Demographic Transition, Human Capital and Economic Growth in China*

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September 26, 2019

Abstract

We assess the impact of demographic changes on human capital accumulation and aggregate output using an overlapping generations model. We focus on China as it has experienced rapid changes in demographics as well as human capital levels between 1970 and 2010. Additionally, further variations in demographics are expected due to the recently introduced two-child policy. Model simulations indicate that education shares and income per capita will be lower with a fertility rebound as compared to status quo fertility. However, declines in the latter can be offset by a 4.7% increase in the government education budget.

JEL classifications: E62, H55, I13, J11, J13
Keywords: China, health, aging, fertility, human capital

*This project was supported by the National Institute of Health (NIH, Grant No.: 5R01AG048037-02). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Institute of Health.

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1 Introduction

Population aging and an associated slowdown in economic growth is a major concern in many countries. Rising old age dependency ratios may increase the private burden of caring for elderly parents and threaten the fiscal sustainability of pay-as-you-go pension and public healthcare systems. This is particularly true in China, which has recently expanded its partially funded pension and health insurance systems into rural areas. While such social insurance programs may overcome market failures and improve welfare (Bairoliya et al., 2017), they may not be as sustainable as a fully funded personal account system (Feldstein and Liebman, 2008). As population aging is driven more by below replacement fertility than longer life spans (Bloom et al., 2010), it seems natural to propose higher fertility rates as one of the potential remedies (Banister et al., 2010; Turner, 2009).

China's fertility decline has been hastened by its one child policy and fertility is now well below replacement at a fairly low level of income, raising the prospect that China will get old, slowing economic growth, before it gets rich. It may be, therefore, that relaxing fertility restrictions in China improves individual welfare, by allowing families to have the number of children they want, while also improving macroeconomic performance. In 2015, China moved to a universal two child policy which has been forecast to raise the total fertility rate (TFR) from the current level of near 1.5 children per women to 1.8 by 2030 (Zeng and Hesketh, 2016). This is bound to cause interesting variations in demographics in the near future. We analyze the effects of these expected changes in demographics on human capital levels and macroeconomic outcomes relative to a counterfactual of a continuation of fertility at the current level of 1.5 children per woman.

Bloom et al. (2010) show in a theoretical framework that a reduction in fertility below replacement levels can result in a sharp decline in the working age share of the population and potential slow down of economic growth. Aging could also substantially increase the tax burden of health care and pension programs due to declining support ratios and increased health expenditures per capita (Christiansen et al., 2006; Bloom et al., 2011; Seshamani and Gray, 2004). However, declining fertility can induce higher investments in health and human capital which can offset some of the negative effects of aging by raising average effective labor supply (Fougère and Mérette, 1999; Lee and Mason, 2010b,a; Prettner et al., 2013). It can also induce higher physical capital accumulation by encouraging workers to save for retirement rather than rely on their children for old-age support (İmrohoroğlu and Zhao, 2018). In the light of these potential countervailing mechanisms, the macroeconomic effects of the recent relaxation of fertility controls by the Chinese government are unclear. Moreover, the macroeconomic outcomes may differ in the short run versus the long run.

In order to quantitatively assess the impact of these demographic variations in China in a general equilibrium framework, we use an overlapping generations (OLG) model featuring inter-generational altruism to mimic the important role of family in China in providing social insurance. The unit of analysis in the model is a household composed of several generations living together and engaging in various economic activities. While we treat fertility as exogenous, we allow for endogenous human capital accumulation to capture the quality-quantity trade-off as it is an important mechanism to determine the effect of fertility changes on macroeconomic outcomes. We allow for public subsidies on education, health insurance, social security and private savings and model uncertainty in survival, labor productivity and medical expenditures. The government operates public pension and health insurance programs and subsidizes primary, secondary and college education in the model. While pension payments are financed through labor income taxes, public spending on health insurance and education is jointly financed through consumption taxes.

Simulations from our quantitative model indicate that higher fertility yields a lower level of income per capita than status quo fertility along the entire transition path. In the short run, the higher fertility rate increases the youth dependency ratio and these children require consumption, child care, and education, while not producing any output until they reach working age. The important point here however is how long the short run lasts. In our benchmark model, it takes approximately sixty years for the working age share to increase with higher fertility. While the first cohort of children from the fertility shock enters the workforce at around age 15, it takes a considerable period of time for the age structure to reach a new steady state. Moreover, even with the eventual increase in working age share associated with higher fertility in the long run, income per capita remains lower than under status quo fertility, primarily due to lower levels of average human capital. This highlights that increasing the working age share of the population is not the same as maximizing income per capita. Income is affected not just by labor supply but by human capital investments that may move in opposite directions to labor supply.

We find that there are significant externalities (both positive and negative) associated with higher fertility through taxes. Higher fertility on one hand reduces the fiscal burden of financing old-age pensions and medical expenditures by increasing the fiscal support ratio. On the other hand, it also lowers the education subsidies per child under the assumption of a fixed government budget (as a share of output) for education. We conduct a number of education policy experiments to further elucidate the importance of these general equilibrium effects. In our simulations, a 4.7% increase in the government education budget can offset the negative long run macroeconomic effects of these expected future demographic variations. Further increases in educational subsidies lead to significant gains in both human capital and income levels under all our future fertility scenarios. However, the speed of transition is again important to consider, with policy experiments under plausibly higher fertility taking over seventy years to yield similar macroeconomic outcomes as our low fertility benchmark simulations.

Our paper contributes to a growing body of related literature on demography and economic growth in China. First, demographics have been shown to have important implications for savings in China. There is empirical evidence that fertility has a negative effect on savings at the household level (e.g. Banerjee et al. 2010; Ge et al. 2012; Choukhmane et al. 2013; Banerjee et al. 2014). At the aggregate level, Modigliani and Cao (2004) use time series data from China to argue that fertility influenced savings over the past several decades through changes in demographic structure. Structural OLG models have since been used to analyze and quantify the link between demographics and the observed increases in aggregate savings in China (e.g. Curtis et al. 2015; Banerjee et al. 2014; He et al. 2015; Choukhmane et al. 2013). With a two-way altruism model most closely related to ours, İmrohoroğlu and Zhao (2018) find the interaction of demographics, productivity growth, and uncertain long-term care of elderly parents to be an important driver of Chinese savings rates. This is consistent with Chamon and Prasad (2010) who find evidence in support of rising average savings rates due to rising private burden of both health care spending and education. However, İmrohoroğlu and Zhao (2018) abstract from human capital considerations and the role of children more broadly. Using a general equilibrium model of endogenous fertility decisions, Liao (2013) looks at the welfare effects of relaxing fertility constraints in China but abstracts away from some key modeling details. For instance, this paper is not able to match the evolution of age-structure over time due to a simple demographic structure. Matching the precise evolution of age-distribution is crucial in pinning down the demographic dividend, hence the short run and the long run effects of fertility changes. It also abstracts away from the government programs on education, pensions and healthcare which have assumed a significant role in China in the recent times. Our general equilibrium effects indicate that the tax externality associated with these public transfer programs is significant.

We include an endogenous schooling decision in our model as fertility has been theoretically and empirically linked to human capital investments in China. Using Chinese twin births for identification, Li et al. (2008) find that higher fertility significantly reduces educational attainment and enrollment while Rosenzweig and Zhang (2009) also find reductions in schooling progress, expected college enrollment, and school grades. Compared to savings, the impact of demographics on human capital accumulation in China has received far less attention in the structural macro literature. An exception is Choukhmane et al. (2013) whose partial equilibrium model predicts that changing demographics lead children of the one-child policy generation to have at least 20% higher human capital compared to their parents.[1] Meng (2003) and Chamon and Prasad (2010) also highlight the potential role of underdeveloped financial markets in amplifying savings motives under demographic change, particularly in terms of education spending. Importantly, we restrict the borrowing capacity of families and allow for an interaction between demographics and public spending on education through a government budget con-

[1]Banerjee et al. (2014) shows that general equilibrium effects can be quantitatively important in a model of aggregate fertility.

straint. Finally, as previous studies have established important connections between demographics and the macroeconomic fluctuations since the end of China's centralized economy, we turn our eye to the future. In the wake of renewed interest in relaxing the restrictive fertility policies in China, we examine the implications of changes in demographic structure moving forward under alternate fertility paths. An important point in our paper is that we assess the economic effects of these upcoming demographic variations, not the welfare effects. Families may enjoy having additional children, and these children may improve their parent's utility level, even if it lowers income per capita and their economic circumstances. In addition, a welfare analysis would have to take into account the utility of the children born due to the policy change which raises difficult ethical questions of measuring welfare with different population sizes (Blackorby et al., 2005).

The remainder of this paper is organized as follows. Section 2 provides a discussion on demographics and human capital in China. Section 3 builds the dynamic general equilibrium model. Section 4 discusses our calibration strategy. Section 5 compares the fit of the model with the data. Sections 6 provides a discussion of the quantitative results and section 7 provides concluding remarks.

2 Background

In this section, we provide some background information on demographics and human capital investments in China. We begin with a brief discussion on the mechanics linking fertility to an economy's demographic structure and provide some time-series data and future projections for China under section 2.1. Next, we discuss an important behavioral response to changing demographics — changes in human capital investments. This behavioral mechanism is briefly detailed along with supporting data in section 2.2.

2.1 Demographics

One of our primary focuses in this paper is how fertility changes affect the age dependency structure across an economy over time. Fertility changes affect the working age share[2] of the population by altering both the old-age and child dependency ratios. For instance, an increase in fertility lowers the working age share by increasing the number of child dependents per worker. On the other hand, higher fertility in the long run also reduces the number of retirees or older dependents per worker, thereby increasing the working age share of the population. On net, the long run effect of fertility on working age share depends on the relative strengths of these two opposing forces.

Figure 1 provides an illustrative example of the theoretical relationship between total fertility rate and working age share of the population in the long run steady state.[3] When there is a marginal decrease in fertility from a very high rate, the reduction in the number of child dependents outweighs the increased share of retirees in the long run, resulting in an overall increase in working age share. This is the case typical in many developing countries (including China prior to the 1990s). However, indefinite declines in fertility ultimately result in a lower working age share in the long run as the relative number of retirees increases. Moreover, when fertility rates are very low, there is a potential for substantial increases in working share from relatively small increases in fertility in the long run.

Figure 2 shows the U.N. estimates (1960-2015) and medium variant projections (2015-2100) for total fertility rate and working age share in China. Between 1970 and 2000 there was a sharp decline in fertility largely attributed to China's one-child policy. Correspondingly, over this time-frame there was a steep rise in the working age share driven by the drop in child dependents. However, now that the one-child generation is moving into the workforce, there is a projected decline in working age share in the coming decades due to a sharp rise in the number of old-age dependents per worker.

2.2 Human Capital

Our framework allows fertility changes to operate through multiple channels to impact individual and aggregate human capital investments. To illustrate this

[2]Working-age share is defined as fraction of population ages 15 to 64.

[3]For this example, we hold age-specific survival rates constant at current levels in China. Survival probabilities are taken from UN life table estimates for 2010-15 (UN, 2015). To obtain an analytic solution, we assume mothers give birth to all children at age 29.

Figure 1: Stable Long run Relationship Between Fertility Rate and working age Share

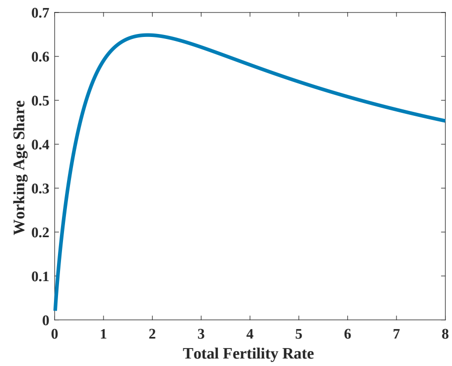
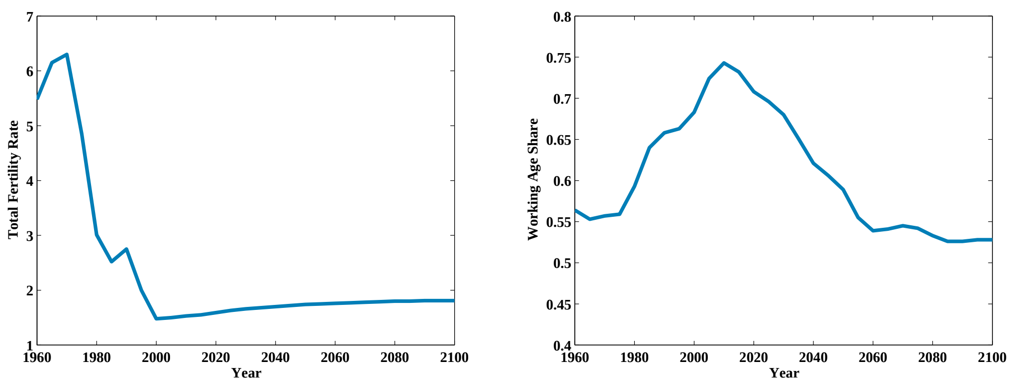


Figure 2: Demographic Transition in China

(a) Fertility

(b) Working-Age Share

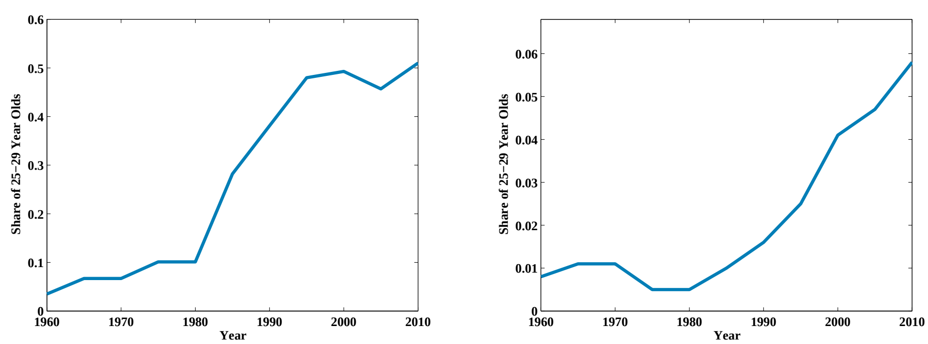


Note: Projections are shown under the medium fertility variant assumed by the U.N.

point, figure 3 shows the estimated share of 25-29 year-olds in China with completed secondary or college education from 1960-2010. Secondary completion rose substantially over the entire time-frame but experienced the sharpest growth during the 1980s and 90s. College completion also started to increase in the 90s and is largely believed to continue to rise substantially into the foreseeable future. The primary channel of influence we focus on is through the child expenditure channel. For example, some households may not be wealthy enough to send a large number of children to school. A decline in fertility would thus promote investments in human capital by relaxing the household budget constraint. The fertility rate may also influence individuals indirectly by altering the budgets of government programs. For example, if government outlays on education are fixed, the decreased share of school-aged individuals accompanying lower fertility results in a decrease in the per student private cost of education. Lastly, there are general equilibrium effects that will influence the strength of the above mechanisms. For example, a decline in after-tax wage relative to interest rate reduces the returns to schooling and has a dampening effect on average educational attainment.

Figure 3: Education shares in China Over Time

(a) Secondary Education (b) College Education



Data Source: Barro and Lee (2013)

In the next section, we build our dynamic general equilibrium model which captures all these important mechanisms linking fertility with demographics and human capital accumulation decisions.

3 Model

Consider an economy populated by a large number of households that each consist of overlapping generations of a family. Household members are altruistic towards each other and make decisions as a single economic unit. Over time, children in the family grow up, have children of their own, and eventually replace their parents in the household. In this way each household in the economy is an infinitely lived dynasty. As children grow up, they accumulate human capital by attending school. As individuals age, they eventually face medical expenditure and mortality risk. Time is discrete and in each period a new generation of individuals is born.

3.1 Technology

Aggregate output in the economy (Y) is assumed to be produced by a representative firm using the technology:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha} \qquad \alpha \in (0,1), \tag{1}$$

where K_t and N_t are the aggregate capital stock and labor inputs (measured in efficiency units) in period t, A_t is total factor productivity, and α is the capital share. Output can be consumed (C), invested in physical capital (I), expended on education (E), or expended on medical care (M):

$$Y_t = C_t + I_t + E_t + M_t.$$

Finally, letting δ equal per-period depreciation, the law of motion of capital is given by:

$$K_{t+1} = (1-\delta) K_t + I_t.$$

3.2 Households

Demographic Structure

The economy is populated by overlapping generations of individuals residing in family households. Each individual lives through four stages of life—child, young adult, old adult, and elderly. As a child, an individual simply consumes and spends a fraction of childhood in primary school. Young adulthood begins by either continuing in school (secondary school and eventually college) or entering the labor market. Regardless of educational choice, after schooling is complete, the remainder of the young adult stage is spent working. As an old adult, an individual continues to work in the labor market and consume. Old adults eventually begin to receive public pension benefits as well. Finally, the elderly continue to receive pension payments but are assumed retired from the labor force. It is upon becoming elderly that individuals begin to face medical expenditure and mortality risk.

The economic decision making unit is a household. Each household in the economy is indexed by "household age" $j = 1, ..., J$. This index completely defines the age structure of the entire household. At each age j, all members of the household pool their resources to maximize a joint objective function. Following Laitner (1992), individuals derive utility from their own lifetime consumption and from the utility of other household members and descendants.

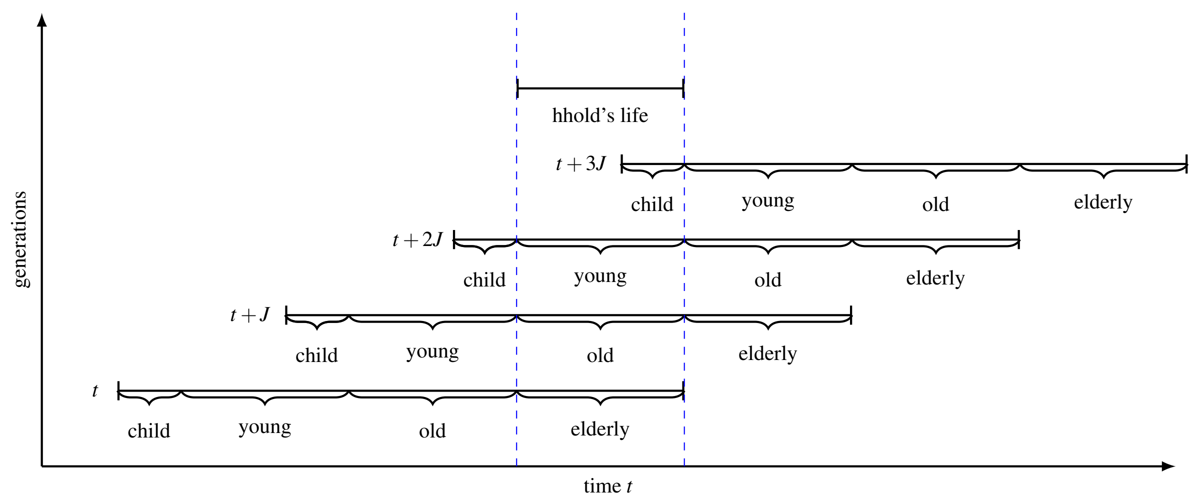
Regardless of age j, each household always consists of one old adult and their n young adult children which is the implied model fertility rate.[4] At household age $j = J_c < J$, each young adult has n offsprings of their own, who live with the household as children until age J. After age J, the young adult siblings become old adults and split into n separate households with their own young adult children. The siblings are assumed to evenly split household assets and share the continuing financial burden of their now elderly parent. This implies that $\frac{1}{n}$ elderly parents are included in each household, conditional on survival. Moreover, any pension income received by the elderly parent is distributed evenly to old adult children to help finance consumption and medical care for the elderly.

Note that due to the birth of children and mortality risk faced by the elderly members of the family, a household can have four different compositions. One where all four generations are present; where only young and old adults are present (children are not born as yet and elderly have deceased); where children, young, and old adults are present and elderly have deceased; and finally where young adults, old adults, and elderly are present. Figure 4 summarizes the timeline for

[4]Note that this is a single-sex model so n is always half of the true fertility rate observed in the data. However, to avoid confusion, through the rest of this analysis we will make no distiction between the two and show calibration results with the true fertility rate.

both households and individuals in the model. The figure highlights the rich demographic structure available in this framework—an individual's life may overlap with that of his children, parents, grandchildren, grandparents, great-grandchildren, and great-grandparents.

Figure 4: Evolution of Generations and Timeline



Labor Earnings

In each model period, every young and old adult is endowed with one unit of productive time. Young adults either spend this time in school, taking care of children, or supply it inelastically to the labor market. More specifically, a young adult of age $j < J_c$ earns the following pre-tax labor income:

$$w\left(1-\kappa_{e_y j}\right) e_y \varepsilon_j \eta_y,$$

where w is the competitive wage rate, ε_j is age-specific life-cycle productivity, and η_y is a permanent idiosyncratic shock realized by an individual upon becoming a young adult $(j=1)$. Labor productivity is also conditional on the young adult's level of education e_y. Moreover, $\kappa_{e_y j}$ indicates whether a young adult of education type e_y is enrolled in school at age j. Specifically, $\kappa_{e_y j}=1$ if the young adult is enrolled in school and $\kappa_{e_y j} = 0$ otherwise.

Schooling is assumed complete by the time young adults have their own children at age J_c. As such, a young adult of age $j \geq J_c$ earns the following pre-tax labor income:

$$we_y \varepsilon_j \eta_y \left(1 - n\theta_f\right),$$

where n is the number of children they have and θ_f is the time-cost of raising their children. Even though our model is gender-neutral, θ_f captures in a simple way, the effect of fertility on female labor supply.

Old adults supply their unit of time inelastically to the labor market. As such, an old adult of age j earns the following pre-tax labor income:

$$we_o \varepsilon_{j+J} \eta_o,$$

where η_o is the permanent idiosyncratic shock that they received when they were a young adult. In this way, the productivity shock η remains constant throughout an individual's life. Moreover, we assume the productivity shock of a young adult (η') is correlated with their parent's shock (η) through a finite-state Markov chain with stationary transitions over time:

$$\Gamma_t^{\eta}\left(\eta', \mathscr{E}\right) = Prob\left(\eta' \in \mathscr{E} \mid \eta\right) = \Gamma^{\eta}\left(\eta', \mathscr{E}\right), \ \forall t.$$

Education

We model three discrete choices for educational attainment—primary school, secondary school, and college. All children exogenously enter primary school at age J_p and are in school for the remainder of childhood (i.e. through household age J). However, at age J, households decide if children will drop out of school and enter the labor market the following period as young adults, will continue their education through secondary school, or will continue through college. Primary school requires an annual tuition cost of θ_p that is entirely subsidized by the government. Continuing education beyond primary school incurs an age-specific tuition cost of θ_j which may be fully or partially subsidized. It is important to note that education level is chosen prior to realization of an individual's productivity shock η. This implies that idiosyncratic returns to education are uncertain at the time when schooling decisions are made.

Medical Expenditures and Mortality

Elderly individuals of age j survive to age $j+1$ with positive probability ψ_j. At the end of period J, they die with probability one. Conditional on being alive, the elderly are characterized by a medical expenditure state $x \in \mathscr{X}$. Conditional on expenditure state, households are required to finance medical expenditure m_x for the care of their elderly parent. The elderly are assumed to start in the lowest medical expenditure state $\bar{x}$. The medical expenditure state then evolves stochastically over the remaining life-cycle. The stochastic process follows a finite-state Markov chain with stationary transitions over time. The Markov process is assumed to be identical and independent across individuals:

$$\Gamma_t^x\left(x', \mathscr{X}\right) = Prob\left(x' \in \mathscr{X} \mid x\right) = \Gamma^x\left(x', \mathscr{X}\right), \ \ \forall t,$$

where x is the current medical expenditure state and x' is that of the following period.

3.3 Government

The government operates three programs in the model. First, a pay-as-you-go social security system which is defined by pension benefits SS for each old adult above age J_{ss} and for all surviving elderly. Pension benefits are determined by a replacement rate b_s of national average earnings. Second, the government subsidizes the health care of the elderly by covering a fraction b_h of their medical expenditure bill. Finally, the government provides a subsidy for education. The cost of primary school is fully covered by the government. For secondary school and college, the government covers a fraction λ_j of the total tuition cost θ_j. As a majority of public revenues in China are collected through direct or indirect consumption taxes, we assume public spending on education and health care is financed with a proportional tax on individual consumption τ. However, as the Chinese pension system is primarily financed with labor income taxes, we assume the social security budget is balanced through a proportional tax on labor income τ_{ss}.

3.4 Decision Problem

At any given time, a household can be characterized by a vector of state variables $\zeta = (a, x, d, e_y, e_o, \eta_y, \eta_o, j)$, where a denotes current holdings of one-period, risk-free assets, x is elderly member's medical expenditure state, d is an indicator for whether the elderly is deceased, e_y and e_o are education levels of the young and old adults respectively, η_y and η_o are productivity levels of young and old adult respectively, and j is the age of the household. Given this state vector, a household chooses total consumption c, and next period assets a', to maximize the present utility of the household plus the expected discounted utility of all future periods of the family dynasty. In period J, the education level of the next generation of adults e'_y is also chosen. The decision problem facing a household of age $j < J$ may be written:

$$\begin{gathered} v\left(a, x, d, e_y, e_o, \eta_y, \eta_o, j\right) = \\ \max_{c, a'} \quad \left\{ \tilde{n} u\left(\tfrac{c}{\tilde{n}}\right) + \beta E_{x'd'}\left[v\left(a', x', d', e_y, e_o, \eta_y, \eta_o, j+1\right)\right]\right\} \end{gathered}$$

subject to:

$$\begin{gathered} c(1+\tau) + a' = y(1-\tau_{ss}) + a\left(1+r\right) + \frac{(1-d)}{n}\left(SS - (1-b_h)\, m_x\right) \\ + SS(j \geq J_{ss}) - n\kappa_{je_y}(1-\lambda_j)\theta_j \end{gathered}$$

$$a' \geq 0, c > 0$$

where y refers to total household labor income given by:

$$y = \begin{cases} we_o\varepsilon_{j+J}\eta_o + n(1-\kappa_{e_y j})we_y\varepsilon_j\eta_y & \text{if } \ j < J_c \\ we_o\varepsilon_{j+J}\eta_o + n[we_y\varepsilon_j\eta_y(1-n\theta_f)] & \text{if } \ j \geq J_c, \end{cases}$$

and $\tilde{n}$ is the number of adult equivalents in the household:

$$\tilde{n} \quad = \quad n + 1 + \frac{(1-d)}{n} + \gamma n n\left(j \geq J_c\right)$$

where γ is the consumption requirement of a child relative to an adult.

The current period utility of an individual is given by $u(.)$ and value function $V(.)$ is the total expected discounted utility of arriving in a period of time with a given state vector. Note that expectations are taken with respect to the stochastic process for the medical expenditure state and the survival risk of the elderly. The first constraint is the household budget constraint. Note that the total private cost of education for each of the n young adults at age j is given by $(1-\lambda_j)\theta_j$. Also note the role of the elderly in the decision problem. Conditional on being alive $(d=0)$, households have access to $\frac{1}{n}$ of the elder's pension income SS but are also responsible for the same fraction of the elder's unsubsidized medical care $(1-b_h)m_x$. Finally, note that households also face a no borrowing constraint $(a' \geq 0)$.

In period J, the decision problem facing a household may be written:

$$v(a,x,d,e_y,e_o,\eta_y,\eta_o,j) =$$
$$\max_{c,a',e_y'} \left\{ \tilde{n}u\left(\tfrac{c}{\tilde{n}}\right) + n\beta E_{\eta_y'}\left[v\left(\tfrac{a'}{n},x',d',e_y',e_o',\eta_y',\eta_o',1\right)\right]\right\}$$

subject to:

$$c(1+\tau)+a' = y(1-\tau_{ss}) + a(1+r) + \frac{(1-d)}{n}(SS-(1-b_h)m_x) + SS$$

$$a' \geq 0, c > 0,$$

and y and $\tilde{n}$ are defined as above. Expectations over next period's value function are now taken with respect to the productivity shock of the children η, who will become young adults. Moreover, in the following period young adults become old adults so we have $\eta_y = \eta_o'$ and $e_y = e_o'$.

3.5 Definition of Stationary Competitive Equilibrium

Let $a \in \mathbb{R}_+$, $x \in \mathscr{X} = \{x_1, x_2, \ldots, x_n\}$, $d \in \mathscr{D} = \{0,1\}$, $e_y, e_o \in \mathscr{E}_d = \{e_1, e_2, \ldots, e_n\}$, $\eta_y, \eta_o \in \mathscr{E} = \{\eta_1, \eta_2, \ldots, \eta_n\}$, $j \in \mathscr{J} = \{1,2,\ldots,J\}$ and $\mathscr{R} = \mathbb{R}_+ \times \mathscr{X} \times \mathscr{D} \times \mathscr{E}_d \times \mathscr{E}_d \times \mathscr{E} \times \mathscr{E} \times \mathscr{J}$. Let $B(\mathbb{R}_+)$ be the Borel σ-algebra of $\mathbb{R}_+$ and $P(\mathscr{X})$,$P(\mathscr{D})$,$P(\mathscr{E}_d)$,$P(\mathscr{E})$,$P(\mathscr{J})$

the power sets of $X, \mathscr{D}, \mathscr{E}_d, \mathscr{E}, \mathscr{J}$ respectively. Let $\Sigma_{\mathscr{R}} \equiv B(\mathbb{R}_+) \times P(\mathscr{X}) \times P(\mathscr{D}) \times P(\mathscr{E}_d) \times P(\mathscr{E}_d) \times P(\mathscr{X}) \times P(\mathscr{X}) \times P(\mathscr{J})$. Let $\mathscr{M}$ be the set of all finite measures over the measurable space $(\mathscr{R}, \Sigma_{\mathscr{R}})$.

Definition 1. Given fiscal policies of the government $\{\lambda_e, b_s, b_h, \tau, \tau_{ss}\}$ and a fertility rate n, a stationary competitive equilibrium is a set of value functions $v(\zeta)$, households' decision rules $\left\{c(\zeta), a'(\zeta), e_y(\zeta)\right\}$, prices $\{r, w\}$, tax rates $\{\tau, \tau_{ss}\}$, pension benefits $\{SS\}$, and time-invariant measure of households $\Phi(\zeta) \in \mathscr{M}$ such that:

1. Given fiscal policies and prices, household's decision rules solve household's decision problem.

2. Prices w and r satisfy:

$$
\begin{aligned}
r &= A\alpha\left(\frac{N}{K}\right)^{1-\alpha} - \delta \\
w &= A(1-\alpha)\left(\frac{K}{N}\right)^{\alpha}.
\end{aligned}
$$

3. Individual and aggregate behavior are consistent:

$$
\begin{aligned}
K &= \int a'(\zeta)\Phi(d\zeta) \\
N &= \int (e_o \varepsilon_{j+J}\eta_o + n\left(\left(1-\kappa_{e_y j}\right) e_y \varepsilon_j \eta_y\right)(1-n\theta_f(j \geq J_c)))\Phi(d\zeta).
\end{aligned}
$$

4. Goods market clears[5]:

$$
\int \left(c(\zeta) + \tfrac{(1-d)}{n} m_x + n\kappa_{e_y j}\theta_j\right)\Phi(d\zeta) + \int n^2\theta_p \Phi(d\zeta(j \geq J_p)) \\
= AK^{\alpha}N^{1-\alpha} - \delta K.
$$

[5]Let $\Phi(d\zeta(j \geq J_p)$ denote the total measure of primary school aged children.

5. Measure of households satisfy:

$$\Phi(a',\bar{x},0,e_y',e_o',\eta_y',\eta_o',1)$$
$$= n\sum_{\left\{\zeta:a'=a(\zeta)/n,e_y'=e_y(\zeta),e_o'=e_y,\eta_o'=\eta_y\right\}} \Gamma_t^{\eta_o}\left(\eta_y',\mathscr{E}\right)\Phi(\zeta) \quad for \quad j=J.$$

$$\Phi(a',x',d',e_y,e_o,\eta_y,\eta_o,j+1)$$
$$= \frac{1}{n^{1/J}}\sum_{\{a,x,d:a'=a(\zeta)\}} \mathit{\Gamma}^x\left(x',\mathscr{X}\right)\Psi\left(d',d_j\right)\Phi(a,x,d,e_y,e_o,\eta_y,\eta_o,j) \quad for \quad j<J$$

where $\Psi\left(d',d_j\right)$ is the probability of transitioning from state d at age j to state d'.

6. Government budget for education and medical expenses balances:

$$\int\left(b_h\frac{(1-d)}{n}m_x+\lambda_j n\kappa_{e_yj}\theta_j\right)\Phi(d\zeta)+\int n^2\theta_p\Phi(d\zeta(j\geq J_p))=\tau\int c(\zeta)\Phi(d\zeta).$$

7. Social security budget balances[6]:

$$\tau_{ss}wN=\int SS\Phi(d\zeta(j\geq J_{SS}))+\int dSS\Phi(d\zeta),$$

where: $SS=\frac{b_s wN}{\int\left(1+n\left(1-\kappa_{e_yj}\right)\right)\Phi(d\zeta)}$.

4 Calibration

We use a calibrated version of the model to understand the effect of demographic transition on macroeconomic variables in China in both the short run and the long run. Since the Chinese economy has undergone massive changes in the last five decades, we calibrate our model economy in two stages. First, we calibrate our initial steady state to match some key features of the Chinese economy and demo-

[6] $\Phi\left(\zeta\left(j\geq J_{SS}\right)\right)$ denotes the total measure of old adults who have reached pension claiming age.

graphics circa the 1960s.[7] Next we calibrate the transition economy to match some key changes in the Chinese economy between 1960 and 2010.

In our calibration exercise, we take some parameter values directly from the literature or estimate them using micro level survey data. For instance, we use data from the China Health and Retirement Longitudinal Study (CHARLS) to estimate the stochastic process for elderly medical expenditures. Other parameters we estimate jointly using our general equilibrium model by minimizing the distance between certain data and model moments. The following subsections lay out the details of our calibration exercise.

4.1 Demographics

Each model period is assumed to represent one calendar year. In order to capture the demographics accurately, we model the entire life cycle of an individual from ages 0 to 98. The final "household age" index is set to $J = 29$. We set $J_c = 17$ implying young adults have children at real age 29. Table 1 gives the number[8] and age-structure of different generations living in a household. Finally, we set set $J_{ss} = 19$ implying that old adults begin receiving pension payments at real age 60.

Table 1: Household Composition

Stage	Individual's age (yrs.)	Number	Household ages lived
Children	0-11	nn	$17 \ldots J$
Young Adults	12-40	n	$1 \ldots J$
Old Adults	41-69	1	$1 \ldots J$
Elderly	70-98	$\frac{1}{n}$	$1 \ldots Death$

In our initial steady state we set $n = 2.7$ so that the implied fertility rate matches the UN estimate for China in 1965-70 of 5.4.[9] Fertility along the transition from

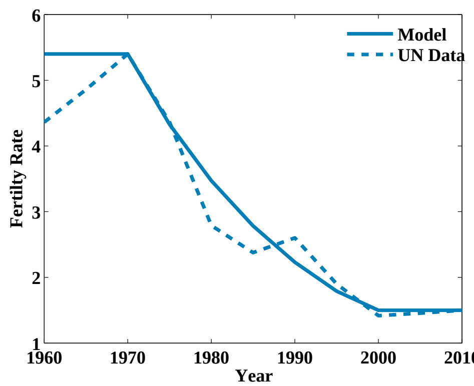
[7]Both fertility and mortality rates were relatively stable during this time. Fertility only started declining dramatically in the 1970's and there were major improvements in life expectancy at birth in the late 1960's (UN, 2015). Hence steady state is a reasonable approximation for this period.

[8]Gives the total number of individuals in each stage in a given household in steady state. Note that fertility rate n will differ across generations in the household along transition paths.

[9]We adjust the UN total fertility rate for under-five mortality to obtain the estimate of 5.4.

1960-2010 is shown in figure 5. We maintain the initial fertility rate for 10 years then gradually reduce the rate to 1.5 between 1970 and 2000 to approximate the declines estimated by the UN.[10]

Figure 5: Fertility Rates: 1960-2010



4.2 Preferences

Individual's preferences over consumption are defined as follows:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}.$$

The parameter σ controls risk aversion and is set to a value of 2, implying an intertemporal elasticity of substitution of 0.5. As children consume fewer resources than adults, we set the child consumption weight $\gamma = 0.3$ following the OECD-modified consumption equivalent scale (Hagenaars et al., 1994).

According to UN (2015), the total fertility rate and under-five mortality rates in China between 1965 to 1970 were 6.3 (per woman) and 143 (per 1000 live births) respectively.

[10]For computational convenience, we reduce fertility to achieve the constant cohort growth rate implied by a fertility rate of 1.5 (given by $0.75^{\frac{1}{J}}$). This by construction takes $J = 29$ periods in the model to reach a fertility rate of 1.5. Alternately, we could feed the fertility paths directly from the data. However, we would still need to adjust the cohort growth rates to achieve a stable demographic structure in the long run.

4.3 Medical Expenditures and Mortality

We assume there are two possible realizations of the elderly medical expenditure state x—high and low. We estimate transition probabilities between states and associated medical expenditures m_x using data from the 2011 and 2013 waves of the CHARLS, a nationally representative survey of Chinese residents ages 45 and older. We first divide surveyed individuals over the age of 70 into percentiles based on reported annual total medical expenditures.[11] As has been documented in other countries, the expenditure distribution is highly skewed with a thin right tail driven by a limited number of catastrophic events. As such, we categorize those in the bottom 90 percentiles of the expenditure distribution as our low expenditure state. Analogously those in the top 10 percentiles are categorized into the high expenditure state. Annualized transition probabilities between states across the two waves of the CHARLS are shown in the first columns of table 2.[12] We next compute the mean expenditures among those categorized into the high/low expenditure state using the 2013 wave. We set low/high medical expenditures m_x to be a constant share of output per capita in every model period. The last column of table 2 shows the estimated average expenditures as a share of output per capita from the CHARLS.

Table 2: Medical Expenditures & Transition Probabilities

x	Transition probability		Mean expenditures (% GDP per capita)
	Low	High	
Low	0.94	0.06	2.4
High	0.53	0.47	156.6

Survival probabilities are taken from UN life table estimates (UN, 2015). As the initial steady state is calibrated to match key features of the Chinese economy circa the 1960s, we use age-specific survival probability estimates for 1965-70 as a starting point in the model. However, age-specific mortality rates have significantly improved in China over the past decades and are projected to continue to improve

[11] Medical expenditures in the two waves are deflated to 2010 value and include both inpatient and outpatient costs.

[12] As waves in the CHARLS are multiple years apart, reported values have been adjusted to an annual transition.

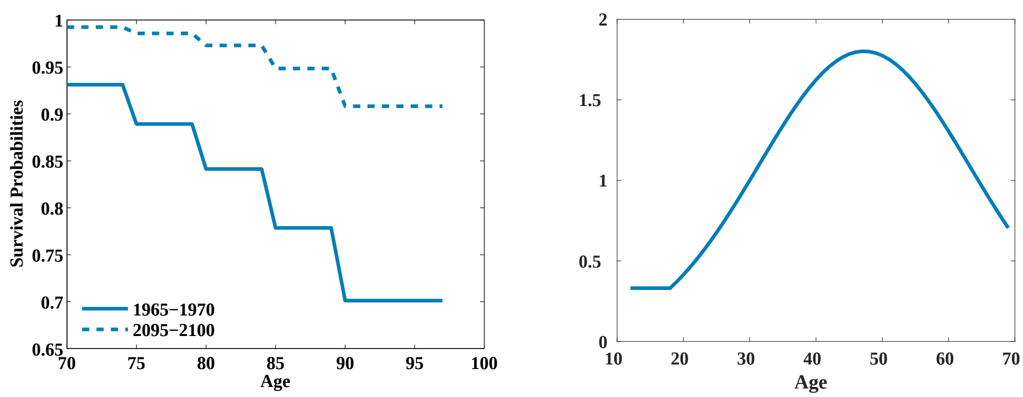
into future. As a simple means of capturing this improvement in the model, we linearly decrease the mortality risk along our transition path from 1970 to 2100 to reach the levels projected by UN for 2095-2100. Figure 6a shows the corresponding set of UN survival probability estimates used in our initial and final steady states.

4.4 Labor Productivity

We use data from the China Family Panel Studies (CFPS) to estimate age-specific labor productivity ε_j over potential working years of the life-cycle (ages 12 to 69).[13] We use the 2010 and 2012 waves and regress log of hourly income on age, age-squared and an individual fixed effect to obtain our life-cycle productivity estimates. Due to lack of observations, we assume productivity is constant prior to age eighteen. Figure 6b plots the estimated life-cycle profile of labor productivity. Productivity increases steadily until age fifty, at which point it begins to decline throughout the remainder of an individual's working life.

Figure 6: Survival and Labor Productivity

(a) Survival Probabilities (b) Labor Productivity Profile



We estimate the Markov chain for the stochastic component of productivity η

[13]The CFPS is a longitudinal survey of Chinese families and communities. While the CHARLS provides excellent data on the medical spending of the elderly in China, it does not include young enough individuals to estimate life-cycle productivity profiles.

by assuming an underlying AR(1) process in logs:

$$\ln\left(\eta'\right) = \rho \ln\left(\eta\right) + \varepsilon_\eta, \quad \varepsilon_\eta \sim N\left(0, \sigma_\eta^2\right).$$

We then use the Tauchen method to approximate this process with a Markov chain over eight discrete states. Parameters governing the stochastic process ρ and σ_η are jointly estimated using the predictions of the model (see section 4.8 for details).

Finally, recall that children in the model (ages 0-11) cost their parents a fraction of their labor time endowment θ_f. Following Bloom et al. (2009) we set $\theta_f = 0.16$.[14]

4.5 Education

We assume primary education lasts for six years (age 6-11), secondary for six years (age 12-17), and college for four years (age 18-21).[15] Empirical estimates suggest very low returns to education in China in the 1970s—in the range of 0-3% (Yang, 2005; Fleisher and Wang, 2005). As such, after normalizing education-specific productivity e for primary education to one, we use a 3% annual return to secondary school and college for our initial (1960) steady state. The compression of wages is largely attributed to equalization policies carried out under the centrally planned economy, with particular downward pressure on more educated workers. Following economic reforms of the early 1980s, there was a steep rise in the returns to schooling.[16] Most recent estimates have found overall annual returns in the 10-20% range (e.g. Li (2003); Li and Luo (2004); Zhang et al. (2005); Fang et al. (2012)). Heckman and Li (2004) estimated annual returns to college close to 10%. Moreover, the average return globally across countries is estimated at around 10% (Psacharopoulos and Patrinos, 2004). As such, to capture the decompression of wages in China over time, we assume annual returns over primary school increase

[14] Bloom et al. (2009) estimate that each birth reduces a woman's total labor supply by 1.9 years over her reproductive life. We convert this to an annual time cost for parents in the model.

[15] This implies $\kappa_j = I\{j \leq 6\}$ for those choosing secondary school and $\kappa_j = I\{j \leq 10\}$ for college, where $I\{.\}$ is the indictor function.

[16] See Fang et al. (2012) for a good review of the literature

to 15% by 2010 for secondary schooling and 10% for college. The initial and final education-specific productivity estimates are given in table 3.

Table 3: Educational Productivity Returns and Costs

Level	Ages	Productivity (e)		Annual total tuition (θ)	
		1960	2010+	1960	2010+
Primary	6-11	1.00	1.00	0.019	0.168
Secondary	12-17	1.19	2.31	0.086	0.251
College	18-21	1.34	3.39	0.886	0.886

In the initial (1960) steady state we set the total annual tuition of each education category $(\theta_p, \theta_s, \theta_c)$ to match the respective total costs as a share of output per capita reported in China for the year 1965 (China Education Statistical Yearbook, 1988)[17]. For example, 1960 college tuition was set to match a reported cost per college student of 379% of GDP per capita. We assume college tuition remains constant over time which endogenously gives a reasonable tuition cost of 180% of GDP per capita in 2010 and 88% in the long run steady state. However, the cost of primary and secondary school relative to college has risen considerably over time (China Statistical Yearbook, 2012)[18]. As such, we adjust the cost of primary and secondary schooling to match their cost relative to college in 2010. The last two columns of table 3 show the total tuition costs used in the model. We assume that the productivity returns and total tuition cost of primary, secondary and college education are constant from 1960 to 1980, then rise linearly from 1980 to 2010.

4.6 Technology

We set α to match the long run average capital share of income (1970-2010) for China while the depreciation rate δ is set to 10%. Total factor productivity A

[17] Reports total cost of primary, secondary and tertiary education per student. We transform them into shares of GDP per capita of 8%, 37%, and 379%. 1965 is the only available year prior to 1978.

[18] Reports total enrollment and total spending on primary, secondary and college education, which we use to calculate per student costs. Primary and secondary were 19% and 28% the per student cost of college in 2010 compared to 2% and 10% in 1965.

is normalized to one, even though we allow for labor augmenting TFP change by increasing returns to education over time as suggested in the literature.

Table 4: Technology Parameters

Parameter	Value	Target/Source
Capital share α	0.48	Feenstra et al. (2015)
Period depreciation δ	0.10	Chow and Li (2002)
Factor productivity A	1	Normalization

4.7 Government Policies

The government operates the pension and health insurance programs and subsidizes primary, secondary and college education in the model economy. The medical expenditure reimbursement rate is set at $b_h = 0.7$. This is the estimated rate for urban workers in China and the target rate for rural workers as well (Yip et al., 2012). The pension replacement rate is set as 35% of national average earnings ($b_s = 0.35$), the target rate for the pay-as-you component of the current urban system (OECD, 2010).

Finally, government subsidizes primary, secondary and college education at the rates of λ_p, λ_s and λ_c respectively. As schools operated under a centralized economy and wages were highly compressed in the 1960s, we assume all three levels of education to be fully subsidized by the government in the initial steady state ($\lambda_i = 1$, $\forall i$). Note that even with no private tuition cost, there remains a time cost of attending secondary school and college.

As primary school is still primarily funded through various levels of government we maintain $\lambda_p = 1$ throughout all analyses. However, to reflect changing demographics, total costs, returns to schooling, and public policies we allow the private tuition cost of secondary school and college to change over time. After 2010, we fix government expenditures on education at 4.3% of GDP. This matches the latest empirical estimates and is near the government's stated long-term goal of 4% (China, 2014; Tsang, 1996). After subtracting the entire cost of primary school from the government's budget, the remainder is split in a 60/40 ratio between secondary school and college in order to determine the respective subsidy rates.[19] This approach implies that in every model period post-2010, the private tuition cost $((1-\lambda)\,\theta)$ of secondary and college education is endogenously determined by aggregate output and the number of enrolled students. In contrast, we exogenously assume the private tuition cost of secondary and college increases linearly from 1960 (free) to 2010. We allow taxes to adjust to ensure the government budget clears each period along the transition.[20]

4.8 Estimation of Other Parameters

We use the model to jointly estimate three remaining parameters—$(\beta, \rho, \sigma_\eta)$—by targeting relevant empirical data moments in the initial steady state. We estimate the discount factor β by targeting the average capital-output ratio (1960-70) of 3.23 in the Penn World Tables 8.1 (Feenstra et al., 2015). For estimating the persistence and standard deviation of the labor productivity shock, we target the inter-generational income mobility and the income Gini coefficient, respectively. Gong et al. (2012) provide estimates of inter-generational income mobility in urban China for father-son, father-daughter, mother-son and mother-daughter. We use a simple average of these for our targeted moment. The income Gini coefficient for China in 1981 is taken from the World Bank Development Indicators.[21] Table 5 provides a summary of all parameter estimates along with data and model moments. The model does an excellent job of matching the data moments.

5 Model-Fit 1960-2010

While our benchmark model is calibrated to match the data in terms of mortality, income mobility, etc., it is useful to compare predictions along some other

[19]Available data shows public spending has stayed at a relatively stable 60/40 ratio between 1996-2011 (China, 2014).

[20]We could alternately fix the government budget starting in 1960 and let the private cost be determined endogenously throughout the transition. However, due to a very small share of college educated in 1960, we face convergence issues in transitions if we allow private cost of education to be determined endogenously between 1960 and 2010.

[21]No estimates are available prior to 1981.

Table 5: Estimation Results

Parameter	Value	Moment	Data	Model
Discount factor β	0.944	K/Y	3.23	3.16
Persistence of prod. shock ρ	0.62	Inter-generational income mobility	0.60	0.60
S.D. of prod. shock σ_η	0.43	Income Gini	0.29	0.29

dimensions not targeted during calibration. First, the model is able to match the changing demographic structure rather well. This is evident from figure 7 showing the old-age and child dependency ratios both in the model and the data (UN, 2015).[22] These dependency ratios were not targeted directly in our calibration exercise. As fertility and mortality rates were not completely stable prior to 1960, the initial steady state somewhat over-predicts these ratios. However, as our demographic structure evolves over time, it become quite similar to the data. This is perhaps unsurprising as we feed in fertility rates and age-specific mortality rates that approximate the data along the transition. Nonetheless, it is reassuring that estimates seem reasonable.

Figure 7: Model Fit: Demographics

(a) Old-Age Dependency Ratio (b) Child Dependency Ratio

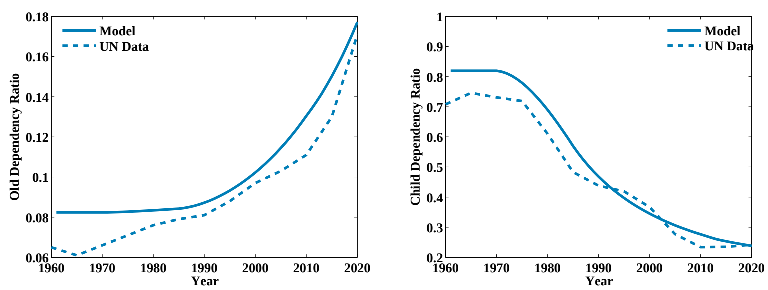


Figure 8 shows the primary, secondary and college share from 1970-2010 both in the model and the data.[23] The model slightly over-predicts the initial secondary

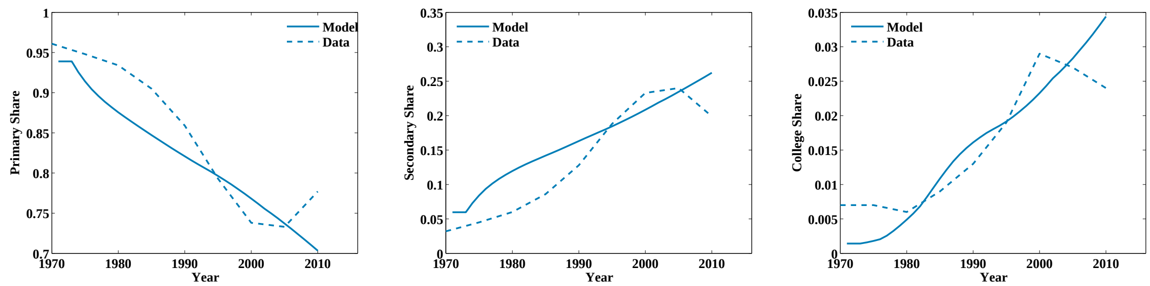
[22]The UN old-age dependency ratio is defined as the ratio of people older than 64 to those aged 15-64. The child dependency ratio is defined as the ratio of people aged 0-14 to those aged 15 to 64. It should be noted that the young dependents in our model correspond to ages 0-11 but we adopt the same definition as UN in these graphs for consistency.

[23]Data is average schooling attainment for population aged 25+ from Barro and Lee (2013).

share and under-predicts the college and primary shares. However, the trends in schooling shares are quite similar over time.

Figure 8: Model Fit: Education Shares

(a) Primary Share (b) Secondary Share (c) College Share



The model also does well in matching the average age-specific consumption, labor earnings and transfer profiles from the National Transfer Accounts (NTA) data (Lee and Mason, 2011).[24] Figure 9 shows these average age-specific profiles for the year 2002 in both the data and the model.[25] In this figure, consumption is expressed as a percentage of age 45 consumption, and earnings and transfers as a percentage of age 45 earnings.

Similar to the data, we have an increase in consumption through early years of life as education expenditures and consumption requirements rise. This is followed by a sustained level of consumption throughout much of the individual's working life before there is an increase due to health expenditures later in life. In contrast to the data, our model maintains the elevated consumption throughout old-age as health expenditures remain high. Moreover, our model over-predicts the gap between mid and late-life consumption as we do not incorporate health spending prior to becoming elderly. In terms of the labor earnings profile, the model matches the data well, though the rise in income is somewhat less steep and the peak a few years later.

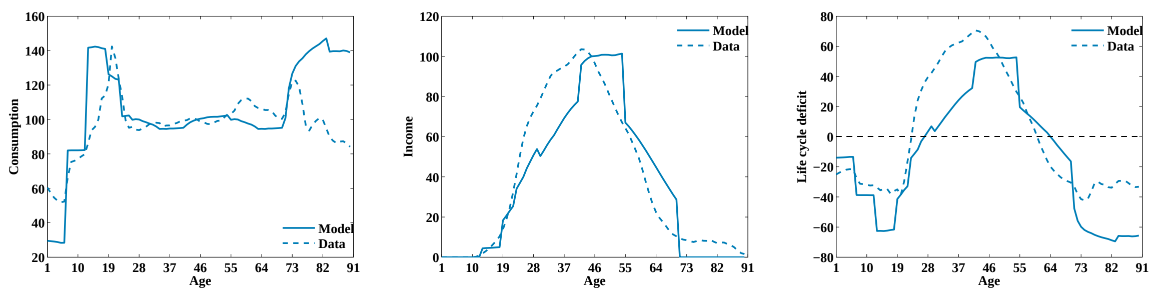
[24]To be consistent with the NTA data, consumption here also includes total public and private medical expenditures and total public and private education expenditures. Labor earnings are before-tax and do not include pensions, transfers are defined as labor earnings less consumption for each age.

[25]Model predictions are shown assuming an indefinite fertility of 1.5 after 2010.

The life-cycle deficit is defined as consumption less labor income and gives a sense of how the model does in predicting intra-household transfers. Life-cycle deficits become positive only a few years later in the model compared to the data, while they return negative a few years later as well. Compared to the data, the deficit is somewhat lager in the model during the school-aged years and for the elderly. This is primarily due to the over-prediction of education and health spending during the respective age ranges.

Figure 9: Model Fit: Consumption, Earnings and Transfers

(a) Consumption (b) Income (c) Transfers



6 Results

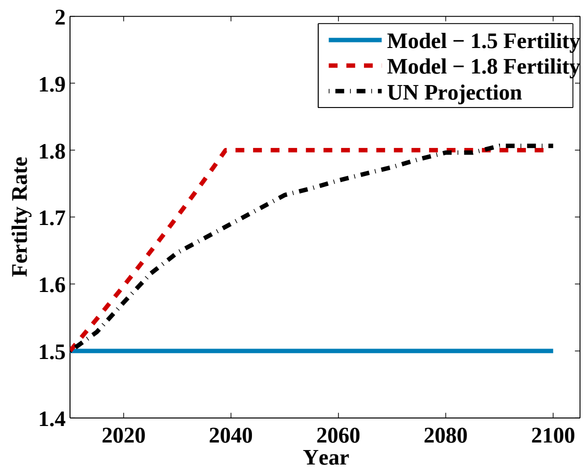
In order to understand the short and long run effects of demographic changes on macroeconomic outcomes in China, we analyze two different future fertility scenarios. First, we assume that the 2010 fertility of 1.5 is maintained indefinitely into the future. Second, beginning in 2010, we assume an unexpected gradual increase to a long-term fertility rate of 1.8, which is somewhat higher than the current average in China.[26] Both fertility paths are identical along all other exogenous dimensions.[27]

[26] Similar to implementing the decline in fertility from 1960-2000, we change the cohort growth rate in 2010 to that implied by a long run fertility rate of 1.8 (given by $0.9^{\frac{1}{J}}$) and back out the implied transition fertility rate. This is done in order to achieve a stable demographic structure in the long run.

[27] However, as detailed in the calibration section, they both differ from the initial steady state in terms of mortality, tuition cost, returns to schooling and public outlays on education.

The fertility rates fed along both transition paths are given in figure 10 along with a comparison to the UN projections (medium variant). These two paths — 1.5 and 1.8 — are henceforth referred to as the "low" and "high" fertility scenarios.

Figure 10: Fertility Rates Along Transition



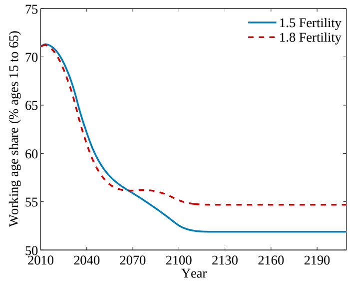
6.1 Benchmark Simulations

As our theory has several countervailing mechanisms, we begin our quantitative analysis by discussing the long run and short run macroeconomic outcomes in our benchmark model as outlined above. Figure 11 shows the transition paths for select macroeconomic variables for both fertility scenarios for the benchmark model. All per capita variables have been normalized to output in the low fertility final steady state. First, notice there are macroeconomic increases along both fertility paths going forward from 2010. However, comparing across fertility paths, we find overall macroeconomic declines when moving from a long-term fertility rate of 1.5 to 1.8. Table 6 gives percentage change in select variables across fertility scenarios in the long run steady state. Despite a higher working age share in the long run, there is a decline of 2.5% in per capita effective labor supply and 1.5% in capital, resulting in lower long term per capita output (2.0%) and consumption (4.3%).

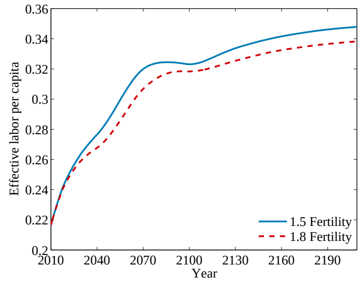
In our model, demographic changes and exogenous improvements in returns

Figure 11: Transition Dynamics: Benchmark

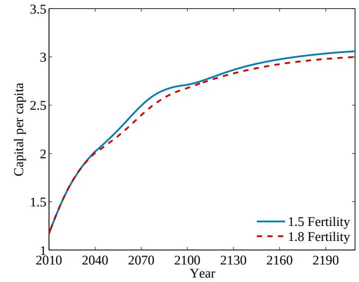
(a) Working-age share



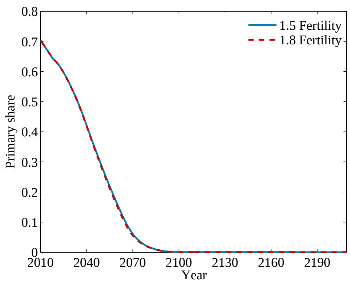
(b) Effective labor per capita



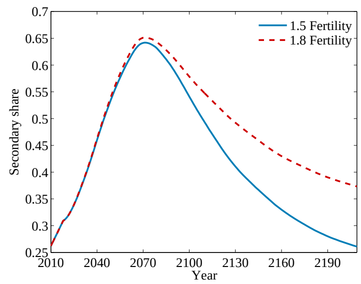
(c) Capital per capita



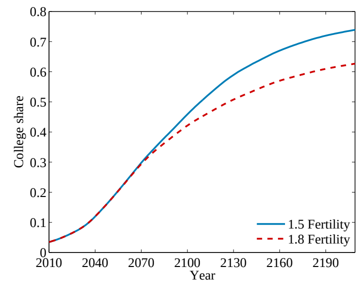
(d) Primary share



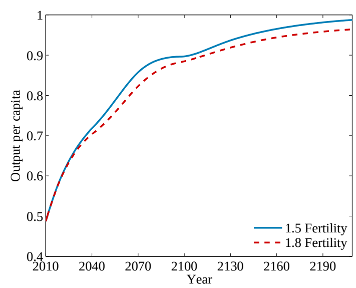
(e) Secondary share



(f) College share



(g) Output per capita



Note: All per capita variables have been normalized to output in the 1.5 fertility final steady state.

to education since the 1980's result in an increase in both college and secondary education shares and a drop in primary share over the coming decades under both fertility scenarios (figures 11d-11f). After 2070, when the primary education share goes to zero, further improvements in educational attainment are brought about by a decline in secondary share and a further increase in college share. However, the

Table 6: Final Steady State Results

TFR	1.5	1.8	%Δ
Old dependency ratio	0.71	0.56	-21.03
Child dependency ratio	0.22	0.27	23.66
Working share (%)	51.89	54.69	5.40
Output per capita	1.00	0.98	-2.04
Consumption per capita	0.54	0.52	-4.29
Consumption per ad equ	0.58	0.57	-2.26
Capital per capita	3.10	3.05	-1.54
Average labor supply	0.52	0.53	1.88
Effective labor per capita	0.35	0.34	-2.51
Investment per capita	0.35	0.37	3.62
Savings rate	0.06	0.09	43.69
Interest rate (%)	5.50	5.42	-1.44
Wage rate	1.48	1.48	0.47
SS tax (%)	28.34	23.35	-17.61
Consumption tax (%)	14.45	13.55	-6.25
Public Medical expenditures (% of GDP)	3.56	2.90	-18.55
SS payments (% of GDP)	14.74	12.14	-17.61
Private college cost	0.34	0.37	10.22
Primary share (%)	0.00	0.00	-
Secondary share (%)	21.48	32.55	51.55
College share (%)	78.52	67.45	-14.10

Notes: TFR refers to total fertility rate. Per-capita outcomes have been normalized to 1.5 steady state output.

gains in college share are smaller under the higher fertility scenario.

The behavioral response to higher fertility is influenced by several additional factors when human capital is endogenous in addition to savings. First, some poor households may not be willing to send additional children to school without the ability to borrow funds for interim consumption, leading them to reduce their choice of educational attainment due to the household borrowing constraint. Moreover, recall that educational returns are uncertain at the time schooling decisions are made, making human capital a riskier investment than physical capital. As our functional form for preferences exhibits decreasing absolute risk aversion, this implies that human capital investment will weakly increase with household wealth, even if the household borrowing constraint does not bind. Thus, long run declines in wealth reduce education both by placing additional budgetary pressure on families and making them less willing to invest in risky human capital. Fertility changes also influence human capital investment decisions by altering the education budget of the government. In our model, government outlays on education are fixed as a share of output so an increase in the share of school-aged children leads to an increase in the per student private cost of secondary school and college (refer to figure A.1e in appendix A). If families are unable or unwilling to invest in lumpy school tuition despite relatively high returns, they may shift resources to physical capital as an alternate means of investment.

With higher fertility, there is a higher transfer requirement for future generations of children. There is also a shift from human capital to physical capital investments due to the aforementioned reason. Together these lead to a 43.7% increase in the long run savings rate which corresponds to 3.6% increase in average annual investments in physical capital. However, despite the increase in savings rate, there is a small decline in average capital stock due to lost income from the long run decline in human capital.

Finally, there are declines in fiscal outlays for elderly social insurance programs with higher fertility. Specifically, there is an 18.5% reduction in public outlays on medical expenditures as share of output, which places downward pressure on the consumption tax. There is also a 17.6% decline in social security pension payments as a share of output, and correspondingly a drop in social security labor income tax. Combining this reduction in distortionary income tax with a small increase in the ratio of physical to human capital results in a net increase in the after-tax wage of more than 7%. Nonetheless, this increase in the private returns to schooling is not able to counteract the negative aggregate effects of higher fertility on education previously detailed. All together, we find that the favorable macroeconomic effects of higher fertility—larger working age share, additional savings for future children, and reduced public spending on pensions and health care—are outweighed by reductions in average educational attainment and capital stock in the long run steady state.

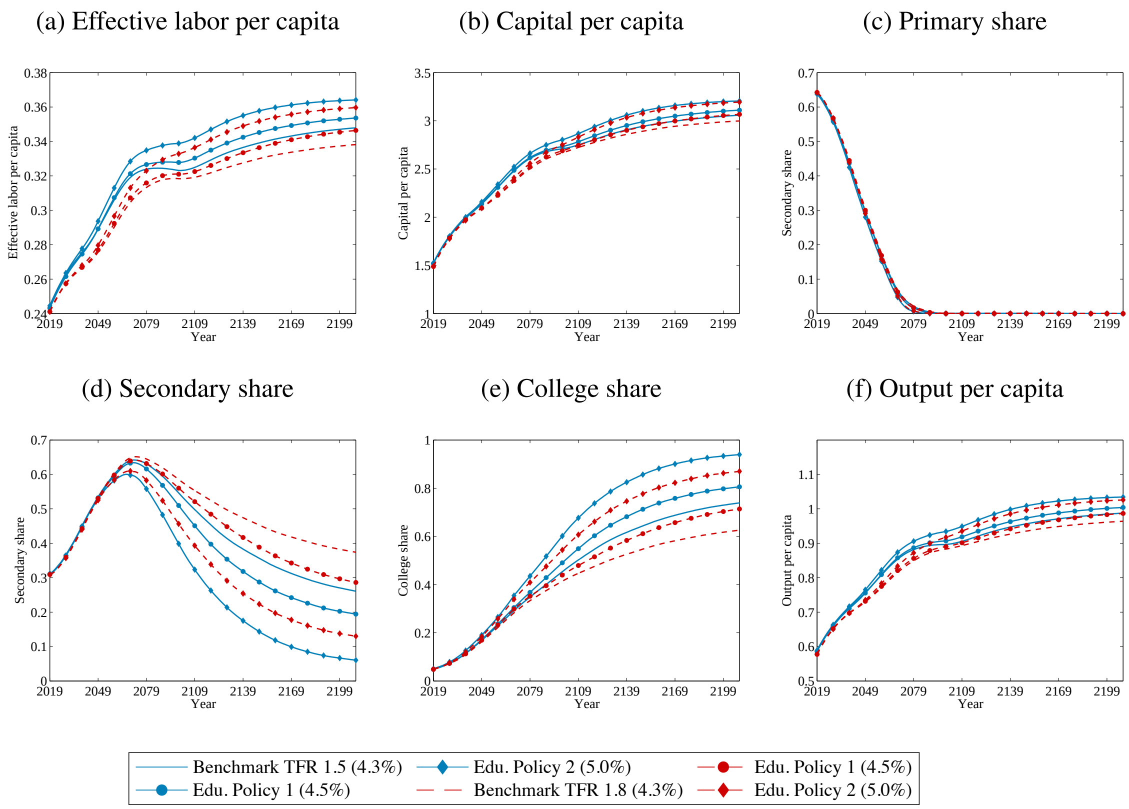
6.2 Policy Experiments

We next conduct a set of experiments to gauge the potential of education policy to influence human capital accumulation in our model. Recall that in the benchmark calibration the public education budget is fixed at 4.3% of GDP starting from the year 2010. Here, we simulate the impact of increasing the education budget to 4.5% or 5.0% of GDP (from the year 2019 onward).Table 7 provides the final steady state results under the different education policy regimes for both fertility scenarios.

Increasing the government budget for education from 4.3% to 4.5% (a 4.7% increase) results in a roughly 2% increase in long run average output in both fertility cases. Moreover, comparing columns (1) and (5) shows that this 0.2 percentage point increase in the government budget on education is able to undo the negative macroeconomic effects of higher fertility in the long run. This underscores the importance of the human capital channel in our model. An increase in per child educational subsidy due to the increase in education budget lowers the private cost of college by 5.4% in the high fertility case. This results in a roughly 15% increase in college shares which—along with higher working age share—make effective labor under higher fertility comparable to the lower fertility benchmark case. Though savings rate remains largely unaffected, a long run increase in earnings, due to improvements in human capital levels, increases the average capital stock in the economy. Together, these effects prevent the long run declines in output observed when fertility increases and the education budget is held fixed at 4.3%. However, note that these are longer run effects. In the short run, as seen in figure 12, the positive effects of this policy regime are unable to counteract other dominant channels including a declining working age share and higher transfer requirements for future generations of children. For example, with an education budget of 4.5%, it takes more than eighty years for the output per capita to reach the low fertility scenario with the benchmark budget of 4.3%.

Next, we increase the government education budget to 5% of GDP (a 16.2 % increase from benchmark). This experiment is elucidative for two reasons. First, as expected, a further increase in the educational subsidy lowers private tuition, thereby raising human capital levels and average physical capital stock in both fertility scenarios. Second, more interestingly, this policy has a relatively larger impact in the higher fertility scenario as compared to the lower fertility case. For instance, compared to the benchmark, long run average output increases by 6.1% and 4% respectively. A relatively low level of human capital in the benchmark higher fertility scenario offers more room for improvement. A reduction in private tuition costs results in a 35.6% increase in college shares as opposed to 23% in the low fertility case. With long run college shares as high as 91.5 and 96.7% respectively, the policy impact in high and low fertility scenarios is now almost identical in terms of long run output (compare columns (3) and (6)). The short run effects are also more pronounced under this experiment. For example, with high fertility and an education budget of 5%, it takes about seventy years for output per capita to reach the low fertility scenario with a benchmark budget of 4.3%.

Figure 12: Transition Dynamics: Policy Experiments



Note: All per capita variables have been normalized to output in the benchmark 1.5 fertility final steady state.

Table 7: Education Experiment Results

TFR	1.5			1.8		
Col. No.	(1)	(2)	(3)	(4)	(5)	(6)
Edu. Subsidy	4.3%	4.5%	5.0%	4.3%	4.5%	5.0%
Output per capita	1.00	1.02	1.04	0.98	1.00	1.04
Consumption per capita	0.54	0.55	0.56	0.52	0.53	0.54
Consumption per ad equ	0.58	0.59	0.60	0.57	0.58	0.59
Capital per capita	3.10	3.15	3.21	3.05	3.12	3.22
Effective labor per capita	0.35	0.36	0.37	0.34	0.35	0.36
Investment per capita	0.35	0.36	0.37	0.37	0.37	0.39
Savings rate	0.06	0.06	0.06	0.09	0.09	0.09
Interest rate (%)	5.50	5.51	5.52	5.42	5.43	5.45
Wage rate	1.48	1.48	1.47	1.48	1.48	1.48
SS tax (%)	28.34	28.55	28.67	23.35	23.50	23.76
Consumption tax (%)	14.45	14.89	15.88	13.55	13.98	15.03
Private college cost	0.34	0.31	0.23	0.37	0.35	0.28
College share (%)	78.52	85.65	96.68	67.45	77.37	91.45

Notes: TFR refers to total fertility rate. Per-capita outcomes have been normalized to 1.5 steady state output. Columns (1) and (4) provide the benchmark results for the respective fertility cases.

7 Conclusion

After having implemented one of the most stringent fertility policies in the late 1970's to slow down population growth, China recently relaxed its one child policy in hopes of promoting economic growth and social welfare. In this paper, we develop a dynamic general equilibrium model for understanding the short and long run macroeconomic effects of feasibly induced changes in aggregate fertility rates. We incorporate endogenous education decisions and intra-household transfers to capture the effect of changing demographics on human and physical capital accumulation.

Our results indicate that a fertility bump results in lower short run income per capita in our benchmark model economy. These results may persist in the long run as well where a small bump in fertility results in big declines in human capital investments. More generally, we find that maximizing the working age share of the population is not the same as maximizing income per capita. As such, even though our focus in this paper has been on China, our findings are generalizable to other countries which are experiencing population aging. Faster aging economies with already high levels of human capital, such as Japan, Germany, Italy, Finland and Portugal (projected to have old-age dependency ratios greater than 40% by 2030), might benefit from a bump in fertility in the long run.

Our study is not without limitations. Most notable being the treatment of fertility as an exogenous change which is homogeneous across households in the model. While this reduces the computational burden of solving our model, it may have important implications for our results. For instance, we implicitly assume that the urban and rural sectors in China will respond in a similar way to the relaxation of the one child policy. However, empirical estimates suggest that the urban sector would see a bigger response to the policy change as compared to the rural sector.[28] If fertility changes are concentrated within the urban sector — composed of wealthier families on average — then higher fertility may have smaller effects on human capital through household budget constraints. We also make several simplifying assumptions about human capital investments and the evolution of labor productivity. We abstract away from labor supply decisions, health dynamics and model medical expenditure uncertainty only for the very old. We are also limited to analyzing the economic impact of fertility changes and stress that a welfare analysis is outside the scope of our current framework. Addressing some these limitations leaves room for important future research in this direction.

[28] Zeng and Wang (2014) estimate that the rural TFR would increase from 2.01 to 2.15 between 2015 and 2030 while the urban TFR would increase from 1.24 to 1.67.

A Additional Figures

Figure A.1: Benchmark Transition Dynamics: Prices

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