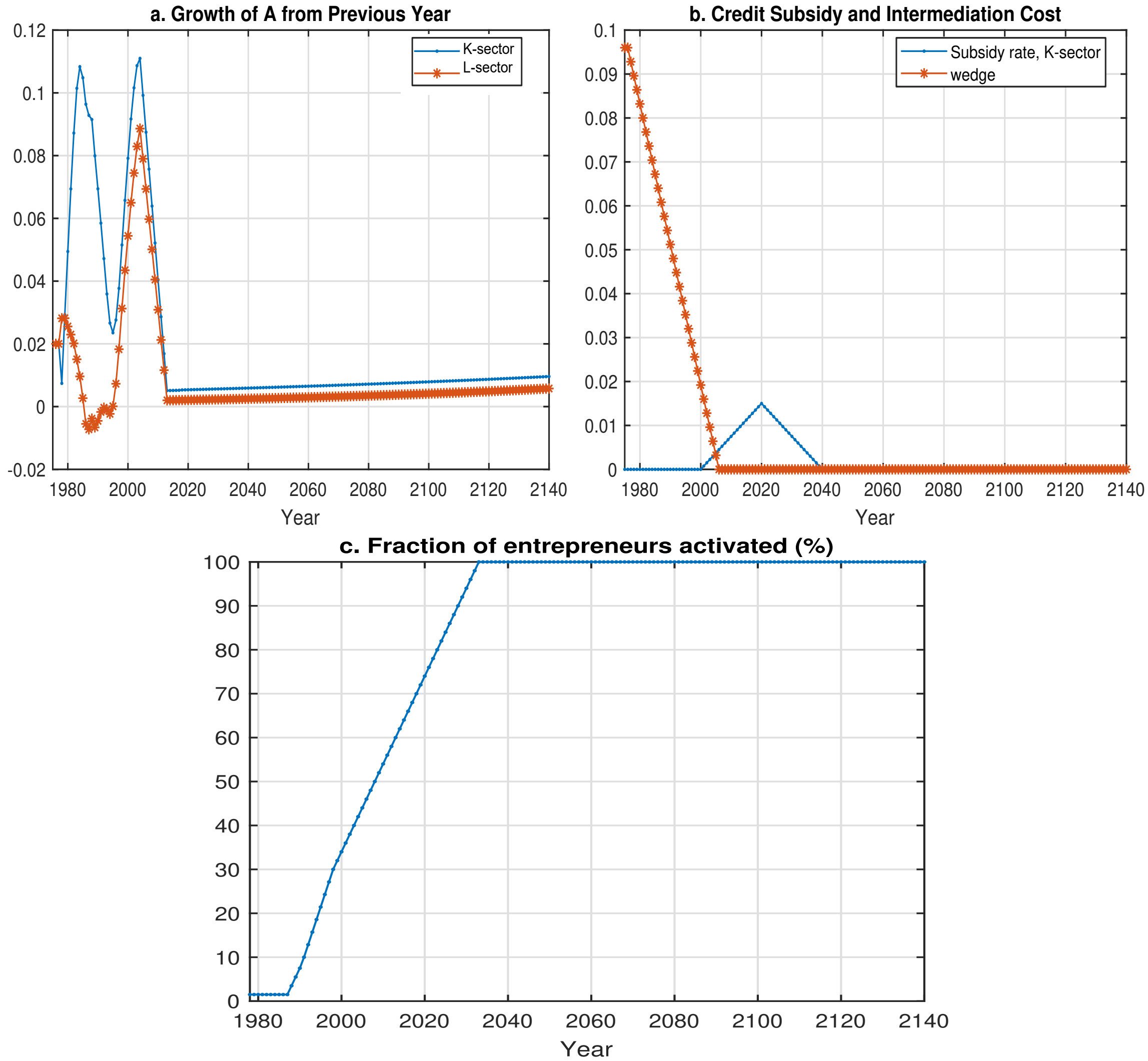

Figure 7: **Firm Side Exogenous Processes Along the Transition** Panel a depicts the growth rates of labor augmenting technology for the K- and L-sector respectively. On Panel b, the dotted line depicts exogenous government interest subsidy changes for firms in the K-sector along the transition path. The solid line describes the intermediation cost. Panel c shows the fraction of entrepreneurs allowed to operate in each cohort of 23-year olds.

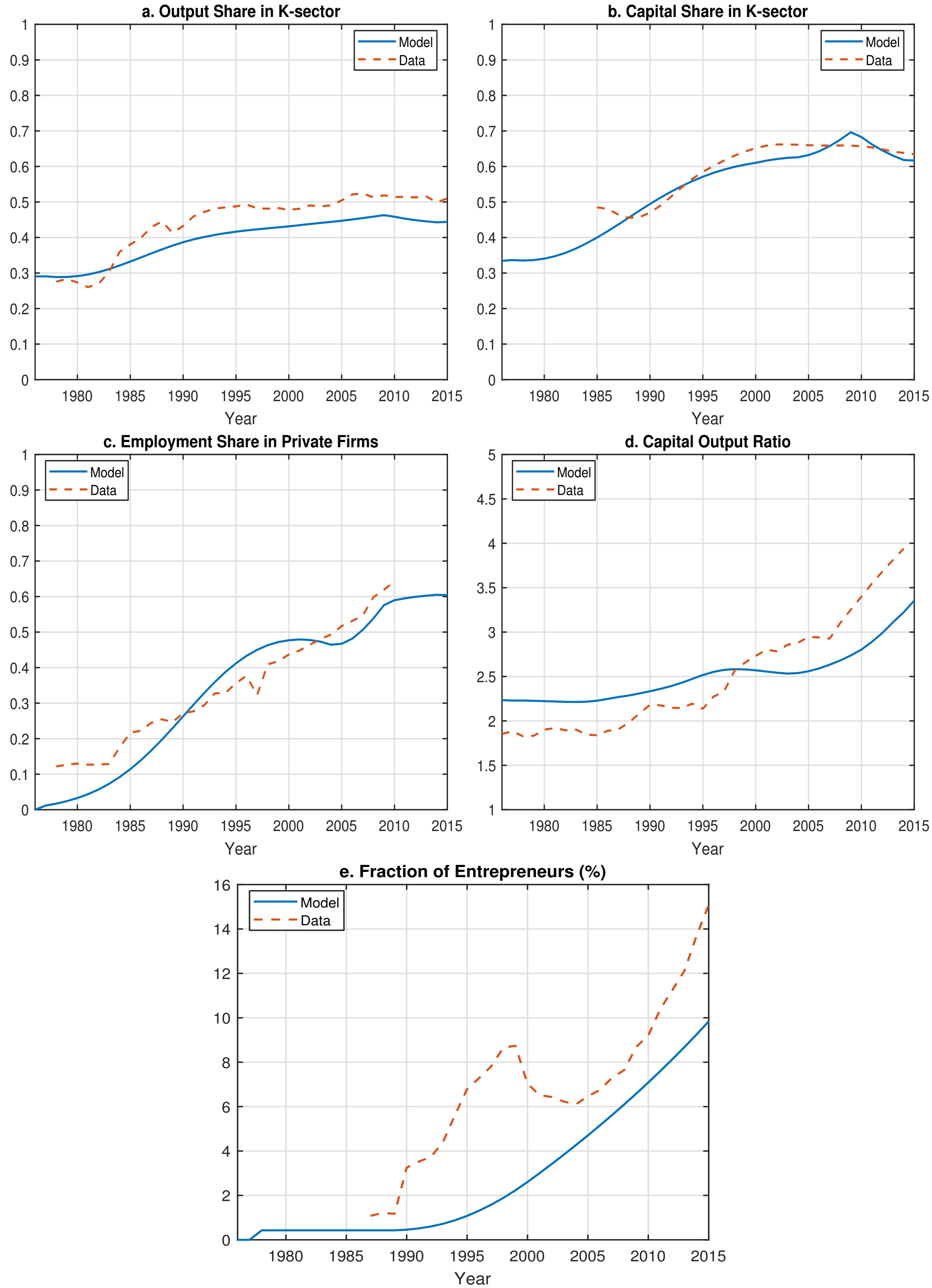

Figure 8: **Firm Dynamics Along the Transition: Data versus Model** Data source: Panels a, b and d: Chang et al. (2015) and China Statistical Yearbook; Panels c and e: China Statistical Yearbook.

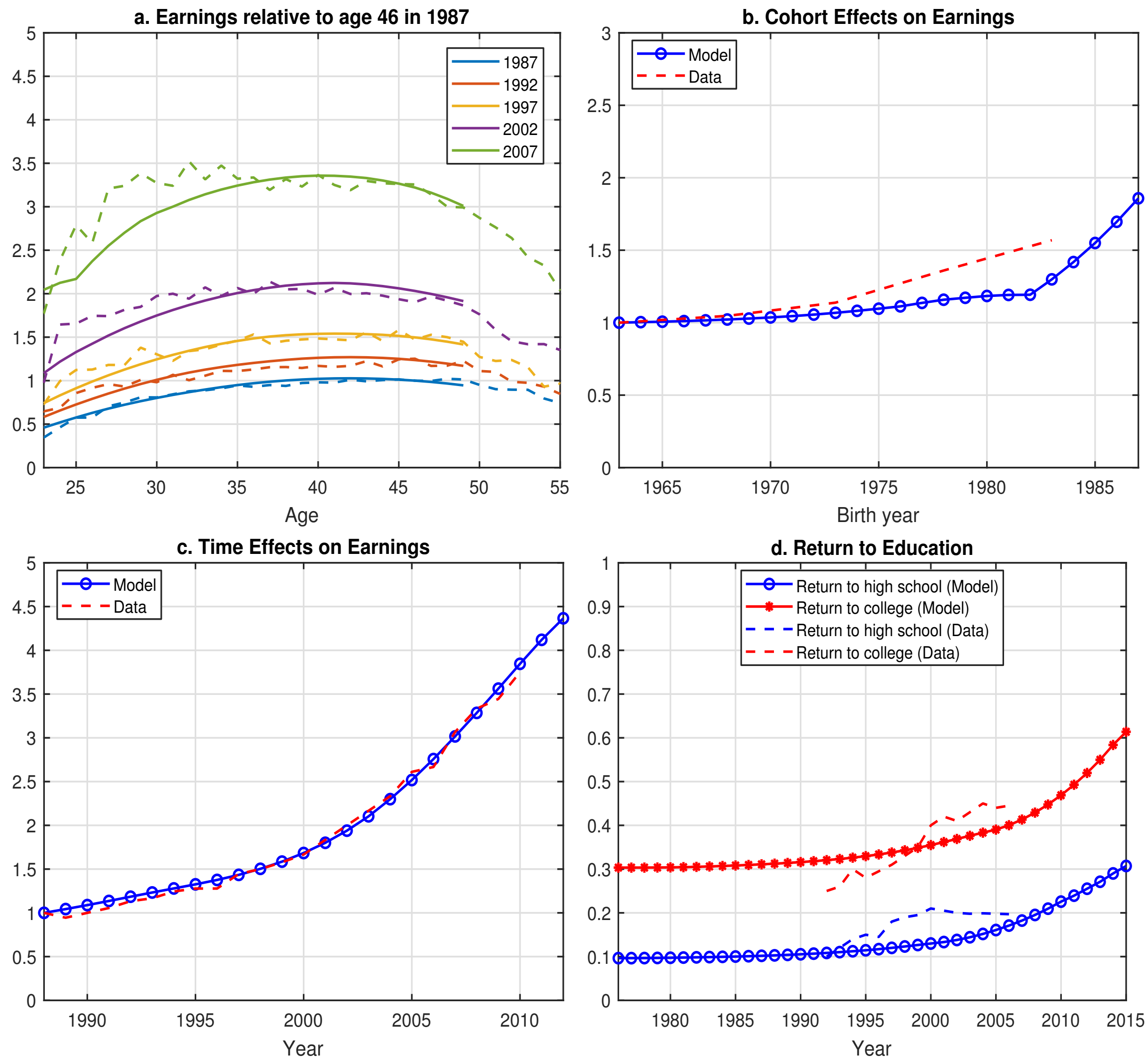

Figure 9: **Return to Human Capital: Model versus Data** In Panel a, earnings are from Urban Household Survey constructed and provided to us by Fang and Qiu (2021). For Panels b and c, the data come from Fang and Qiu (2021) Figure 4. The cohort effect is defined as inter-cohort human capital growth and the time effect refers to changes in the human capital rental price, i.e., wages over time. In Panel d, the return to high school education in our model is defined for each individual as his human capital at age 19 over that at age 16. Similarly, return to college is defined as a person's human capital at age 23 over that at age 16. What is plotted is the log of the economy wide average return to high school and college. The data come from Figure 1 Panel b in Ge and Yang (2014).

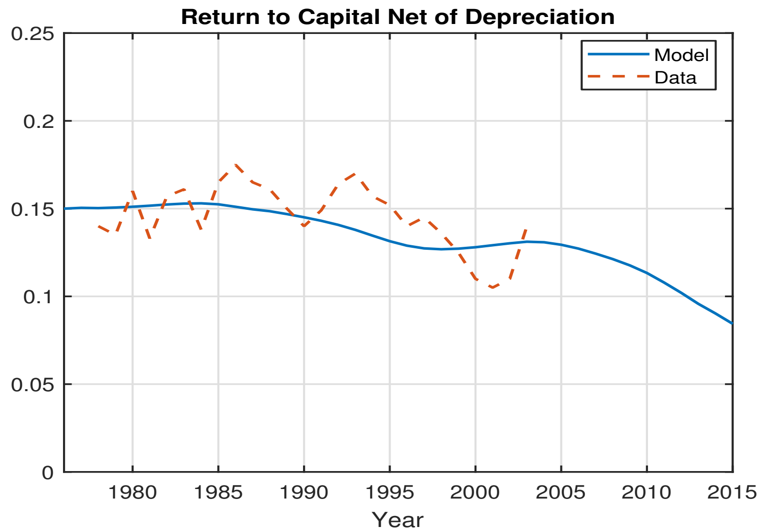

Figure 10: **Marginal Product of Capital** Data come from Bai et al. (2006) Figure 7.

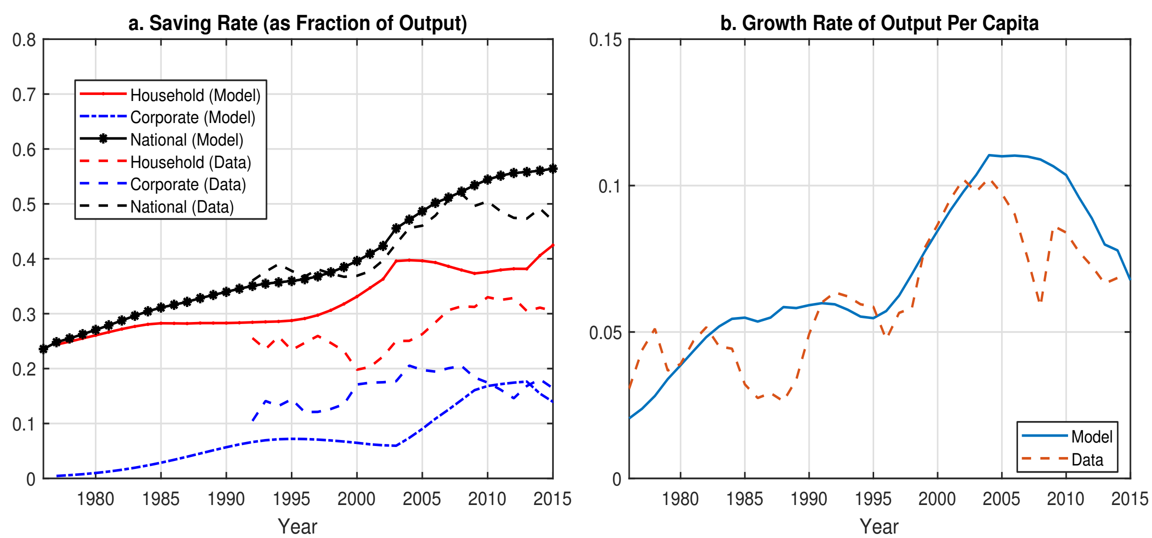

Figure 11: **Savings Rate and Per Capita Output Growth: Model versus Data** Aggregate savings include household and corporate savings. Data on aggregate savings rate are provided by Chang et al. (2015). To arrive at data on the per capita output growth, we first divide output-side real GDP at chained PPPs (2011 US$) by total population, take the growth rates, and then HP filter the series.

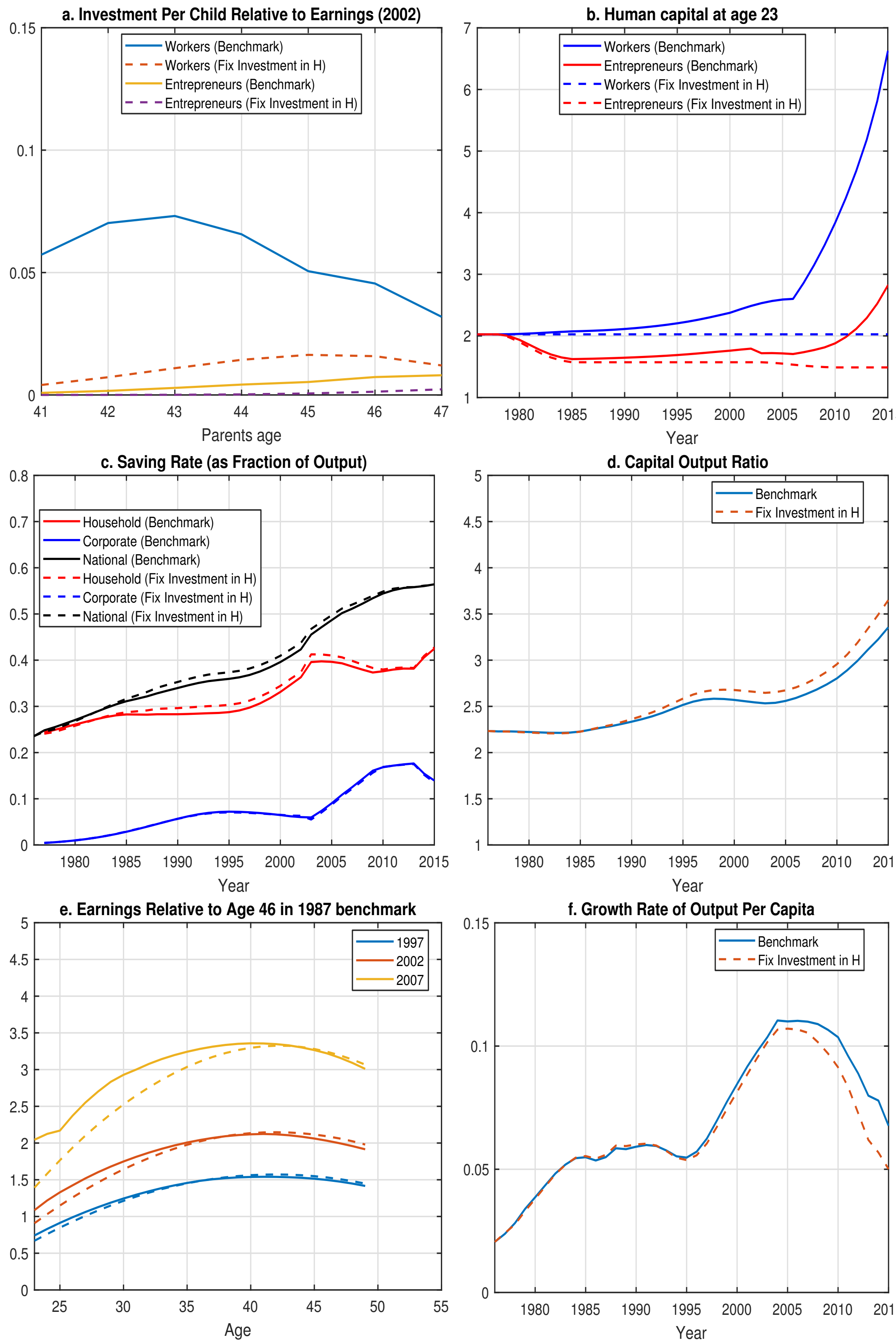

Figure 12: **Selected Economic Statistics: Benchmark versus Exogenous Human Capital Investment** In the exogenous human capital investment experiment, we keep optional education expense per child as a fraction of parent earnings the same as in the initial balanced growth path. The solid lines depict the benchmark economy and the dashed lines depict the experiment.

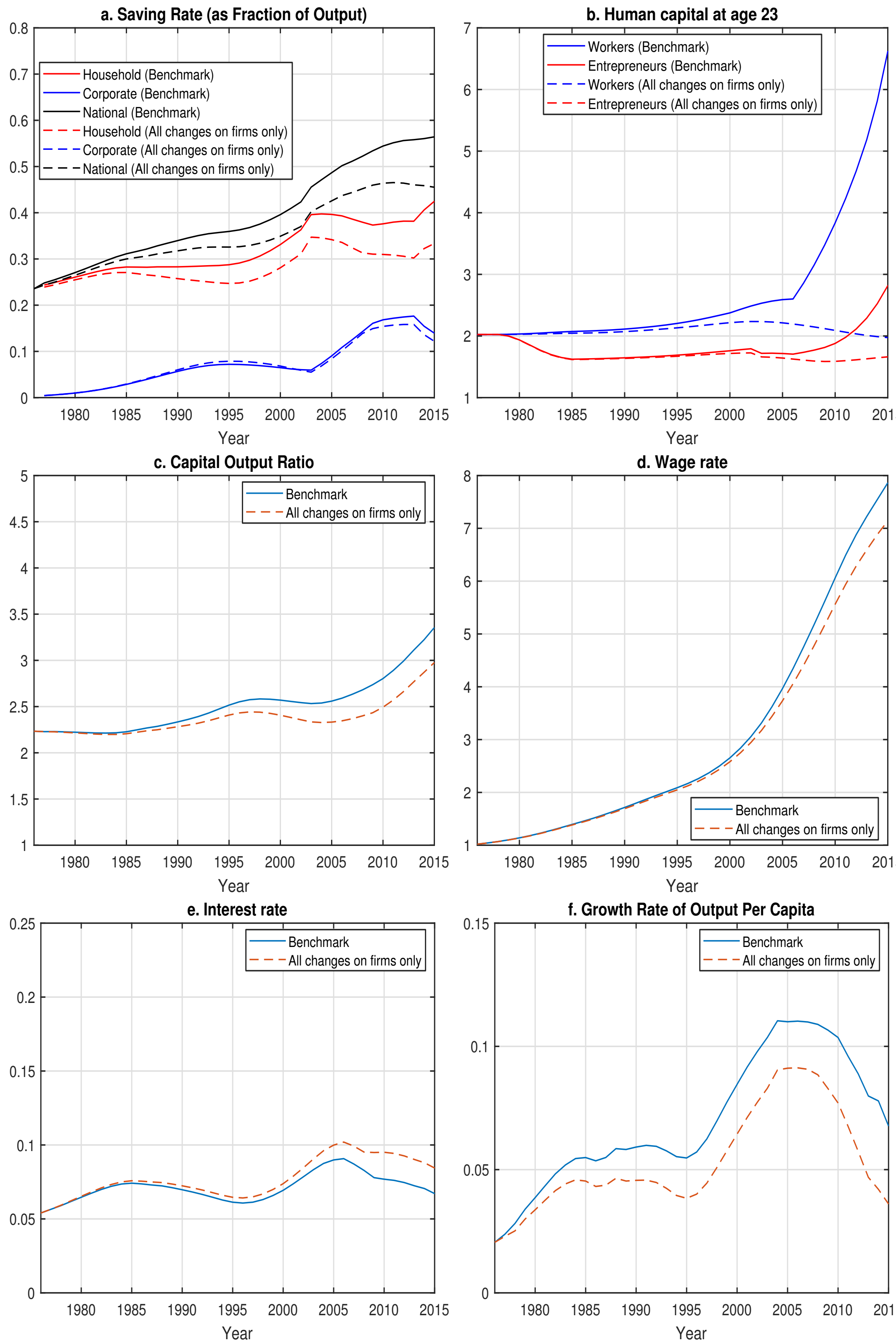

Figure 13: **Selected Economic Statistics: Benchmark versus Firm Side Policy Changes Only Experiment** In the experiment, we implement only firm side structure and policy changes as detailed in the paper. The solid lines depict the benchmark economy and the dashed lines depict the experiment.

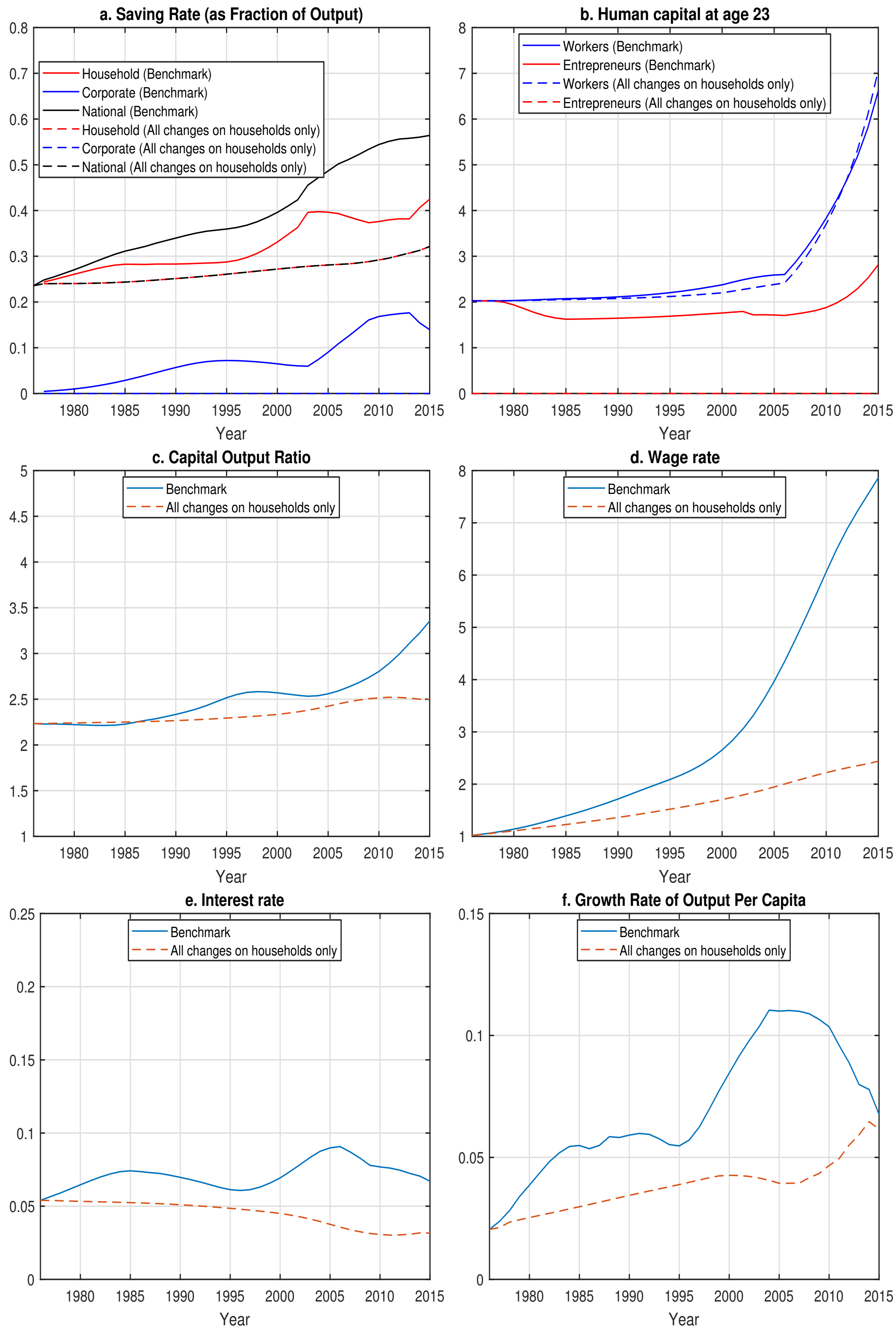

Figure 14: **Selected Economic Statistics: Benchmark versus Household Side Policy Changes Only Experiment** In the experiment, we implement only demographic transitions as detailed in the paper. The solid lines depict the benchmark economy and the dashed lines depict the experiment.

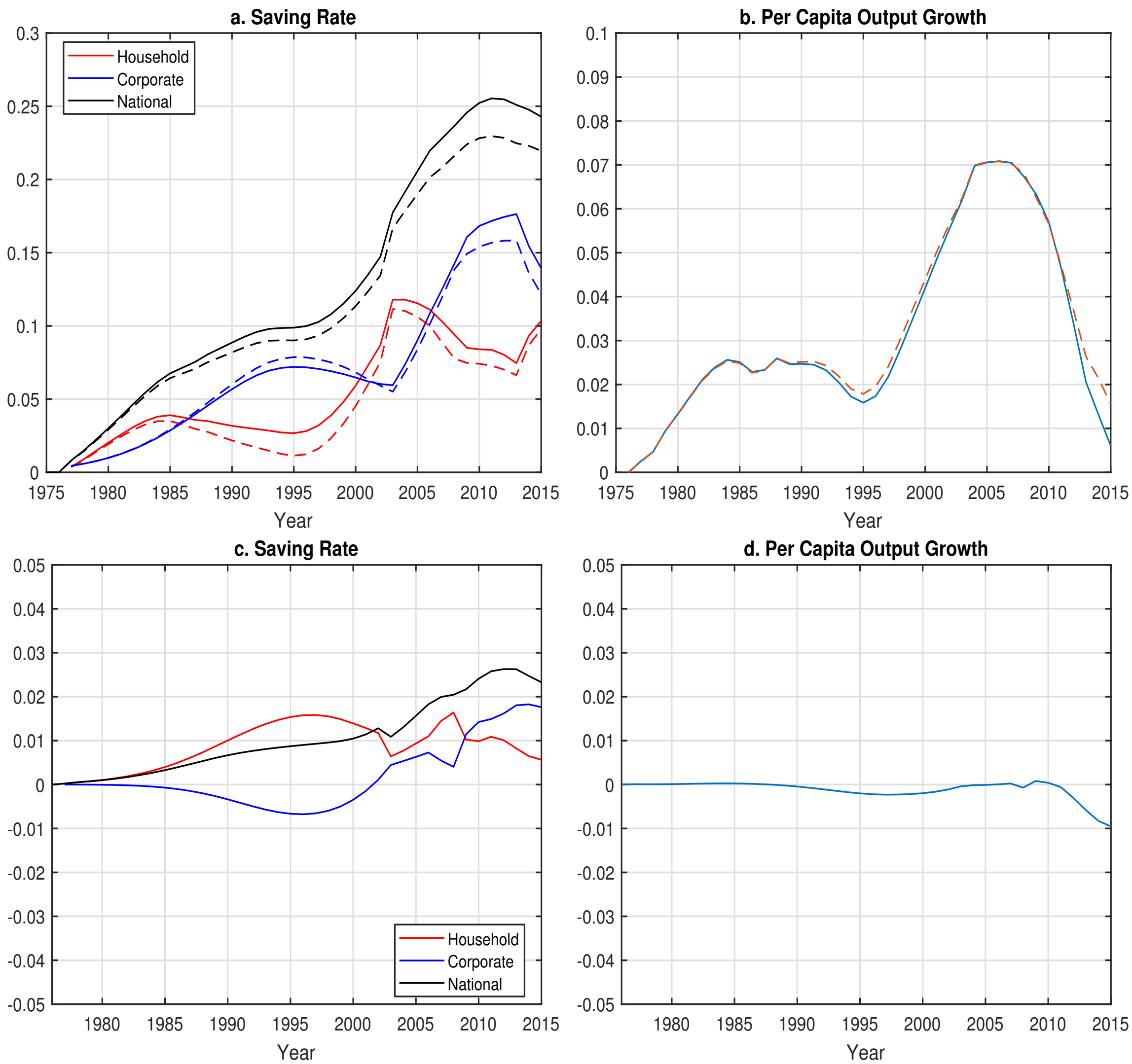

Figure 15: **Savings Rate and Per Capita Output Growth: Impact of the Interactions of Firm Structure and Policy Changes with Demographic Transitions.** The solid lines in Panels a and b are results from Section 7.2 subtracted from results from the benchmark, which capture effects due to the firm side changes and their interactions with the demographic transitions. The dashed lines in Panels a and b are results from Section 7.1 subtracted by their respective 1976 balanced growth path, which capture effects due to firm side changes only. The lines in Panels c and d are the difference between the solid lines and the dashed lines and capture the interaction. See the main text for more details.

Table 1: Household Decisions

Age	$[J_1, J_f + 6]$	$[J_f + 7, J_f + 15]$	$[J_f + 16, J_f + 22]$	$[J_f + 23, J_{r,B} - 1]$	$[J_{r,B}, J_B]$
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 $J_{r,B} - J_f \leq j \leq J_B - J_f$		
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; $J_{r,B}$ is the age at which workers/entrepreneurs 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 age 7 and 15. High school and college education between age 16 and 22 is optional.

Table 2: Growth Rates Along the Balanced Growth Path for Major Economic Variables

Parameter	Description	Growth Rates
Π	Population measure	g_{pop}
$Y, Y_k, Y_l, Y_{l,i}$(i=s,p)	Aggregate output	$(1 + g_A)(1 + g_{pop}) - 1$
$K, K_k, K_l, K_{l,i}$(i=s,p)	Aggregate capital	$(1 + g_A)(1 + g_{pop}) - 1$
$L, L_k, L_l, L_{l,i}$ (i=s,p)	Aggregate labor	g_{pop}
w_t	Per efficiency unit of wage	g_A
$c_j, a_{j+1}(j = J_1, ..., J_B)$	Individual consumption and assets	g_A
i_h	Endogenous human capital investment	0

Note. This table describes the growth rates for different variables at the balanced growth path.

Table 3: Fixed Parameters: First Stage

Parameter	Description	Value	Source
Household			
J_1	Initial age	23	
J_f	Fertility	25	World Bank
σ	Relative risk aversion	1	Macro literature
$\{\Phi_1, \Phi_2\}$	Children living, required educ. exp.	{0.040, 0.030}	Chinese Household Income Project
$\{\mu_0, \mu_1\}$	Transfer to parents	{0.1512, 0.6500}	Choukhmane et al. (2017)
Firms			
α_k	Capital income share in k-sector	0.54	Data, Chang et al. (2015)
α_l	Capital income share in l-sector	0.44	Data, Chang et al. (2015)
φ	Share of k-sector in final good prod.	0.85	Chang et al. (2015)
γ	Elasticity of subst. bt. k- and l-goods	2	Chang et al. (2015)
δ	Capital depre. rate in k- and l-sectors	0.06	Standard
g_A	Exogenous growth rate in balanced growth path	2%	

Table 4: Calibration of Fixed Parameters: Second Stage

Parameter	Description	Value
Household		
β	Discount rate	1.0065
$\{\eta_j\}_{j=16}^{22}$	Human capital invest. efficiency	{0.3266 0.4302 0.4924 0.5208 0.5228 0.5061 0.4783}
$\{e_j\}_{j=j_1}^{J_r-1}$	Polynomial of labor efficiency profile	[-0.0000 -0.0016 0.1384 -1.8545]
$\varkappa$	Weight on human capital invest.	0.58
Firms		
$[A_k, A_{lp}, A_{ls}]$	relative productivity	[0.099, 0.541, 0.969]
η	Collateral constraint for entrepreneurs	0.2853

Table 5: Calibration Results

Moments	Model	Data
Age profiles of earnings in 1986		Figure 3
Education expenditure by age in 2002		Figure 4
Capital-output ratio of state firms (1998–2005)	2.50	2.49 (Song et al. 2011)
Loan to asset ratio of private firms	0.50	0.5 (Song et al. 2011)
Interest rate in 1976(%)	5.400	5.000 (IMF)
Wage rate in 1976	1	1 (normalization)