Demographic Change and Long-term Growth in China:

Past Developments and the Future Challenge of Aging

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Abstract

This paper explores the influence of demographic changes, particularly the sharp decline in fertility and the evolution of the population age structure, on economic development in China. A general equilibrium overlapping generations model with endogenous decisions on fertility, educational investment and factor accumulation is employed for our analysis. The family support provided by children to the elderly, which is a component of traditional culture in Chinese society, is also considered. We find that technological changes matter most for growth. Demographic changes, on average, account for approximately 4% of the growth in China, while their effect is negative in the pre-1980 period. With an extension to include population aging, we find that aging is not necessarily adverse to growth. This finding reflects that a longer life expectancy requires more savings and makes an educational investment for children more attractive, which accelerates physical capital and human capital accumulation. However, if the social norm of family support for aging parents is strict, aging will significantly increase the children's burden and crowd out physical and human capital accumulation.

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1 Introduction

China has experienced rapid economic growth in the past three decades, particularly following its market-oriented economic reform. Figure 1 shows the per capita GDP of China during the period from 1952 to 2014. China experienced stagnation in the 1950s and 1960s and significant growth since the early 1980s.

China's high economic growth has been associated with a sharp decline in fertility. As Figure 2 shows, the total fertility rate (TFR, number of children per woman) in the 1950s and 1960s was above 6 (disregarding the drought period from 1959-65). The TFR rapidly declined to fewer than 3 children at the implementation of the one-child policy and remained between 1 and 2 after 1990.

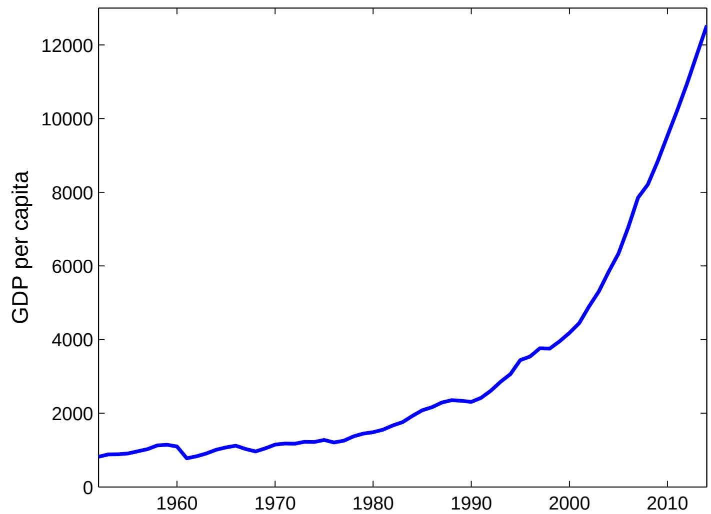
The decline in fertility reduces the dependency ratio in China. Figure 3 shows that the total dependency ratio in China has sharply declined since the 1980s. Labor quality also greatly improved during the same period, as shown in Figure 4. The literature studying demographic transition and economic growth has documented the quantity-quality trade-off mechanism for children and discussed the benefit of lower fertility in the early stage of development.[1] The aforementioned figures also suggest a similar pattern in China. Therefore, in addition to productivity growth and factor accumulation, it is natural to ask the following question: how important is demographic change for China's growth?[2]

This paper undertakes a structural approach. We first develop a structural model that is consistent with certain main economic/demographic features and the pattern of the quantity-quality trade-off of children in China to quantify the importance of the demographic transition in China's development. Although the total dependency ratio has largely declined since 1970, China will soon confront population aging due to the low fertility rate and extended longevity. Figure 5 plots the projected old-age dependency ratio until 2100 in China. The old-age dependency ratio will increase five times, from

[1] For example, Liao (2011) suggests that the demographic transition contributed to approximately 30% of the economic growth from 1970-2004 in Taiwan.

[2] The existing literature mainly focuses on the importance of total factor productivity growth (TFP) or factor accumulation; for example, refer to Chow (1993) and Young (2003). A few empirical studies have attempted to link the demographic transition to China's growth. For example, Li and Zhang (2007) suggest that a decline in the birth rate by 0.1 percent will increase economic growth by 0.9 percent in a year in China's post-reform period. Bloom et al. (2010) suggest that an increase in life expectancy and a rise in the proportion of the working-age population are important for China's growth experience.

Figure 1: GDP per capita in China



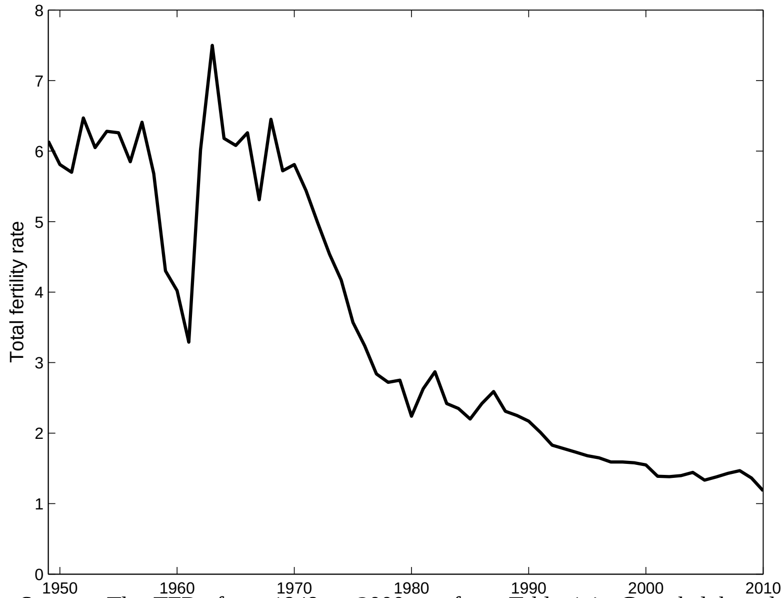
Source: Penn World Table version 9.0. The series of real GDP at constant national prices (2011 US dollars) and population are used to compute the per capita GDP.

approximately 10% in 2010 to 50% in 2100. The impacts of aging on the economy are at least three-fold. First, the proportion of the working-age population will decline, which reduces the labor supply. Second, increased savings are required for a longer retirement life. Third, the extended longevity may affect the incentives for education investment. Therefore, this paper also investigates the potential impact of rapid aging on China's future development.

A general equilibrium overlapping generations model with endogenous decisions on fertility, education investment and factor accumulation is employed for a structural analysis.[3] Given the Chinese culture and social norms, adult children are expected support their retired parents. To incorporate the feature of family support into the model without adding considerable complexity, we adopt a reduced form of transfer from children to retired parents such that the support from adult children in the model is consistent with the data. In our theoretical framework, parents perform the following actions: choose fertility and children's education; allocate their time between raising children and working; and allocate their income between consumption, savings, and expenditures on children.

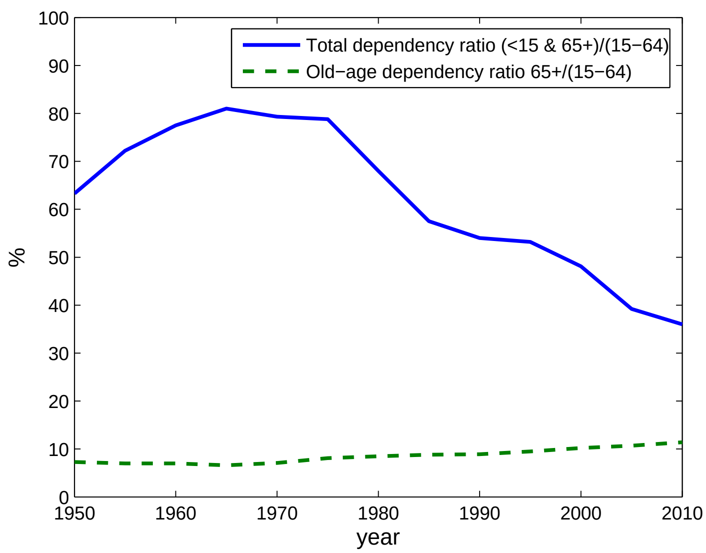
[3]Similar settings can be observed in Liao (2011), Doepke and Zilibotti (2005) and Doepke (2004).

Figure 2: Total Fertility Rates in China



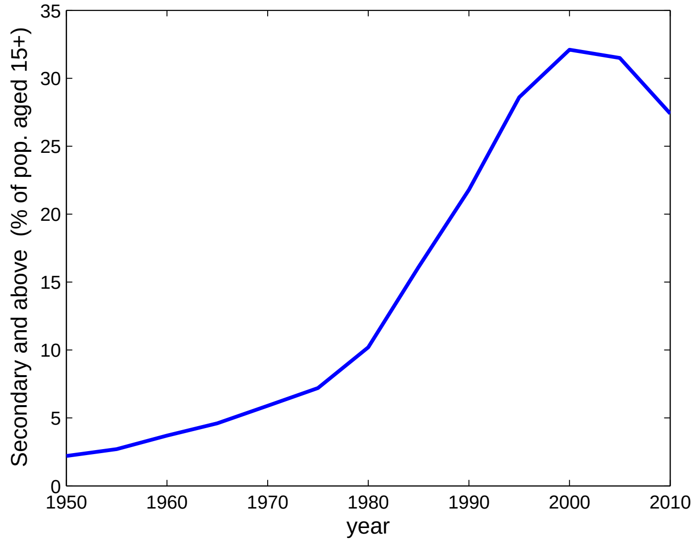
Source: The TFRs from 1949 to 2000 are from Table 1 in Greenhalgh and Winckler (2005). The TFRs from 2001 to 2014 are obtained from *China Population Statistics Yearbook and China Statistical Yearbook.*

Figure 3: Dependency Ratios in China



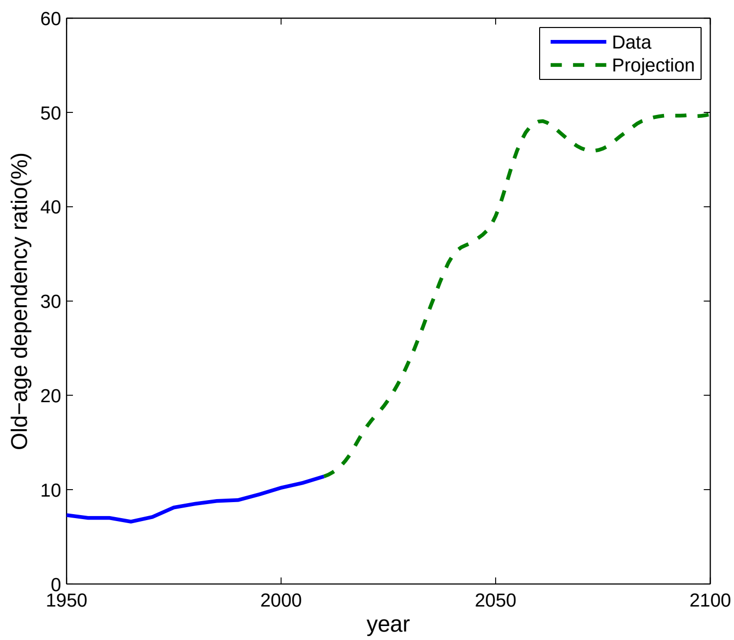
Source: World Population Prospects: The 2012 Revision, Population Division, Department of Economic and Social Affairs, United Nations.

Figure 4: Labor Quality in China



Source: Barro and Lee (2013).

Figure 5: Old-age Dependency Ratio in China



Source: World Population Prospects: The 2012 Revision, Population Division, Department of Economic and Social Affairs, United Nations.

Human capital is discrete, either skilled or unskilled. On the production side, there is a representative firm using skilled labor, unskilled labor and physical capital as inputs.

The demographic transition may affect economic growth through the following channels: 1) change in the working-age population; 2) physical and human capital accumulation; and 3) change in the burden on adult children of family support for the elderly. In the early stage of a demographic transition, a reduction in fertility allows parents to transfer their resources from raising a large number of children to savings and/or education investment in fewer children, which improves the accumulation of physical and human capital. Demographic dividends, physical capital accumulation, and the formation of human capital all contribute to economic growth. In the later stage of a demographic transition, population aging lowers the proportion of the working-age population and increases the burden of family support on adult children; thus, it may slow economic growth. The extended longevity requires more savings and makes education investment more attractive; these have positive effects on growth. The overall influence of aging depends on the relative magnitude of each effect and is not necessarily negative for economic development.

Endogenous fertility is essential to our analysis. The fertility choice is combined with the decision on education investment. Therefore, there is a quantity-quality trade-off for children. Second, technological change has a feedback effect on fertility and the quality of children. If fertility is exogenous in the model, the contribution of demographic transition to growth may be misleading. We further incorporate fertility constraints to capture the main spirit of the one-child policy implemented in the early 1980s in China. Specifically, we differentiate the fertility constraint imposed on skilled parents from that imposed on unskilled parents to represent the stricter enforcement of the one-child policy in cities.

The benchmark model is calibrated to data from China during the period from 1957 to 2007. In particular, data moments around the 1950s, the early 1980s and approximately 2007 are used as our calibration targets to represent the following three stages of China's demographic and economic development. The first stage (the 1950s) denotes a command economy with a high TFR (above 6) and slow economic growth. In the second stage (the early 1980s), the TFR fell to approximately 3, and China was at the beginning of its economic reform and openness. The last stage represents China currently, a market-oriented economy with a low TFR (approximately 1.5) and rapid growth.

To discover the role of demographic change in China's growth, counterfactual experiments are conducted. Specifically, the potential sources of growth are classified into the following two categories: (skill-biased) technological change and demographic transition. Our numerical result suggests that technological change is the most important source in explaining China's growth throughout the entire period. This finding is consistent with the growth accounting literature, which generally attributes the rapid growth of China in the post-reform period to TFP growth and a high rate of physical capital accumulation.[4] We also find that demographic transition represents approximately 4% of the growth in the post-reform period of China, while its impact is negative in the pre-reform period.[5]

To study the effect of aging on the future development of China, we conduct experiments by increasing the survival rate of adults to represent the extension of longevity. The result suggests that the negative effect from a worse population age structure (a decline in the labor supply) can be offset by the higher physical and human capital accumulations. Therefore, the income level can be higher in an aging economy. However, if the social norm strictly requires adult children to take the same responsibility in an aging society, the heavier burden of family support on adult children will crowd out physical and human capital accumulations.

The remainder of this paper is organized as follows. Section 2 provides the theoretical framework and its characteristics in equilibrium. Section 3 describes the selection of parameters and the benchmark results. Section 4 discusses the contribution of technological change and demographic transition to China's growth in the past and investigates the potential impacts of population aging on future economic development. Finally, Section 5 concludes this paper.

2 The Model

The theoretical framework based on Liao (2013), with an extension for family support from adult children to retired parents. We undertake a three-period overlapping generations (OLG) model with endogenous fertility and education investment. Human capital

[4]For example, Borensztein and Ostry (1996); Chow (1993); Hu and Khan (1997); and Wang and Yao (2003).

[5]Cheng (2003) chooses the year 2000 as the initial condition in his calibration. He finds that demographic structures had a small effect on economic growth. Our analysis extends the investigated periods to 1957 to include the periods with a dramatic decline in fertility.

is discrete, either skilled (s) or unskilled (u). Parents make educational choices for children. If parents invest in their children's education, the children will become skilled adults; otherwise, the children will be unskilled adults. Furthermore, to capture the primary essence of the one-child policy in China, a fertility constraint is introduced. Specifically, we differentiate the fertility constraint imposed on skilled parents from that on unskilled parents to represent the stricter enforcement of the one-child policy in cities.

2.1 Demographics

At any point of time, the current population (N) consists of three generations: children (N^c), young adults (N^y), and old adults (N^o):

$$N = N^c + N^y + N^o.$$

Human capital is discrete. A young adult is either skilled or unskilled, which was determined by his parents. Therefore, the population of young adults is given by:

$$N^y = N^y_s + N^y_u.$$

Assume that young adults give birth at the beginning of the period. Fertility is denoted as n_{ij}, which represents the number of j-type children that an i-type young adult has, $(i, j) \in \{s, u\}$.[6] A young adult can have both skilled and unskilled children. The population of children is then given by:

$$N^c = (n_{ss} + n_{su})N^y_s + (n_{us} + n_{uu})N^y_u.$$

Although human capital is discrete, the accumulation of human capital in the economy can be measured by the ratio of skilled young adults (skilled workers) to total young adults (total workers), $\frac{N^y_s}{N^y}$ ($\frac{L_s}{L}$).

Children survive to young adulthood with probability π^c. In addition, young adults will be alive in old adulthood with probability π^y. Therefore, the evolution of the population in this economy is given by:

$$\begin{aligned} N^{y'} &= \pi^c N^c; \\ N^{o'} &= \pi^y N^y; \end{aligned}$$

where $N^{y'}$ is the population of young adults in the next period, and $N^{o'}$ is the population of old adults in the next period.

[6] In this paper, we use i to denote the type of a young adult and j to represent the type of his/her children.

2.2 Production

There exists one representative firm that uses skilled labor L_s, unskilled labor L_u, and physical capital K as inputs. The firm uses a CES technology, and the production function is given by:

$$Y = A\{\mu L_u^{\alpha} + (1-\mu)[\theta K^{\rho} + (1-\theta)L_s^{\rho}]^{\frac{\alpha}{\rho}}\}^{\frac{1}{\alpha}}, \tag{1}$$

where Y denotes the aggregate output; A denotes the total factor productivity (TFP); μ is the factor weight on unskilled labor; θ is the factor weight on physical capital; α determines the elasticity of substitution between L_u and K; and ρ determines the elasticity of substitution between K and L_s. The above setting implies that the elasticity of substitution between unskilled labor and physical capital is equal to the elasticity of substitution between unskilled labor and skilled labor. The capital-skill complementarity requires $\alpha > \rho$.[7]

Equation (1) is a constant-return-to-scale function. Therefore, output per capita (y_{pc}) is given by:

$$y_{pc} = \frac{L}{N} A[\mu l_u^{\alpha} + (1-\mu)(\theta k^{\rho} + (1-\theta)l_s^{\rho})^{\frac{\alpha}{\rho}}]^{\frac{1}{\alpha}},$$

where $l_u = \frac{L_u}{L_s+L_u}$, $l_s = 1 - l_u$, and $k = \frac{K}{L_s+L_u}$. Demographic change results in changes in the labor-population ratio, the fraction of skilled labor as a percentage of total labor, and the physical capital per unit of labor; therefore, it affects output growth.

2.3 Individuals' Problem

The life-cycle is simplified to be three periods. By assumption, child labor is not allowed. Thus, children cannot work and depend on their parents for support. Old adults retire from the labor market. They consume their own savings and family support obtained from their adult children. Only young adults can supply labor and make decisions. A young adult with skill type i chooses consumption at young adulthood (c_i^y), savings (a_i'), the number of children for each type n_{is} and n_{iu}, and children's education. However, the one-child policy established a fertility upper bound for each parent. Therefore, in our framework, the number of children that a young adult has should satisfy the fertility constraint $\sum_{j=\{s,u\}} n_{ij} \leq \overline{n}_i$.

[7] The hypothesis of capital-skill complementarity is also used in the demographic literature, such as Fernández-Villaverde (2001). Empirical studies find evidence to support this hypothesis. See Griliches (1969) and Papageorgiou and Chmelarova (2005).

The maximization problem of an i-type young adult can be expressed by:

$$V_i = \max_{\{c_i^y, a_i', n_{is}, n_{iu}\}} \left\{ \frac{c_i^{y\,1-\sigma}}{1-\sigma} + \beta\pi^y \frac{c_i^{o'\,1-\sigma}}{1-\sigma} + \psi[\pi^c(n_{is}+n_{iu})]^{-\varepsilon}[\pi^c n_{is} V_s' + \pi^c n_{iu} V_u'] \right\},$$

subject to

$$\begin{aligned} c_i^y + \pi^y a_i' &= (1-\tau_i^f)[1-\phi(n_{is}+n_{iu})]\tilde{w}_i - \phi_s n_{is}\tilde{w}_s; \\ c_i^{o'} &= (1+\tilde{r}')a_i' + F_i; \\ \sum_{j=\{s,u\}} n_{ij} &\leq \overline{n}_i; \\ \tilde{w}_i &= (1+\tau_w)w_i; \quad \tilde{r} = (1+\tau_r)r; \end{aligned} \tag{2}$$

where $c_i^{o'}$ denotes the agent's consumption in old age; w_i represents his wage income; β is the subjective discount factor; σ is risk aversion; ψ is an altruism coefficient that represents how much the young adult loves his children; ε is the elasticity of altruism; V_s' is the utility that a child will have when he becomes a skilled young adult; and V_u' is the utility that a child will enjoy when he becomes an unskilled young adult. V_s' and V_u' are both foreseeable for the young adult when he is making decisions.

Assume each young adult has one unit of time. ϕ is the time cost of raising a child. A young adult supplies the remainder of his time to the labor market and earns the wage rate w_i. ϕ_s is the education time cost. We assume that only skilled young adults can teach children. Therefore, if a young adult, skilled or unskilled, wants to provide education to his children, he has to send his children to school and pay the education costs $\phi_s\tilde{w}_i$ for each child.[8]

There is a perfect competitive annuity market that allows a young adult to contribute $\pi^y a_i'$ at young adulthood and receive this annuity when retiring. An old adult consumes his own savings with the before-tax asset return, $(1+r')a_i'$. r' is the interest rate in the next period. To consider the command economy in early China, two distortions of factor prices, which may alter the levels of labor supply and investment, are introduced in the model. τ_w denotes the distortion on wage income for both skilled and unskilled labor. τ_r denotes the distortion on rate of asset return. We use $\tilde{w}_i$ to denote the observed wage rate for type-i labor ($\tilde{w}_i = (1+\tau_w)w_i$), and $\tilde{r}$ is the observed interest rate ($\tilde{r} = (1+\tau_r)r$).

[8]The wage rate for being a teacher is equal to the skilled wage rate, so that in equilibrium, a skilled adult is indifferent between working in the production sector and being a teacher. The setting implies that the contribution of teachers is not counted in aggregate output.

In addition, Chinese society has a social norm that children are expected to support elderly parents. To incorporate the feature of family support into the model without adding too much complexity, our strategy is to adopt a reduced form of transfer from children to retired parents such that the support from children in the model is consistent with the data.[9] We assume that because of the social norm, adult children have to transfer a fraction τ_i^f (which is skill-type dependent) of her/his total income to support retired parents. The total support from children for a type *i* parent is denoted by F_i.

2.4 Characteristics in Equilibrium

Two characteristics can be shown in equilibrium. First, for the education investment in children, only corner solutions exist: parents will either send all children or no children to school. A simple intuition for this feature is that children within one family are exactly identical in the model. Therefore, skilled and unskilled children will not live in the same family. Second, a young adult will be indifferent between having skilled (paying for the educational cost) and unskilled (not paying for the educational cost) children if the following condition holds:

$$\frac{V_s}{V_u} = \left(\frac{p_{is}}{p_{iu}}\right)^{1-\varepsilon}, \tag{3}$$

where $p_{is} = \phi(1-\tau_i^f)\tilde{w}_i + \phi_s\tilde{w}_s$ and $p_{iu} = \phi(1-\tau_i^f)\tilde{w}_i$. The right side of (3) represents the relative cost of a skilled child to an unskilled child for an *i*-type adult. Since the relative costs are different between skilled adults and unskilled adults, it can be shown that only one type of parent will be indifferent between having skilled and unskilled children.[10]

The maximization problem for a type-*i* individual thus can be rewritten as:

$$\max_{\{c_i^y, a_i', n_{ij}\}} \left\{ \frac{c_i^{y\,1-\sigma}}{1-\sigma} + \beta\pi^y \frac{c_i^{o'\,1-\sigma}}{1-\sigma} + \psi(\pi^c n_{ij})^{1-\varepsilon} V_j' \right\}, \tag{4}$$

[9] Using the 1987 Survey on China's Aged Population, Xiong (2005) reports that in urban areas, on average, 14.7% of the elderly's total income was contributed by children, and the ratio is even higher, 39.5%, in rural areas. We use these numbers to approximate the averages of family support from skilled and unskilled workers, respectively.

[10] The proofs of the two equilibrium properties are similar to Liao (2013) and omitted here.

subject to

$$c_i^y + \pi^y a_i' = (1-\tau_i^f)(1-\phi n_{ij})\tilde{w}_i - \mathbf{1}\{j=s\}\phi_s n_{ij}\tilde{w}_s; \tag{5}$$

$$c_i^{o'} = (1+\tilde{r}')a_i' + F_{ij}; \tag{6}$$

$$n_{ij} \le \overline{n}_i; \tag{7}$$

where $(i,j) \in \{s,u\}$; $\mathbf{1}\{j=s\}$ is an indicator function: $\mathbf{1}\{j=s\}=1$ if $j=s$ and 0 otherwise. $\overline{n}_i$ is the fertility constraint for an i-type parent. F_{ij} is the total transfer received from type-j children. For the interior solution, the first order conditions are given by:

$$\begin{aligned} n_{ij}^{\varepsilon} p_{ij} &= \psi(1-\varepsilon)\pi^{c^{1-\varepsilon}} V_j'[(1-\tau_i^f)\tilde{w}_i - \pi^y a_i' - p_{ij}n_{ij}]^{\sigma}; \\ \frac{c_i^{o'}}{c_i^y} &= [\beta(1+\tilde{r}')]^{1/\sigma}. \end{aligned} \tag{8}$$

where $p_{ij} = \phi(1-\tau_i^f)\tilde{w}_i + \mathbf{1}\{j=s\}\phi_s\tilde{w}_s$, representing the total cost of a j-type child for an i-type adult.

Children are normal goods in our model. An individual's fertility decisions follow Equation (8). Fertility is positively affected by the survival rate of children but negatively influenced by longevity (the survival rate of young adults). In addition, fertility increases as income increases. However, an increase in wage rate pushes the opportunity cost of child-raising up, thus lowering fertility.[11] If the optimal fertility is beyond the fertility constraint $\overline{n}_i$, fertility is exactly equal to the constraint.

Based on the two characteristics, only the following case (the set of combinations of parents' and children's types) leads to a desirable balanced growth path, in which both skilled and unskilled workers exist: $(i,j) \in \{(s,s),(u,s),(u,u)\}$. That is, skilled parents always choose skilled children, a fraction of unskilled parents (λ) choose skilled children, and others ($1-\lambda$) choose unskilled children. This case implies that educational attainment is highly correlated across generations, which is consistent with empirical

[11] We are aware that child labor in rural areas may lower the child-rearing cost and differentiates the child-rearing cost between urban and rural areas. Although we do not model urban and rule areas explicitly, skilled and unskilled workers in our model may approximately contain the same economic mechanisms. Unskilled individuals largely represent the rural residents in the model. The gain of child labor that reduces the cost of having children has been implicitly taken into account in our calibration of child-rearing cost for unskilled parents. We allow the child-rearing cost to be different between skilled and unskilled parents. In the benchmark model (Section 3.2), unskilled parents have a higher fertility rate than skilled parents, which is consistent with data.

findings.[12]

Total family support received by skilled parents (from skilled children) in equilibrium satisfies

$$F_{ss}N_s^o = F_{ss}\pi^y N_{s,-1}^y = \tau_s^f(1-\phi n_{ss})\tilde{w}_s\pi^c n_{ss}N_{s,-1}^y.$$

Thus, we have

$$F_{ss} = \tau_s^f(1-\phi n_{ss})\tilde{w}_s(\pi^c/\pi^y)n_{ss} = \xi_{ss}^f\tilde{w}_s, \tag{9}$$

where $\xi_{ss}^f \equiv \tau_s^f(1-\phi n_{ss})(\pi^c/\pi^y)n_{ss}$. Similarly, the family support to a retired unskilled parent with skilled children (F_{us}) and one with unskilled children (F_{uu}) can be expressed as

$$F_{us} = \tau_s^f(1-\phi n_{ss})\tilde{w}_s(\pi^c/\pi^y)n_{us} = \xi_{us}^f\tilde{w}_s, \tag{10}$$

$$F_{uu} = \tau_u^f[\lambda(1-\phi n_{us})+(1-\lambda)(1-\phi n_{uu})]\tilde{w}_u(\pi^c/\pi^y)n_{uu} = \xi_{uu}^f\tilde{w}_u, \tag{11}$$

where $\xi_{us}^f \equiv \tau_s^f(1-\phi n_{ss})(\pi^c/\pi^y)n_{us}$ and $\xi_{uu}^f \equiv \tau_u^f[\lambda(1-\phi n_{us})+(1-\lambda)(1-\phi n_{uu})](\pi^c/\pi^y)n_{uu}$. In Equation (11), λ is the fraction of unskilled young adults who have skilled children. Population aging implies a higher π^y such that the life expectancy becomes longer. If the social norm only requires type-i children to maintain the same fraction τ_i^f of their earnings to support parents in an aging society, the family support F_{ij} received by an old adult will decrease according to Equations (9)-(11), given all else being equal.[13]

[12]The OECD (2010) has reported that social-economic background has a considerable influence on the secondary education achievement of students and that this persists in tertiary education across generations in all European OECD countries. Previous studies investigating the intergenerational mobility of education in China have similar findings. Gong, Leigh, and Meng (2012) report that the education correlation across generations ranges from 0.62 to 0.73. Golley and Kong (2013) confirm that urban children at least maintain the education level of their parents, while the intergenerational correlation is low in rural areas. Alternatively, intergenerational income mobility can be a proxy of education persistence across generations. Guo and Min (2008) as well as Gong, Leigh and Meng (2012) conclude that the relative positions of children in the income distribution are largely related to the income of their parents. In addition, they assert that education plays an important role in explaining the income correlation.

[13]We assume that parental support is equally shared by children within a family for two reasons. (1) The total fertility rate has been below 2 for decades in China. Because most families only have one child, birth order or gender difference becomes less relevant for parental support, particularly in our analysis of population aging. Therefore, we abstract from the birth order and the gender of children to reduce the complexity of the theoretical model. (2) In a recent study, Lin et al. (2003) use Taiwanese data (because Taiwan preserves the traditional Chinese culture and does not have any strict population control such as the one-child policy) and find that birth order does not have a significant effect on the responsibility for parental support.

In contrast, if the social norm strictly requires children to maintain the same level of family support to parents (maintain the ratio $\frac{F_{ij}}{c_i^o}$) in an aging society, it implies a higher burden for each child – the fraction of earnings for transfer to parents τ^f will have to increase. This can be shown from the following equation of τ^f for a type-j young adult with a type-i parent:

$$\begin{aligned}\tau^f &= \left(\frac{\pi^y}{\pi^c}\right)\frac{F_{ij}}{(1-\phi n_{ss})\tilde{w}_j n_{ij}}, \text{ if } \ j = s; \\ &= \left(\frac{\pi^y}{\pi^c}\right)\frac{F_{ij}}{[\lambda(1-\phi n_{us})+(1-\lambda)(1-\phi n_{uu})]\tilde{w}_j n_{ij}}, \text{ if } \ j = u\end{aligned} \tag{12}$$

All else being equal, a higher π^y increases τ^f.

The government maintains a balanced budget every period. This implies that institutional distortions, including taxes, subsidies and other government policy tools, are self-financed. In equilibrium, the following condition holds:

$$\begin{aligned}&\tau_r r \pi^y [a_{ss} N^y_{s,-1} + a_{us} \lambda N^y_{u,-1} + a_{uu}(1-\lambda) N^y_{u,-1}] + \tau_w \{[1-(\phi-\phi_s)n_{ss}] w_s N^y_s \\ &+ [(1-\phi n_{us}) w_u + \phi_s n_{us} w_s] \lambda N^y_u + (1-\phi n_{uu}) w_u (1-\lambda) N^y_u\} = 0.\end{aligned}$$

The above equation implies that either τ_r or τ_w is negative.[14]

In the model, a lower fertility rate contributes to growth through the following mechanism. First, a lower fertility rate means fewer children and more time to work. Second, a lower fertility rate implies more resources for parents' savings. Hence, physical capital is accumulated. Finally, parents may be willing to provide more education if they have fewer children, which leads to human capital formation. These three channels then affect the aggregate output.

2.5 Market vs. Command Economies

Our analysis includes the pre-reform period, when China was a planned economy. Thus, here we provide a discussion of the appropriateness of using the above model to characterize China's economy before proceeding to the calibration of the model.

To capture the influence of the planning element in the Chinese economy, the literature usually introduces certain costs or price distortions to a "neoclassical-type" market framework.[15] Chow (1985) also uses a market-oriented model to study Chinese output,

[14]The definition of a recursive competitive equilibrium in Liao (2013) can be applied here.

[15]See, for example, Scotese and Wang (1995) and Liao (2013).

consumption and investment paths and suggests that the market model was a reasonable characterization of how the economy would evolve without political interference. He uses the residuals from the estimated model as indicators for periods of political importance. He finds that except for certain periods with special government policies, such as the Great Leap Forward and the Cultural Revolution, the residuals were not large.

Some previous studies employ a market-oriented model to study the Chinese economy. However, to carefully address this issue, we still introduce price distortions in our framework to describe the elements of a planned economy. The institutional distortions will be captured by the price distortions. In addition, the inefficiency of a command economy will be captured by the calibration of TFP (i.e., A in the production function) in our quantitative analysis. Therefore, in our analysis, the effect of technological change on growth includes that from efficiency improvements.

3 Parameter Selection and the Benchmark Economy

The benchmark is calibrated to the data for China in the 1950s, the 1980s and the 2000s to represent the three stages of China's demographic and economic development. In the first stage, the TFRs in the economy were stable at a level around 6 (except for the three years of the Great Chinese Famine from 1959 to 1961), and economic growth was low. The TFR began to sharply decline during the 1960s and 1970s. Then, the TFR stayed at a level of approximately 2 to 3 in the 1980s (the second stage), and China was at the beginning of economic reform and openness. The one-child policy was officially introduced at this stage. The last stage represents the current China, a market-oriented economy with a low TFR (approximately 1.5) and rapid growth. Since the TFRs in the three stages were relatively stable, each stage is solved as a steady state.[16]

Specifically, data moments around 1957, 1982 and 2007 are used as our targets in the calibration. We first choose 1982 for the following three reasons: (i) it was the beginning of China's economic reform; (ii) China's one-child policy was made compulsory in 1982, although it was initiated in 1979; and (iii) a population census was held in 1982.

[16]We are aware of some institutional reforms in the first and the second stage. For example, 1957 is the last year of the First Five-Year Plan, and 1982 is the year when the one-child policy officially became effective. However, from the perspective of TFR, the population in the three stages we choose was relatively stable. To simplify the quantitative procedure and focus on our questions, each stage is solved as a steady state.

Therefore, we choose 1982 to be the middle stage and select a twenty-five-year interval, i.e., 1957 and 2007, to be the first and the third stages.[17] In practice, we use the data of those years with relatively stable fertility rates around each target period to approximate the steady-state moments in each stage.

3.1 Parameters

Table 1 summarizes the parameters in each steady state. The model period in the economy is equal to 25 years. Hence, childhood in the model refers to age 0-24 and young adulthood ranges from age 25 to 49.[18] Because we study population aging and its impacts on the economy, our calibration target is to ensure that the dependency ratios (child-young and old-young ratios) match the data targets. The survival rates from young adulthood to old adulthood (π^y) are chosen to match the old-young ratios (age 50+/ age 25-49) in the three development stages, 0.4835, 0.4975 and 0.5237, respectively. The survival rates for young adults in the three stages of the model are 0.4879, 0.5114 and 0.5164, respectively.

Regarding the survival rates from childhood to young adulthood (π^c), because we have used other parameters to match the targeted child-young ratio in each steady state (that will be discussed later), we possess no full capacity to select π^c.[19] According to the steady state model properties,

$$\pi^c = (1 + g_{N^y})/(\frac{N^c}{N^y}). \tag{13}$$

The latter portion (N^c/N^y) in the formula has been determined (as our targets). Thus, we select π^c such that model population growth rate g_{N^y} reflects the targeted young population growth rate.[20]

[17] Although we use the years 1957, 1982, and 2007 to name the three stages (with 25-year intervals), the data moments, which we match, are those around the target years or the yearly averages around the target years. With regard to the choice of the target periods, given that we focus on demographic changes, we choose periods with relatively stable fertility rates as our targets. Moving the target years to a few years before or after the original targets will not affect our analysis results.

[18] Because we undertake a three-period OLG model for analysis, the length of each period should be equal. For example, Doepke (2004) uses a two-period OLG model, and each period is 25 years (for childhood and adulthood). Hansen and Prescott (2002) also use a two-period OLG model, and each period is 35 years (for young adulthood and old adulthood).

[19] The targeted child-young ratios in the three stages are 1.7592, 1.6997 and 0.9861, respectively.

[20] According to the law of demographic motion, $N^y_{t+1} = \pi^c_t N^c_t$, the number of young adults next period is

We only use the data of those years with relatively stable fertility rates around each target period to approximate the steady-state growth rate g_{N^y} and the steady-state population ratios. The data moment we used for the stage labeled 1957 is the average of 1950-1957, for the stage labeled 1982 is the average of 1980-1989 and for the stage labeled 2007 is the averages of 2001-2007. The data source is World Population Prospects. The average annual gross growth rates of the young population for 1950-1957, 1980-1989 and 2001-2007 were 0.91%, 2.79% and 0.29%, respectively. As a result, the survival rates for children in stages 1957, 1982 and 2007 are 0.5736, 0.6047 and 0.9999, respectively.

The annual discount factor (β_a) in the third steady state is calibrated to match the average (physical) capital-output ratio 3.15 from 2002 to 2006.[21] Thus, the annual discount factor in the third steady state is 0.9853. Then, the annual discount factor is converted to be consistent with the model period. We further assume that the annual discount factor does not change across time. Therefore, the discount factors in the first and second stages are both equal to the level of the third stage. In accordance with Doepke and Zilibotti (2005), risk aversion (σ) is set at 0.5. The elasticity of altruism (ε) in the third stage is chosen to be 0.5 such that the relative fertility of unskilled parents to skilled parents is close to that in the data, at 1.9.[22] The elasticity of altruism in the first and second stage are assumed to be equal to the level of the third stage. Finally, the altruism coefficient ψ in the third stage is set as 0.1553 to match the child-young ratio 0.986 in 2007. The altruism coefficients of the first and second stage are fixed at the 2007 level.

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the number of current children last period that survive to the current period. Then, we obtain

$$\pi_t^c = \frac{N_{t+1}^y}{N_t^c} = \frac{N_{t+1}^y}{N_t^y}\frac{N_t^y}{N_t^c} = (1+g_{N_{t+1}^y})\frac{N_t^y}{N_t^c}, \tag{14}$$

When the model economy is in steady state,

$$\pi^c = (1+g_{N^y})\frac{N^y}{N^c}, \tag{15}$$

where subscript t or $t+1$ is removed because the population ratio and the growth are constant over time.

[21]There is no direct information on China's capital stock. Therefore, in accordance with Chow (1993), we estimate the sequence of capital stock in 1952-2006 using the law of motion of capital. Following Chow (1993), the depreciation rate is set at 0.05 in our estimation, and the initial value of capital stock at the end of 1952 (including land values) is approximately 2.7 times the output of 1952. To prevent the effects of initial values, our estimation begins with 1952. We find that the estimated capital-output ratios in the 2000s are not sensitive to the initial capital stock because the investment before 1978 was relatively small.

[22]Data source: China 1990 Population Census Data. We compute the fertility rate by skill type according to the standard definition of total fertility rate.

There are two parameters associated with raising children. The education time cost is chosen to match the ratio of skilled workers to total workers. Barro and Lee (2013) provides the education attainment for the total population in China during 1950-2010. We choose secondary (completed) and tertiary (total) to be the proportion of skilled workers to total workers. However, Barro and Lee (2013) report the ratio for every five years. Thus, interpolation is applied here to obtain the fraction of skilled workers in 1957, 1982 and 2007: approximately 3.0%, 12.6% and 29.9%, respectively. Therefore, we set ϕ_s to be 0.0058, 0.0087 and 0.0270 for each of the three stages, respectively. As reported in Liao (2013), the child-rearing cost in the third stage is set as 17.08%. Then, the child-rearing costs in the first and second stages are chosen to match the child-young (N^c/N^y) ratios 1.7592 in 1957 and 1.6997 in 1982, respectively.

China's one-child policy was initiated in 1979. In 1982, the implementation of the one-child policy was officially formalized in government documents. Hence, no fertility constraints are imposed at the first stage of 1957. We assume that fertility constraints are binding in the second stage of 1982. Liao (2013) adopts the implied national-wide TFR (weighted by population) to compute the country-wide fertility constraint. It is well-known that the one-child policy was strict in cities, while it was not easy to strictly implement in the countryside. Therefore, we set the fertility constraint for skilled parents to be 0.75 because the majority of skilled workers were located in cities. In the calibration, the fertility constraint for unskilled parents is set to be 1.829 such that the relative fertility of unskilled to skilled parents implied by our calculation is around 2.4, which is close to Scharping (2003).[23] Finally, as shown in Figure 2, the TFR in China continuously decreased regardless of the relaxation of the one-child policy since 1991. This indicates that the fertility constraints are not binding in the third stage of 2007. Therefore, the strictness of the one-child policy does not affect the calibrated result in the last stage of 2007. We simply assume that the fertility constraints remain constant.

There are six parameters in the production side, A, α, ρ, μ, θ and δ. TFP (A) in the third steady state is normalized to 100. In the first and second stages, A is calibrated such that the annual growth rate of per capita output in 1957-1982 and 1982-2007 matches 3.8% and 9%, respectively.[24] Thus, A is equal to 15.619 for the first stage and 25.394

[23] The fertility constraint in the model should be interpreted as an average constraint on the whole young population (age 25-49) in the stage of 1982, and most parents already had more than one child at the moment.

[24] Source: China Statistical Yearbook, National Bureau of Statistics.

for the second stage.

According to the estimate in Krusell et al. (2000), we set the elasticity of substitution between unskilled labor and physical capital at 1.67 and the elasticity of substitution between skilled labor and physical capital at 0.67. Their estimate implies that α is equal to 0.401 and ρ is -0.493. α is greater than ρ; thus, capital-skill complementarity is guaranteed in our calibration.

To compute μ and θ, the following procedures are applied. First, the income share of physical capital is calculated. Hu and Khan (1997) compute the income share of total labor for China. However, the time series data are computed until 1994. In accordance with the researchers' methods and data sources, we extend the income share of total labor to 2007.[25] The income share of physical capital in the first steady state is 0.664, which is the average of 1953-1957; 0.604 in the second steady state, which is the average of 1978-1982; and 0.490 in the third steady state, which is the average of 2003-2007. Second, we compute the income share of unskilled labor to total labor income. To do this, the skill premium and the fraction of skilled workers as a percentage of total workers are required. In 1957, the fraction of skilled workers was approximately 3.0 percent; in 1982, it was 12.6 percent. However, the survey of wage rates by education is not available in 1957 and 1982. We thus chose the average wage in the public sector to be a proxy of the skilled wage rate and the average wage in the manufacturing sector to be a proxy of the unskilled wage rate.[26] In addition, as reported in the China Statistical Yearbook 1983, the wage in the public sector is adjusted to represent the additional benefits rather than cash income. The adjustment was 1.179 and 1.217 in 1957 and 1982, respectively. The corresponding skill premium was equal to 1.078 and 1.165.[27] Therefore, the ratios of unskilled labor income to total labor income are 0.967 and 0.857 for the first and second steady state, respectively. The 2006 household survey reported that the skill premium was 1.528 in 2005.[28] The skilled labor ratio rose to 29.9 percent in 2007. These two values reduce the income share of unskilled labor to 0.606 in the third steady state.

With the physical capital income share and unskilled labor income share, we are now ready to compute the factor weights μ and θ in production. They are solved in the

[25] Source: China Statistic Yearbook, National Bureau of Statistics, 2008.

[26] Source: China Statistical Yearbook, various issues, National Bureau of Statistics.

[27] In 1957, the wage was 690 Yuan in the manufacturing sector and 631 Yuan in the public sector. Thus, the skill premium is obtained by $\frac{631}{690} \times 1.179 = 1.078$. In 1982, the skill premium is computed by $\frac{827}{864} \times 1.217 = 1.165$.

[28] Source: National Bureau of Statistics, unpublished data.

process of solving a steady state using the income share of physical capital and unskilled labor.[29] Therefore, μ and θ are respectively equal to 0.4252 and 0.9983 for the first stage steady state; 0.5449 and 0.9883 for the second stage; and 0.6769 and 0.9714 for the third stage. The last parameter is the annual depreciation rate of physical capital. We follow Chow (1993) and set the annual depreciation rate in China at 0.05 and convert it into a 25-year basis.

China in the third stage of 2007 was close to a market-oriented economy. We set the distortions on factor prices (τ_r and τ_w) in the third steady state at 0. Zhuang (1996) uses a general equilibrium model to quantify distortions on factor prices in 1983 of China. Following his estimate, we set τ_r in the second stage to -0.35. With the assumption of a balanced budget, τ_w is solved by the government budget constraint and is equal to 0.457. This calibration result implies that the government taxes capital gains to finance the subsidy on labor returns. This implication is consistent with the findings in Zhuang (1996) that labor was overpaid and physical capital was underpaid in the sample periods. Because we have no information for the distortions in the 1950s, we also assume that τ_r in the first steady state is equal to -0.35. The calibrated τ_w is 0.617.

There are two parameters for family support to retired parents, τ_s^f and τ_u^f for skilled and unskilled workers, respectively. Using the 1987 Survey on China's Aged Population, Xiong (2005) reports that in urban areas, on average, 14.7% of the total income of the elderly was contributed by children and that the ratio was even higher, 39.5%, in rural areas. We assume that adult children are required to support their retired parents such that 14.7% of old-age consumption for individuals with high education (skilled) and 39.5% of old-age consumption for individuals with low education (unskilled) is financed by transfers from their children in our benchmark model. τ_s^f and τ_u^f are chosen such that the above condition is satisfied in each development stage. The details are reported in Table 1.

[29]They are given by the following equations:

$$\frac{K(r+\delta)}{Y} = \frac{(1-\mu)(\theta k^{\rho}+(1-\theta)l_s^{\rho})^{\frac{\alpha}{\rho}-1}\theta k^{\rho}}{\mu l_u^{\alpha}+(1-\mu)(\theta k^{\rho}+(1-\theta)l_s^{\rho})^{\frac{\alpha}{\rho}}}; \tag{16}$$

$$\frac{w_u L_u}{w_s L_s + w_u L_u} = \frac{1}{\frac{1-\mu}{\mu}(\theta k^{\rho}+(1-\theta)l_s^{\rho})^{\frac{\alpha}{\rho}-1}(1-\theta)l_s^{\rho}l_u^{-\alpha}+1}. \tag{17}$$

Table 1: Parameters

	1957 (SS1)	1982 (SS2)	2007 (SS3)	Source/Target
Survival Rates				
π^c	0.5736	0.6047	0.9999	implied by data $\frac{N^c}{N^y}$
π^y	0.4879	0.5114	0.5164	match $\frac{N^o}{N^y} = 0.4835, 0.4975$ and 0.5237 in 1957, 1982 and 2007
Preference				
β_a	0.9853	0.9853	0.9853	2007: match $\frac{K}{Y} = 3.15$ 1957 and 1982: fixed at 2007 level
σ	0.5	0.5	0.5	Doepke and Zilibotti (2005)
ε	0.5	0.5	0.5	2007: fertility ratio (unskill/skill) 1.9 1957 and 1982: fixed at 2007 level
ψ	0.1553	0.1553	0.1553	2007: match $\frac{N^c}{N^y} = 0.986$ 1957 and 1982: fixed at 2007 level
Education/Child-rearing Costs				
ϕ_s	0.0058	0.0087	0.0270	match $\frac{L^s}{L}$=3.0%, 12.6%, and 29.9%
ϕ	0.1073	0.0971	0.1708	1957 and 1982: match $\frac{N^c}{N^y} = 1.7592$ and 1.6997 2007: Liao (2013)
Production				
A	15.619	25.394	100	1957: match annual growth rates of $y_{pc} = 3.8\%$ 1982: match annual growth rates of $y_{pc} = 9\%$ 2007: normalization
kr	0.664	0.604	0.490	1957 and 1982: Hu and Khan (1997) 2007: China Statistic Yearbook
ur	0.967	0.857	0.606	calculated by the definition
$\frac{1}{1-\alpha}$	1.67	1.67	1.67	Krusell et. al. (2000)
$\frac{1}{1-\rho}$	0.67	0.67	0.67	Krusell et. al. (2000)
δ_a	0.05	0.05	0.05	Chow (1993)
Fertility Constraint				
$\overline{n}_s$	-	0.75	0.75	preset
$\overline{n}_u$	-	1.829	1.829	1982: fertility ratio (unskill/skill) 2.4 2007: fixed at 1982 level
Distortion				
τ_r	-0.35	-0.35	0	Zhuang (1996)
Family Support				
τ_s^f	0.381	0.395	0.347	match F_{ss} = 14.7% c_{ss}^o
τ_u^f	0.563	0.456	0.464	match F_{uu} = 39.5% c_{uu}^o

Table 2: Benchmark Economy

	1957 (SS1)		1982 (SS2)		2007 (SS3)	
	Data	Model	Data	Model	Data	Model
Demographics						
n_{ss}		1.171		0.750		0.614
n_{us}		1.762		1.747		0.863
n_{uu}		1.776		1.829		1.190
λ		0.95%		7.07%		17.10%
$\frac{N^c}{N^y}$	1.759	1.759	1.700	1.700	0.986	0.986
$\frac{N^o}{N^y}$	0.484	0.484	0.498	0.498	0.524	0.524
Production						
$\frac{L_s}{L}$	3.0%	3.0%	12.6%	12.6%	29.9%	29.9%
$\frac{w_s}{w_u}$	1.078	1.138	1.165	1.161	1.528	1.525
$\frac{K}{Y}$	2.30	2.466	2.89	2.923	3.15	3.150
$\frac{L}{N}$		0.250		0.261		0.328
Distortion						
τ_w		0.617		0.457		0
Family Support						
τ_s^f		0.381		0.395		0.347
τ_u^f		0.563		0.456		0.464

Note: $\frac{K}{Y}$ in the table refers to the annual capital-output ratio.

Table 3: Benchmark – Average Annual Growth Rates

	1957-1982	1982-2007	1957-2007
y_{pc}	3.8%	9.0%	6.4%
A	2.0%	5.6%	3.8%

3.2 Benchmark Economy

The three steady states are independently solved to represent the three stages of economic development in China. The main features of the three steady states are summarized in Table 2.

In the first stage (SS1), the fertility difference between skilled and unskilled parents is small.[30] Every household has more than three children. However, in the second stage (SS2), fertility constraints are introduced. Both *ss*- and *uu*-type parents are regulated by the fertility constraints. Because the constraint is stricter for skilled parents, the fertility difference between skilled and unskilled parents becomes larger. In the third stage, no parents are affected by the fertility constraints because the optimal fertility choices are lower than the fertility constraints. Thus, the fertility difference declines again.

Our calibration target is to ensure that the dependency ratios (child-young and old-young ratios) match the data. The child-young ratio ($\frac{N^c}{N^y}$) decreases over time from 1.76 in the first stage in 1957 to 0.99 in the third stage in 2007. In contrast, the old-young ratio ($\frac{N^o}{N^y}$) increases over time from 0.48 in the first stage to 0.52 in the third stage. The dependency ratios at a time point are jointly determined by the fertility and survival rates in the past 25 years. The TFR in the model is implied by the target dependency ratios. Thus, the values of TFR in the benchmark economy are not directly comparable to the TFR in the data for a specific period.

Along with the development stages, an increasing number of unskilled parents are willing to invest in education for their children. The percentage of unskilled parents with skilled children increased from 1.0% to 7.1% from SS1 to SS2 and more than 2.5 times (17.1%) from SS2 to SS3. Therefore, the level of human capital($\frac{L_s}{L}$) in the economy has grown, increasing from 3.0% to 29.9%. The increase in the labor force ($\frac{L}{N}$), human capital accumulation and physical capital accumulation ($\frac{K}{Y}$) all contribute to China's growth. As reported in Table 3, the annual growth rate of the per capita output in the data (also in the model) during 1982-2007 is 9.0%, while it is lower during 1957-1982, at 3.8%. The model implies that TFP (productivity) growth rates are 2.0% and 5.6% for 1957-1982 and 1982-2007, respectively. These rates are comparable to the estimates in the literature. For example, Hu and Khan (1997) estimate that TFP growth was 1.1% in 1953-1978, 3.9% in 1979-1994, and 2.1% in 1953-1994. Conversely, Borensztein and

[30]The model is measured at an individual level, so fertility n_{ij} in this paper refers to half of the TFR in the data.

Ostry (1996) estimate that it was -0.7% in 1953-78 and 3.8% in 1979-1994.

The average burden of family support on each skilled and unskilled young adult, respectively τ_s^f and τ_u^f, are chosen such that the fraction of family support from adult children is consistent with the data. As shown in Table 2, they are 0.381 and 0.563 in 1957, 0.395 and 0.456 in 1982 and 0.347 and 0.464 in 2007, respectively.

4 Demographic Change, Development and Aging

The first part of this section conducts counterfactual experiments to examine the influences of demographic change on past economic development in China. The following potential growth factors are particularly analyzed: technological change and demographic transition. The second part of this section is an investigation of the potential impacts of aging on China's future economic development. The impacts of aging can affect economic development through (at least) three channels. First, there is a change in labor supply: the proportion of the working-age population declines, which reduces labor supply. Second, there is a change in the saving incentive: more savings are required for a longer retirement. Third, there is a change in education investment: extended longevity may affect the incentive of education investment. With all else being equal, experiments with various population age structures to represent the degrees of population aging will be performed to discuss their impacts on future economic development.

4.1 The Role of Demographic Change in the Past

China had a crucial economic reform in the early 1980s. For comparison, our quantitative analysis is separated into two periods: the pre-reform period 1957-1982 and the post-reform period 1982-2007. We analyze the impacts of two growth factors: technological change and demographic transition. Specifically, technological change is represented by changes in the three production parameters: A, μ and θ. Changes in the three parameters imply both TFP growth and skill-biased technological progress. Demographic transition refers to changes in the following four demographic parameters: π_c, π_y, ϕ and ϕ_s. They represent the changes in survival rates and the cost of raising children.

The results are summarized in Table 4 for the pre-reform period 1957-1982, Table 5 for the post-reform period 1982-2007 and Table 6 for the entire period 1957-2007. In

Table 4, the column “Technology only” refers to an experiment that only allows technological changes from SS1 (1957) to SS2 (1982), while all others remain unchanged at the level of SS1 (1957). The column “Demographics only” refers to an experiment that only allows demographic changes from SS1 (1957) to SS2 (1982), while all others remain unchanged at the level of SS1 (1957). We perform the same experiments in Table 5 and Table 6. These experiments allow us to isolate the effect of each growth factor.[31]

From 1957 to 1982, the annual growth rate of per capita output in the benchmark is 3.8%. As reported in Table 4, in the scenario with technological change only, the annual growth rate of per capita output is 2.36%. This result is due to the impacts of technological change through the three channels. First, since children are normal goods, the fertility rates of all skill types increase as the child-rearing cost (as a proportion of parent’s income) does not alter. Thus, the labor-population ratio slightly declines (-2.5%). Second, the skill-biased technological change increases the skill premium and makes education more attractive. Thus, the proportion of unskilled parents having skilled children is larger and human capital (L_s/L, the skilled labor share) is accumulated. Third, due to higher fertility rates, the generation with asset holdings (young adulthood) is smaller. Therefore, the capital-output ratio slightly declines even though the asset holdings of each young adult increases. Our result suggests that the effect through human capital accumulation dominates others, so the annual growth rate of per capita output is positive.

Unlike the scenario with technological change only, the annual growth rate of per capita output becomes negative in the scenario with demographic transition only (-2.53%). Demographic transition and higher survival rates make the labor-population ratio smaller than that in SS1. In addition, without the fertility constraint, fertility rates increase due to demographic transition, especially the rate of unskilled parents. The skilled labor proportion is reduced. The capital-output ratio is also lower due to the smaller proportion held by the generation with asset holdings. Therefore, because of the lower factor accumulations and a smaller labor force, a negative growth rate of per capita output is observed. We conclude that in the pre-reform period, technological change plays a more important role in the development of China during 1957-1982, while the demographic transition has a negative impact on it.

[31]The scenario with demographic change and fertility constraints from 1957 to 1982 converges to a steady state in which the fertility rates of all skill types are binding. This is a different equilibrium from those in the technological and demographic experiments. Thus, the scenario with demographic change and fertility constraints is not reported here.

Table 4: China's Growth from 1957-1982 (SS1-SS2)

	Benchmark	Technology only	Demographics only
y_{pc} growth	3.80%	2.36%	-2.53%
$\frac{L}{N}$	0.261	0.244	0.202
	(4.23%)	(-2.47%)	(-19.31%)
$\frac{L_s}{L}$	0.126	0.097	0.018
	(328.31%)	(228.75%)	(-37.87%)
$\frac{K}{Y}$	2.923	2.403	1.931
	(18.55%)	(-2.54%)	(-21.70%)

Note: y_{pc} growth refers to the annual growth rate of per capita output from 1957-1982 (between SS1 and SS2) in the model. Values in parentheses are the percentage change relative to the SS1 of 1957.

The story is slightly different in the post-reform period (1982-2007). Fertility constraints are imposed in the second steady state. As shown in Table 5, the labor-population ratio is greater than that in SS2, and the capital-output ratio increases. Furthermore, skilled-biased technological change encourages the accumulation of human capital. We find that in the scenario with technological change only, the higher labor-population ratio and the human- and physical capital accumulation lead to the rapid growth of per capita output.

The demographic transition during this period has a slightly positive effect on the economic growth in China. As shown in the last column of Table 5, because fertility is lower, the labor-population ratio is greater than that in SS2. The demographic effect explains approximately 4% (0.35/9) of the economic growth in the post-reform period of China. We also find that without technological change, the demographic transition leads to a lower level of human capital (-22.33%). Because education investment becomes more expensive and production technology does not shift toward a skill-bias, parents have less incentive to provide education.

Table 5: China's Growth from 1982-2007 (SS2-SS3)

	Benchmark	Technology only	Demographics only
y_{pc} growth	9.00%	8.47%	0.35%
$\frac{L}{N}$	0.328	0.281	0.312
	(25.96%)	(7.91%)	(19.83%)
$\frac{L_s}{L}$	0.299	0.369	0.098
	(137.30%)	(193.25%)	(-22.33%)
$\frac{K}{Y}$	3.150	3.188	2.757
	(7.77%)	(9.07%)	(-5.68%)

Note: y_{pc} growth refers to the annual growth rate of per capita output during 1982-2007 (between SS2 and SS3) in the model. Values in parentheses are percentage changes relative to the benchmark SS2 of 1982.

Table 6: China's Growth from 1957-2007 (SS1-SS3)

	Benchmark 2007	Technology only	Demographics only
y_{pc} growth	6.37%	5.19%	-0.18%
$\frac{L}{N}$	0.328	0.242	0.293
	(31.28%)	(-3.20%)	(17.21%)
$\frac{L_s}{L}$	0.299	0.282	0.019
	(916.38%)	(858.49%)	(-36.80%)
$\frac{K}{Y}$	3.150	2.445	2.158
	(27.76%)	(-0.85%)	(-12.49%)

Note: y_{pc} growth refers to the annual growth rate of per capita output during 1957-2007 (between SS1 and SS3). Values in parentheses are percentage changes relative to the SS1 of 1957.

Table 7: Impacts of Aging

	Benchmark	Baseline Aging		Strict Social Norm	
		Aging I	Aging II	Aging I	Aging II
π^y	0.516	0.700	0.990	0.700	0.990
Old-Young ratio (Age 50+/25-49)	52%	74%	110%	69%	94%
τ_s^f	0.347	0.347	0.347	0.382	0.416
τ_u^f	0.464	0.464	0.464	0.493	0.519
Average TFR	1.97	1.89	1.80	2.03	2.10
n_{ss}	0.614	0.614	0.614	0.613	0.613
n_{us}	0.863	0.864	0.865	0.877	0.891
n_{uu}	1.190	1.191	1.193	1.260	1.342
$\frac{L}{N}$	0.328	0.309	0.279	0.303	0.271
$\frac{L_s}{L}$	0.299	0.369	0.445	0.316	0.331
$\frac{K}{Y}$	3.150	4.026	5.121	3.430	3.704
$\frac{w_s}{w_u}$	1.525	1.528	1.531	1.567	1.615
Deviation from Benchmark					
Change in output per capita Δy_{pc}	–	23.41%	45.93%	0.88 %	-1.85%
(average annual growth)	–	(0.53%)	(0.95%)	(0.02%)	(-0.04%)

Note: In the scenarios of baseline aging, τ_s^f and τ_u^f are fixed at the benchmark levels. In the strict social norm scenarios, F_s/c_s^o and F_u/c_u^o are fixed at the benchmark levels.

4.2 Population Aging in the Near Future

To study the potential impacts of population aging on future development, we extend the benchmark model with a longer life expectancy to present an aging society. Two aging scenarios with various levels of parental support are presented in Table 7. These scenarios are conducted by increasing the survival probability π^y to 0.70 such that the old-young ratio becomes 74% (denoted by 'Aging I'), and to 0.99 such that the old-young ratio reaches 110% (denoted by 'Aging II'). In a baseline analysis, we assume that the burden on children of supporting retired parents remains constant (i.e., τ_s^f and τ_u^f are fixed at the benchmark levels). We also assume that the capital market is open in China and therefore we adopt a small open economy setting – r is fixed at the international level (which is the same as the benchmark level of 2007 by assumption). All other parameters are fixed at the level of benchmark 2007. The results are summarized in Table 7 under the panel of 'Baseline Aging'.

The result suggests that aging has a relatively small effect on fertility: TFR decreases slightly with a longer life expectancy because parents have an incentive to increase the number of children, who can support them in their old age, but the higher demand of savings for a longer retirement life crowds out the resources for raising children. Furthermore, longevity makes education more attractive. Skilled workers earn more compared with unskilled workers and can save more during the working age to finance their retirement life. The extended longevity requires extra savings for a long retirement life, thus, makes education investment highly valuable. Given that parents care about their children, they are more willing to invest in education in an aging society. Thus, the level of human capital (measured by skilled labor share L_s/L) in the economy increases to 44.5% in the scenario Aging II from 29.9% in the benchmark. In addition, individuals have more savings in response to the extended longevity, and hence, the capital-output ratio K/Y increases from 3.15 in the benchmark to 5.12 in Aging II. Although labor-population ratio declines in the aging economies (Aging I/II), the more accumulations of physical capital and human capital both improve per capita output (y_{pc}). Our result suggests that the effect of human capital and physical capital accumulations dominate and thus the net effect on output is positive. This reflects the increases in per capita output y_{pc} – compared with the level in the benchmark, it increases by 23.4% in scenario I and 45.9% in scenario II, i.e., 0.5%-1.0% annual growth in output per capita, if we assume it takes 40 years to reach the aging scenarios from the benchmark year (2007).

Discussion: Strict Social Norm on Family Support

If the social norm is strict and still requires children to take the same responsibility for the consumption of their retired parents in an aging society, the implications of aging will be flipped. In this case, the proportion of parents' old-age consumption supported by children, F/c^o, remains the same as in the benchmark. Therefore, parents will have less incentives to increase savings for their longer retirement life but higher incentives to have children. As a result, compared with the benchmark and the baseline aging scenarios, the TFRs in the aging scenarios with a strict social norm are higher and the labor-population ratios become lower. However, young adults will have to bear a heavier burden on financing their parents' consumption that crowds out savings and education investment. Thus, the levels of human capital and physical capital are both lower than those in the baseline aging scenarios. We find that with a strict social norm on family support, aging may largely reduce the economic growth and even lead to a lower output per capita level in Aging II. The results are presented in 7 under the panel of 'Strict Social Norm'.

Discussion: Labor Supply from the Elderly

An implicit assumption of our model is that the elderly retire from the labor market. Because our main analysis abstracts from the fact that a proportion of elderly people still work, it is worth exploring the robustness of our results in a case in which old workers are taken into account.

To focus on the effect of the labor supply from the elderly and reduce the complexity of analysis, we consider an economy without parental support from adult children. We assume that a type-i old adult supplies a fraction ξ_i^w of time to the labor market. The budget constraint of the old period is modified as follows:

$$c_i^{o'} = (1+\tilde{r}')a_i' + (1+\tau_w)\xi_i^w w_i^{o'}, \tag{18}$$

where $w_i^{o'}$ is the wage income for type-i old workers. The rest of an individual's maximization problem remains unchanged. The production function is modified accordingly:

$$Y = A\{\mu(L_u^o + L_u^y)^\alpha + (1-\mu)[\theta K^\rho + (1-\theta)(L_s^o + L_s^y)^\rho]^{\frac{\alpha}{\rho}}\}^{\frac{1}{\alpha}}, \tag{19}$$

where L_i^o and L_i^y, $i \in \{(s,u)\}$, denote labor from i-type old and young workers, respectively. The production technology implies that old and young workers within the same

Table 8: Aging with Elderly Workers

	Benchmark	Aging I	Aging II
π^y	0.516	0.700	0.990
Old-Young ratio (Age 50+/25-49)	52%	70%	97%
ξ_s^w	0.3	0.3	0.3
ξ_u^w	0.3	0.3	0.3
Average TFR	1.97	1.99	2.04
n_{ss}	0.693	0.711	0.739
n_{us}	0.801	0.821	0.853
n_{uu}	1.163	1.193	1.241
$\frac{L}{N}$	0.388	0.380	0.368
l_s	0.298	0.332	0.358
$\frac{K}{Y}$	3.150	3.569	3.903
Annual r	4.7%	4.7%	4.7%
$\frac{w_s}{w_u}$	1.531	1.533	1.536
Deviation from Benchmark			
Change in output per capita Δy_{pc}	–	12.28%	19.95%
(average annual growth)	–	(0.29%)	(0.46%)

skill type are perfectly substitutable in production. The benchmark economy of 2007 is then re-calibrated.[32] The new benchmark economy is reported in the first column of Table 8.

Based on the new benchmark economy, we perform experiments on aging with the same two scenarios, Aging I and Aging II, as in the main analysis. As shown in Table 8, the results of the aging experiments with the existence of old workers are consistent with the baseline aging cases in the main analysis (see Table 7).

5 Conclusion

This paper explores the influence of demographic change on economic development in China. A general equilibrium overlapping generations model with endogenous decisions on fertility, education investment and factor accumulations is employed for our analysis. In particular, family support from adult children to retired parents is considered in our framework to capture one of the important family features in Chinese society.

The benchmark model is calibrated to characterize main economic/demographic features in China during the period from 1957 to 2007 to provide the quantitative analysis. We first study the role of demographic change in the past development of China. We find that technological changes matter most for growth. The demographic transition in the post-1980 period explains approximately 4% of the growth in China, while its effect is negative in the pre-1980 period.

With an extension of the benchmark model, we further discuss the potential impacts of aging on the economy in the near future. We find that population aging is not necessarily adverse to growth because the longer life expectancy requires more savings and makes the education investment in children more attractive, which accelerates physical and human capital accumulation and leads to a higher income level. However, if the social norm of supporting parents in an aging society still strictly requires children to take the same responsibility as before, this heavy burden will crowd out savings/education

[32] We further re-define the following variables in the model: $L = L_s^y + L_s^o + L_u^y + L_u^o$; $l_s = \frac{L_s^y + L_s^o}{L}$; $l_s^o = \frac{L_s^o}{L_s^o + L_u^o}$; $l_s^y = \frac{L_s^y}{L_s^y + L_u^y}$. In the benchmark economy of 2007 with old workers, the annual discount factor β_a is set at 0.9702 to match the capital-output ratio 3.15; the altruism coefficient ψ is chosen to be 0.1776 to match the child-young ratio 0.9861; the cost of education ϕ_s is adjusted to 0.0505 so that $l_s^y = 29.9\%$. Following the definition, the unskilled labor income share is computed to be 0.6059. Then, μ and θ are solved to be 0.6768 and 0.9714, respectively. Finally, we assume that ξ_s^w and ξ_u^w are both at 0.3. Other parameters remain unchanged.

investment, and the effect of aging on development could be reversed.

The impact of population aging on an economy is multi-dimensional. This paper focuses on one dimension – economic development through the channels of labor supply and human and physical capital accumulation. We abstract from other dimensions to highlight the main mechanism and simplify the model's complexity.[33] This paper suggests that in terms of economic development, we can be more positive regarding the impacts of population aging in developing countries, such as China.

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[33] For example, in the literature studying the impacts of aging on public finance, previous research typically focuses on the heavy fiscal burden caused by aging. We abstract from this dimension in the current study and place a limitation on discussing fiscal arrangements for aging under the current framework. It is worth considering further study with the dimension of fiscal burden to provide a comprehensive analysis. Nevertheless, this extension would not be trivial when modeling developing economies because of the high inequality on pension/social insurance coverage between rural and urban areas. Also, considering the existence of a large informal (untaxable) sector in developing economies is also an important extension.

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Appendix: The One-Child Policy in China

China's one-child policy was initiated in 1979. In 1982, the implementation of the one-child policy was officially formalized in government documents. The main rules were as follows: one couple could have one and only one child, a second child was allowed with permission in a few cases, and a third child was not allowed under any circumstances. Based on the main rules, the one-child policy was strictly applied during the period from 1980 to 1984. At that point (1984-1991), the one-child policy was adjusted and slightly relaxed. For example, minorities were allowed to have two children after 1984, and some special cases could even have a third child. In 1988, if the first child was a girl, couples in rural areas could have another child with permission and a birth interval arrangement. After 1991, due to the relatively low fertility rate, the aim of China's population policies shifted to maintaining a stable birth rate. Therefore, the regulation of the one-child policy was gradually relaxed. For example, after 2001, a couple was allowed to apply for and schedule a second child if they were qualified. Starting in 2013, if one of a couple was a single child, that couple would be allowed to have two children. Finally, the one-child policy was abolished in 2015.