The Impact of College Expansion on Human Capital Investment and Inequality *

Shijun Gu[†]
University of Minnesota

November 13, 2019

CLICK HERE FOR THE LATEST VERSION

Abstract

This paper studies how China's public college expansion program impacts human capital investment in children and inequality in the long run. I introduce a heterogeneous-agent overlapping-generations model in which altruistic parents invest in their children's education, which can raise their children's future working efficiency as well as their chance of passing the College Entrance Examination. After estimating the model using Chinese data, I examine the effects of the 1999 college reform, which led to a six-fold expansion in college attendance. I find that the increase in college attainment, human capital, and ex ante welfare is substantial but unevenly distributed, with disadvantaged children benefiting least from the existing policy. The simulation also reveals that the reason for the unequal outcomes is that college expansion primarily incentivizes rich parents to spend more on their children's education, which is consistent with the empirical evidence. Furthermore, I show that relative to the current policy, a remediation policy that diverts a part of the college tuition subsidy to support the development of disadvantaged children can result in not only additional human capital and welfare gains but also a reduction in inequality and intergenerational persistence.

JEL Classifications: I24, I25, J13, J24

Keywords: College Expansion, Human Capital, Inequality, China

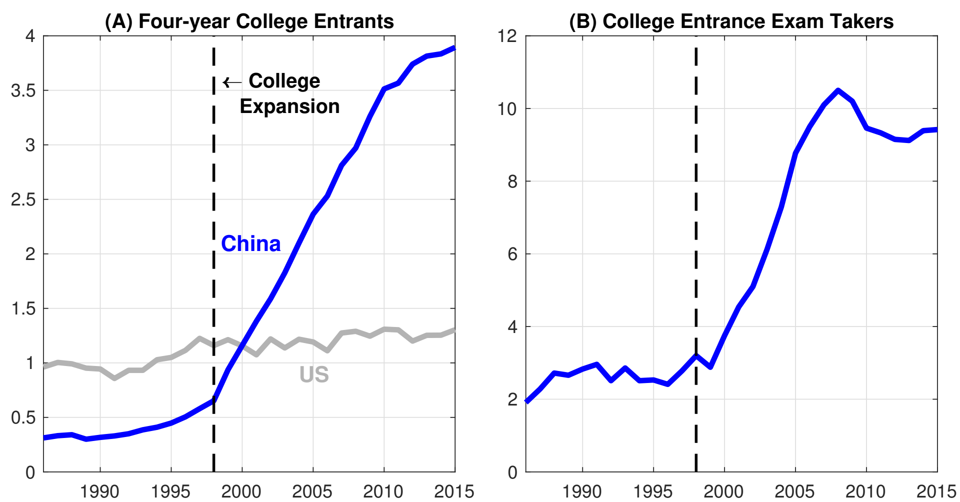
*I am grateful to Anmol Bhandari, Ellen McGrattan, and Joseph Mullins for their guidance and support throughout this project. I also thank Job Boerma, J. Carter Braxton, Macricristina De Nardi, Matthias Doepke, Salomón García, Han Gao, Fang Yang, and Lichen Zhang for their helpful suggestions. Finally, I thank participants in the Workshop in Macroeconomics at University of Minnesota for helpful discussions and comments. All remaining errors are my own.

†Department of Economics, University of Minnesota. Email: guxxx385@umn.edu

1 Introduction

Individuals living in developing countries face difficulties in gaining access to higher education due to the limited capacity of public college[1]. Since education attainment and skill accumulation are complementary, this situation can substantially distort intergenerational investment in human capital and lead to slow growth in labor productivity. Therefore, government intervention in the market for higher education is crucial to promote economic development.

Figure 1: Chinese College Admission Data (1986-2015)



Note: Data source: China Statistical Yearbook and US National Center for Education Statistics. The blue solid line in Panel (A) plots the number of new entrants (in million) to four-year colleges in China from 1986 to 2015. The grey solid line plots the US counterparts, which are derived from the number of high-school graduates and the immediate college enrollment rate. The blue solid line in Panel (B) plots the number of College Entrance Examination takers (in million).

Since the late 1990s, China has implemented a large-scale public college expansion program. As shown in figure 1 (left panel), this policy has led to an additional three million students passing the College Entrance Examination and attending four-year colleges every year. Meanwhile, college becomes more affordable for households due to the rapid growth in disposable income. Figure 1 (right panel) shows that the number of test takers has dramatically increased since the early 2000s, which reflects that an increasing fraction of high-school graduates prefer going to college over immediately entering the labor force.

[1] Private institutions in developing countries are characterized by their poor quality of teaching and expensive tuition. As a result, public college is the only affordable channel through which people can acquire a high-quality college education.

As the capacity of public college constrains college attendance and an exam-based selection scheme is in place, investing in children's human capital can raise their probability of admission. If the college expansion policy can further reward children with high human capital by increasing their admission chances, parents will have more incentives to make intergenerational educational investments. The goal of this paper is to quantify how much college expansion affects long-run human capital investment and to examine the impact of the policy change on the education expenditures of parents as well as the educational outcomes of children with different socioeconomic backgrounds. Moreover, this investigation also provides a framework to analyze the effects of alternative education policies.

To these ends, I build an overlapping-generations framework where altruistic parents invest in their children's skills and make the decision on whether or not their children should take the College Entrance Examination. Specifically, I incorporate childhood development into an otherwise standard incomplete market model. Parents augment their children's human capital children through multiple-period skill investments according to a technology that features dynamic complementarity and self-productivity. A critical feature of this model is that intergenerational skill investment can increase not only children's future labor efficiency but also their probability of passing the College Entrance Examination. To specify how each level of human capital (proxied by test score) is associated with the probability of college admission, I estimate an admission policy function that resembles the college selection scheme of China. I find that with a score below the average, a test taker has a very low probability of attending college. However, if the score is above the average, the probability of passing increases significantly with higher test scores. The nonlinear correlation between the admission probability and human capital plays an essential role in the analysis of the distributional effects of the college expansion program.

Intergenerational investment in the model is disciplined using Chinese household-level data on education expenditure, income, and education attainment. The data provide detailed information on how parental skill investment in children and the education outcomes of children are associated with the parent's characteristics. I document four facts that are informative for the model's estimation and validation: (1) the share of education expenditure in household income increases as children age; (2) education expenditure become less elastic to changes in household income as children age, (3) high-income and college-educated parents spend significantly more on child education, and their children are more likely to attend four-year colleges; and (4) after the college expansion, there is a substantial but unequal increase in education expenditure towards children and in college attainment across socioeconomic groups, with disadvantaged children benefiting least from the existing policy.

The model is estimated to match both macro and micro moments constructed using

Chinese data. The crucial part is the estimation of skill formation technology, which combines the current-period child's skill, parent's skill, as well as monetary investment to produce the next-period child's human capital. The model requires me to specify how current-stage investment in children's education is complementary to that in the previous stage. I recover the parameters controlling the degrees of dynamic complementarity at different childhood developmental stages via indirect inference. Specifically, for each developmental stage, I first pin down the share of the child's skill in the production function by matching the corresponding average household education expenditure to income ratio. Then I design an auxiliary model to highlight data patterns on the stage-dependent effects of household income on education expenditure towards children. I search for the model parameters by matching model-predicted auxiliary coefficients to their empirical counterparts.

To quantify the long-run macroeconomic and distributional consequences of college expansion programs, I lower the tuition-to-income ratio by 22 percentage points and feed in a new admission policy function, which reflect the college costs and passing probability respectively in 2015. Besides, I feed in a skill-biased technological change that perfectly counterbalance the decline in college wage premium resulting from the general equilibrium effect. I find that the existing policy yields an education expenditure increase of 16.5% and ex ante welfare gains of 17.2%. Meanwhile, income inequality and intergenerational persistence in human capital and education rise significantly. To understand this result, I explore how changes in education expenditures are correlated with the human capital and education group of parents. I find that consistent with the data, for the high-skill and college-educated parents, their education expenditures are more elastic to the policy change following the college expansion. In turn, their children's human capital, as well as the college admission probability increases more than in the case of disadvantaged children. As a result, parents with high human capital and a college degree are more likely to transmit their socioeconomic status to their children than before, which leads to a widening income gap between rich and poor and more persistent skill and schooling across generations.

To explore a more efficient way for the government to implement education policies, I use the calibrated model to conduct a counterfactual policy exercise. I analyze an economy in which the government implements a targeted early childhood intervention. This program subsidizes 60% of the education expenditures made by the parents of disadvantaged children whose ages are between 2 to 9. The expenditure is financed by raising college tuition. I find that this policy yields an education expenditure increase of 29.4% and ex ante welfare gains of 26.1%, both of which are significantly higher than the numbers under the existing policy. Furthermore, since the program exclusively targets disadvantaged children, it redistributes human capital and welfare gains to children of parents with low human capital. Consequently, the remediation policy can generate a substantial decline in inequality, which suggests that policy makers should consider diverting a part of the government subsidy on college tuition to support early childhood development for disadvantaged children.

Related Literature. There is extensive literature that quantitatively evaluates the effects of higher education policies. Garriga and Keightley (2007), Meghir, Abbott, Gallipoli, and Violante (forthcoming) study the impact of various financial aid programs in the US under a general equilibrium context. Krueger and Ludwig (2016) focus on characterizing the optimal fiscal and education policy mix. Bohácek and Kapicka (2016) explore whether the variation in education and tax policies can explain differences in educational outcomes in the US and Europe. Kindermann (2012) proposes a reform that would transform the publicly funded college education system to a privately funded system. Among the papers that study higher education policies in developed economies, the public education sector can accommodate everyone who chooses to study in college. This paper complements this literature by examining the impact of education policies in China, where the capacity of public college constrains college attendance. The main issue of education reform is hence expanding the size of the college. Additionally, all of the literature mentioned above ignores the effect of education policies on parental investments. This paper endogenizes the skill formation process of children and studies the distributional impact of college expansion on children's development.

My work contributes to the literature which examines the impact of college expansion in China. Ma (2014) quantitatively studies the impact of college expansion on college wage premiums for different age groups. In her model, whether or not an individual can go to college depends on the exogenous ability draw. In my model, a child's performance in the College Entrance Examination depends on the level of human capital accumulated by their parents. Through explicitly modeling the intergenerational transmission of skill, the richer model allows me to study how college expansion affects the educational outcomes of children whose parents differ in their socioeconomic background. Additionally, Feng (2019) develops a discrete college choice model, estimates a college admission probability function, and studies heterogeneous effects of college expansion on individuals in different cohorts. S. Li, Whalley, and Xing (2014) empirically examine the short-run labor market outcomes of college expansion and find that the policy increased the unemployment rate among young college graduates[2].

[2]Other literature studies the education system of China and its labor market consequences. Jia and Li (2016) empirically find that access to elite education through the College Entrance Examination does not promise one's entry into the elite class, nor alter the intergenerational link between parents' status and children's status. S. Lee and Malin (2013) quantify a novel channel through which access to higher education

There are two building blocks of my model. The first one is a heterogeneous-agent framework where individuals are facing uninsurable idiosyncratic earnings risk introduced by Bewley (1986), Huggett (1993), and Aiyagari (1994). The second is the framework of intergenerational linkage, beginning with the work of Becker and Tomes (1979). The model of this paper is most closely related to Daruich (2018), which incorporates intergenerational human capital investment and education choice into individuals' life-cycle. Relative to the prior work, this paper highlights a new channel that incentivizes parents to invest in children's education. That is, since the capacity of college constrains college attendance, skill accumulation can make college easier to get into by increasing children's college admission probability. With this mechanism in place, college expansion will significantly affect parental investments because it impacts the aggregate tightness of the capacity constraint.

The estimation of the skill formation function is essential in previous literature (e.g., Agostinelli and Wiswall, 2016; Cunha, Heckman, and Schennach, 2010; Cunha, 2013; S. Y. Lee and Seshadri, 2019; Moschini, 2019; Daruich, 2018; Mullins, 2019; Caucutt and Lochner, forthcoming) since the technology specifies how parental investments map onto children's outcomes[3]. In this paper, I present a human capital production function consistent with two properties regarding childhood development: dynamic complementarity and self-productivity. I estimate skill formation technology using Chinese household-level education expenditure data. The dataset highlights the empirical patterns on the effects of household income on education expenditure on children. An indirect inference approach is then put into use to pin down the stage-dependent dynamic complementarity parameters.

This paper also contributes to the recent literature which studies the Chinese economy by endogenizing human capital investment in a quantitative framework. Choukhmane, Coeurdacier, and Jin (2017) study the contribution of the 'one-child policy' to the rise in China's household saving rate and education investment in recent decades. Doesey, Li, and Yang (2019) use a model featuring endogenous human capital investment to examine the role of demographics and industrial policies in accounting for the rise of the savings rate and economic growth in China. Both papers focus on quantifying the linkage between the changing demographic structure and skill investment. Relative to their work, college expansion in my paper is the key driving force that leads to an increase in educational expenditure towards children. Additionally, different from prior work, this paper focuses on the distributional consequences of the policy on human capital accumulation and welfare.

policy can reduce the labor market friction in China. H. Li, Meng, Shi, and Wu (2012) reviews the history and discuss the potential impact of the reform.

[3] As highlighted by several papers mentioned above, parental time is also an important input for developing skills of children. However, monetary investment is the only endogenous input in the skill formation technology.

The rest of the paper is organized as follows. Section 2 introduces the institutional background of the Chinese college admission system. Section 3 lays out the life-cycle model. Section 4 presents the empirical findings on parental investments, college admission probability, and returns to skills. Section 5 describes the parameterization and model fit. Sections 6 present the quantitative results from the existing college expansion policy and counterfactual policies, respectively. Finally, Section 7 concludes.

2 Institutional Background

Higher education system and types of college. In 2015, the total number of Chinese national higher institutions was 2,845, most of which were funded by the government. Private universities in China are a complement to public universities to meet the needs of those students who failed in their College Entrance Examination but could not afford the tuition fees to study abroad.

Students are sorted into different public universities through the college entrance exam. The public university has two tiers: regular university (four-year college), and vocational college (three-year college). Test takers are required to receive much higher scores on the exam to attend regular universities. This feature suggests that parents have to spend more on their children's education to make children more likely to enter a four-year college. As a result, skill accumulation plays a more crucial role in determining the four-year college admission probability[4]. Zhang, Zhao, Park, and Song (2005) estimate that the return to completing vocational college relative to high-school graduates was 17.8% in 2001, whereas regular university graduates earned 37.3% more than high-school graduates. This evidence suggests that an individual's labor market result can be very different if they attend a four-year, rather than a three-year college. Motivated by these facts, throughout this paper, I define individuals who graduate from three-year colleges as non-college workers in the model and calibration.

College entrance exam. The National College Entrance Examination is a standardized test taken by high-school graduates who want to pursue their undergraduate studies at college. This exam is uniformly designed by the Ministry of Education of China based on the curriculum of (senior) high school and is held annually in summer. Since the test is knowledge-based and highly selective, students normally spend their entire high-school

[4]In recent years, the total college admission rate (including both three- and four-year colleges) in China has been as high as 80%, whereas the admission rate of four-year colleges has been only 40%. Therefore, whether or not one can attend college indicates more about her education choice, but whether or not one can attend the four-year college indicates more about her skill level.

years to prepare for the exam[5]. All of the students take tests on Chinese, English, and mathematics. In addition, students choose between two concentrations, either the social science-oriented area or the natural science-oriented area.

College admission entirely depends on students' performance on the College Entrance Examination. Students are required to apply for their intended university prior to the exam. The authority will announce official cutoff scores for universities in different tiers after all the exams have been graded. Each university also announces a cutoff score (must be higher than the official cutoff) based on the number of applicants and vacancies. If a student's test score can make the official cutoff, as well as the cutoff of the university to which they applied, they will be enrolled in that institution. Although students can apply for several universities by filling a list of ordered preferences, many good institutions only admit students who apply to it as their first choice, which means a student with a test score higher than the official cutoff may end up failing in the test[6] if they cannot make their first-choice university's cutoff.

College expansion. The four-year college admission rate in 1998 was 20.4%. In 1999, the Chinese government suddenly announced its college expansion plan, and the admission rate dramatically increased to 32.5%[7]. Throughout the last two decades, college has been continuously expanding in China. From 1998 to 2015, the enrollment of new undergraduate students on average grew by 11.1% annually, increasing from 0.65 million in 1998 to 3.89 million in 2015. In recent years, the government has begun to control the rapid expansion of college education.

3 Model

I study an overlapping-generations model in which parents, for altruistic purposes, choose intergenerational human capital investment and choose whether or not their children will take the College Entrance Examination. A skill formation technology maps the monetary investment to child development outcomes. Accumulating human capital can raise a child's future labor productivity as well as her probability of passing the test. Whether the child can earn a college degree depends not only on the endogenous education choice but also on the government admission policy because the public college has a limited capacity. Once the

[5] Since high-school education mainly serves as a mechanism to select college students, it does not teach students much practical knowledge for working. That is why H. Li, Liu, and Zhang (2012) estimate that the return to high-school education is low in China.

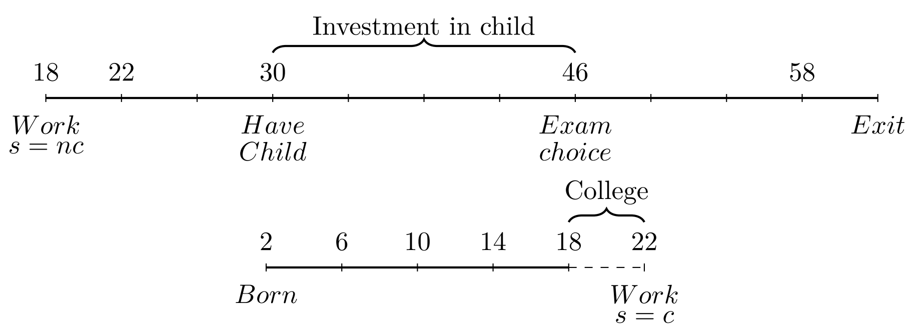
[6] Because this paper defines college as a four-year institution (regular university), attending a three-year college (vocational college) is also considered failing the test.

[7] The policy was announced just four months before the exam, but the exam preparation takes years. Hence, the policy did not boost the number of exam takers.

education outcome (whether to attend college) is realized, the individual's human capital becomes fixed for the rest of her life. Except for the intergenerational linkages through human capital investment, households solve a standard consumption-savings problem for maximizing lifetime utilities. I abstract from modeling the retirement stage. As a result, individuals exit the economy immediately after the end of the working stage. A representative firm combines capital, college labor, and non-college labor to produce the final consumption good.

3.1 Demographics and Timing

Figure 2: Timeline in the Model



Time is discrete, and one model period is four years. There is no mortality risk. There are $J = 11$ overlapping generations, each with a unit mass of households. The demographic structure is assumed to be uniform. Let j denote the model period, and represent the stage of the life-cycle between ages $[14+4j, 17+4j]$. Before reaching adulthood, children live with their parents and do not make any economic decisions. Individuals become economically active at different stages, depending on their education level. College-educated individuals spend the first period (age 18-21) in college and start working as college labor in period 2. Non-college individuals enter the labor market in period 1. At the beginning of period 4, all of the individuals give birth to a child (age 2). From period 4 to 7, parents make monetary investments in their children's human capital. At period 8, they decide whether or not to support their children taking the College Entrance Examination. Whether a child can attend college also depends on the result of the test. Parents pay tuition and living expenses for their children during their college stage. After their children become independent, parents continue to work until the end of period 11 (age 61).

3.2 Aggregate Production Function

An individual's education outcome is endogenously determined before she becomes independent. The education level s falls into the set $s \in \{nc, c\}$, where nc denotes non-college-educated individuals, and c denotes college-educated individuals. I assume that college and non-college-educated labor are imperfectly substitutable in production. Let H_s denote the aggregate effective labor of education level s, measured in efficiency units. The total labor efficiency units aggregate across education groups, which is given by

$$H = (\mathit{\Phi}(A_c H_c)^{\Omega} + (1 - \mathit{\Phi}) H_{nc}^{\Omega})^{\frac{1}{\Omega}},$$

where A_c captures a skill-biased change in productivity that directly affects the relative contribution of college-educated workers to output, $\frac{1}{1-\Omega}$ is the elasticity of substitution between non-college and college-educated labor, and Φ denotes the share of college educated labor in production. The college wage premium will be endogenously determined by the supply of college workers, conditional on $\Omega < 1$.

A representative firm combines the aggregate labor and physical capital to produce final output according to a Cobb-Douglas production technology

$$Y = F(K, H) = K^{\Lambda} H^{1-\Lambda} = K_t^{\Lambda} (\mathit{\Phi}(A_c H_c)^{\Omega} + (1 - \mathit{\Phi}) H_{nc}^{\Omega})^{\frac{1-\Lambda}{\Omega}}$$

where Λ measures the capital share. The firm chooses two types of labor and capital to solve

$$\underset{H_c, H_{nc}, K}{max} Y - w_c H_c - w_{nc} H_{nc} - (r + \xi + \delta) K,$$

where w_s is the wage per efficiency unit of labor of skill s, r is the capital rental rate, ξ is the intermediation cost in capital market[8], and δ is the depreciation rate of capital.

3.3 Preference

Individuals derive utility from consumption of all household members that are representable by a expected lifetime utility function

$$E_1 \sum_{j=1}^{J} \beta^{j-1} u(\frac{c_j}{1 + 1_c \zeta}),$$

[8]The intermediation cost captures the fact that the return to capital in China is puzzlingly high, whereas the deposit rate at State-owned banks are set to be low by the government. Song, Storesletten, and Zilibotti (2011) interprets this cost as the operational costs, red tape, etc.

where c_j is the total consumption in period j, $\mathbf{1_c}$ is an indicator function taking the value one during the period when the child is living with their parents[9], and ζ is a parents equivalence parameter. Labor hours are assumed to be supplied inelastically. Expectations are taken with respect to the stochastic processes governing labor productivity risk.

Additionally, at the period $j = 8$, the child's expected lifetime utility enters the parental lifetime utility function with a weight ν, which measures the strength of parental altruism.

3.4 Human Capital Formation

Parents accumulate their children's human capital through multiple-period skill investments according to a technology that features dynamic complementarity (i.e., human capital produced at one stage can raise the investment at subsequent stages) and self-productivity (i.e., human capital produced at one stage is input in the next stage).

Let $h_{j,c}$ denote the human capital stock of children in period j, which is endogenously shaped by parental skill investment before the education outcome is realized. Let h_p denote the human capital of parents[10], which is fixed during the entire working stage.

I assume that every child is born with the same level of human capital endowment $\underline{h}$. The evolution of each child's skills $h_{j,c}$ over time is determined by a human capital production function. The next-period child's human capital $h_{j+1,c}$ depends on her parent's human capital h_p, her current stock of human capital $h_{j,c}$, and the parental investment m. I specify the technology of human capital formation as:

$$h_{j+1,c} = \psi h_p^w \left[\alpha_j h_{j,c}^{\rho_j} + (1-\alpha_j) m_j^{\rho_j} \right]^{\frac{1-w}{\rho_j}}$$

where ψ is an anchor that transforms the child's human capital into adult outcomes, w captures the contribution of parental human capital in the child's skill formation, α_j represents the share of current stock of the child's human capital, and ρ_j measures the complementarity between the investment in period $j-1$ and j. The technology parameters ρ_j and α_j can vary across investment stages, which is well appreciated in recent literature. Skills are persistent over generations because parents with a higher stock of human capital have more resources to invest in their children's skills and they are more productive in educating their children.

[9] Note that college-educated children leave their families a period after the non-college-educated children in the same cohort, which implies that parents have to raise the children in college in period 8, which in turn increases the opportunity cost for supporting their children's college education.

[10] At the first three stages, individuals don't have their children yet, but they are still regarded as parents in this model.

3.5 Labor Earnings

An individual with education attainment s, human capital stock h_p , and idiosyncratic labor productivity shock ϵ earns a labor income

$$w_s \eta(h_p, \epsilon),$$

where w_s is the wage rate of type-s human capital, and $\eta(h_p, \epsilon)$ is an efficiency units function depending on individual's human capital and labor productivity shock. The wage rate is endogenously determined in a competitive labor market. There is no on-the-job human capital accumulation. The productivity shock ϵ is mean-reverting and follows a Markov chain with states $\varepsilon = \{\epsilon_1, \epsilon_2, ..., \epsilon_M\}$ and transitions $\pi(\epsilon'|\epsilon) > 0$.

3.6 Government Policies

3.6.1 Education Policies

The government has two education policy tools. First, because the demand for public college is greater than its capacity, the government has to utilize an admission policy function to decide who is eligible for attending four-year colleges. The probability of passing the College Entrance Examination only depends on the human capital of children. In this paper, I assume that test scores are perfectly correlated with test takers' current stock of human capital. I specify that for a test taker with human capital h_c, $\chi(h_c)$ is the probability of admission, where $\chi(\cdot)$ is a strictly increasing admission function that will be estimated using micro-level admission data.

Second, I assume that a fraction θ of the tuition is borne by the government. Suppose the per-student cost of college is κ. Then the tuition net of subsidy is $(1-\theta)\kappa$. The government can commit to subsidizing tuition for all the students who have passed the College Entrance Examination during the entire college stage.

3.6.2 Labor Income Tax

Labor income taxes are progressive. The total amount of labor income taxes paid takes the following form

$$T(y) = \bar{\tau}_y max(y-d, 0),$$

where y is labor income, d is the amount of income tax deduction, and $\bar{\tau}_y$ is the income tax rate applied to the taxable labor income.

3.7 Recursive Problems

Next, I lay out the dynamic individual problems at the different stages in the life cycle recursively.

Problem at $j = 1, 2$ Right after their independence, before having children, individuals choose how much to consume (c) and how much to save (a). Households are not allowed to borrow, so the next period asset (a') is non-negative. The value function of individuals of age j, with education level (s), human capital stock (h_p), labor productivity shock (ϵ), asset (a) reads as

$$V_j^s(h_p, \epsilon, a) = \max_{c,a'} \left\{ u(c) + \beta \sum_{\epsilon'} \pi(\epsilon'|\epsilon) V_{j+1}^s(h_p, \epsilon', a') \right\}$$

subject to the budget constraint

$$c + a' = (1 + r)a + y - T(y)$$

$$y = w_s \eta(h_p, \epsilon), \; c \geq 0, \; a' \geq 0.$$

I assume that all of the individuals start their life with $a = 0$, which means there is no inter vivos financial wealth transfer from parent to child. The initial labor productivity is drawn from an invariant distribution $\pi(\epsilon)$. Note that college graduates start solving this dynamic problem in period 2 because they spend period 1 in college.

Problem at $j = 3$ In period 3, individuals solve the same problem as before. I lay out the problem separately because the parent will have a child in period 4, so the child's initial endowment of human capital $h'_c = \underline{h}$ enters the continuation value of the Bellman equation in period 3. The value function of individuals is given by

$$V_j^s(h_p, \epsilon, a) = \max_{c,a'} \left\{ u(c) + \beta \sum_{\epsilon'} \pi(\epsilon'|\epsilon) V_{j+1}^s(h_p, \epsilon', a', h'_c) \right\}$$

subject to the budget constraint

$$c + a' = (1 + r)a + y - T(y)$$

$$y = w_s \eta(h_p, \epsilon), \; c \geq 0, \; a' \geq 0.$$

Importantly, under this specification, children do not differ in their innate ability or initial endowment of human capital. As a result, all of the post-independence variation in human capital is due to the differences in the intensity of monetary investment and the parents' human capital.

Problem at $j = 4, 5, 6, 7$ At the beginning of period 4, the child is born and the state space of the parent is expanded to include the child's human capital (h_c). During these four periods, in addition to the standard choices of consumption, savings, the altruistic parent also decides how much money (m) to invest in child's development of skill. Then using the technology specified in subsection 3.4, the next-period human capital of child (h'_c) is produced by combining the current-period child's skill (h_c), parent's human capital (h_p), and education expenditure (m). The dynamic problem becomes

$$V_j^s(h_p, \epsilon, a, h_c) = \max_{c, a', m} \left\{ u(\frac{c}{1+\zeta}) + \beta \sum_{\epsilon'} \pi(\epsilon'|\epsilon) V_{j+1}^s(h_p, \epsilon', a', h'_c) \right\}$$

subject to the budget constraint

$$c + a' + m = (1+r)a + y - T(y)$$

$$y = w_s \eta(h_p, \epsilon), \ c \geq 0, \ a' \geq 0, \ m \geq 0$$

$$h'_c = \psi h_p^w \left[\alpha_j h_c^{\rho_j} + (1-\alpha_j) m_j^{\rho_j} \right]^{\frac{1-w}{\rho_j}}.$$

Notice that since children live with their parents during these periods, I use a consumption equivalence parameter ζ to capture the fact that parents should transfer some additional resources to child. Also, it borrowing against the current stock of human capital is not allowed, which implies that money investment must be non-negative.

Problem at $j = 8$ At period 8, the final education outcome of children is realized. A critical feature of the model is that parents will decide whether their children should take or skip the College Entrance Examination. If they choose to have their children take the exam, then their children can attend college as long as they pass the test. Additionally, I assume that taking the test requires an upfront cost κ_e paid by parents. Her parents will also cover tuitions $(1-\theta)\kappa$ as well as living expenses (captured by ζ) during their children's college stage. If parents choose to have their children skip the exam, or their children fail the test, then the children will immediately leave their family and enter the labor market as non-college worker. I assume that the exam choice is irreversible, and that the College Entrance Examination can be taken only once.

I first lay out the dynamic problems solved by parents conditional on the exam choice being and the exam result being. Let $V_j^s(\cdot|c)$ denote the value of an individual with education level s if her child passes the exam and attends college. The maximization problem is given by

$$V_j^s(h_p,\epsilon,a,h_c|c) = \underset{c,a'}{max} \left\{ u(\frac{c}{1+\zeta}) + \beta \sum_{\epsilon'} \pi(\epsilon'|\epsilon) \underbrace{V_{j+1}^s(h_p,\epsilon',a')}_{parent's\ value} + \nu \sum_{\epsilon'} \pi(\epsilon') \underbrace{V_2^c(h_c,\epsilon',0)}_{child's\ value} \right\}$$

subject to the budget constraint

$$c + a' + (1-\theta)\kappa + \kappa_e = (1+r)a + y - T(y)$$

$$y = w_s \eta(h_p,\epsilon),\ c \geq 0,\ a' \geq 0$$

where ζ captures the fact that college students still live with their parents during the college stage. The exam cost κ_e is in the parent's budget constraint because children must have passed the test before going to college. In additional, I assume that the exam cost only gives children the knowledge that is specific to the test. Consequently, children's human capital is not affected by whether or not their parents pay the upfront cost.

Notice that in the next period, the child will leave the family. As a result, her human capital (h_c) no longer appears in her parent's state space in period 9. In addition, the child's initial value function V_2^c enters the parent's value function at period 8. The superscript (c) indicates that the child is college labor, and the subscript (2) implies that the child will not become independent until the next period since she spends one more period in college. The parameter νcontrols the strength of altruism.

Let $V_j^s(\cdot|nc)$ denotes the value of an individual with education level s if her child does not attend college. The maximization problem is given by

$$V_j^s(h_p,\epsilon,a,h_c|nc,\mathbf{1_e}) = \underset{c,a'}{max} \left\{ u(c) + \beta \sum_{\epsilon'} \pi(\epsilon'|\epsilon) \underbrace{V_{j+1}^s(h_p,\epsilon',a')}_{parent's\ value} + \nu \sum_{\epsilon} \pi(\epsilon) \underbrace{V_1^{nc}(h_c,\epsilon,0)}_{child's\ value} \right\}$$

subject to the budget constraint

$$c + a' + \mathbf{1_e}\kappa_e = (1+r)a + y - T(y)$$

$$y = w_s \eta(h_p,\epsilon),\ c \geq 0,\ a' \geq 0$$

where $\mathbf{1_e}$ denotes an indicator function taking the value one if the child takes the College Entrance Examination.

The child's initial value function V_1^{nc} still enters the parent's value function at $j = 8$.

The superscript (nc) indicates that the child is a non-college labor, and the subscript (1) implies that the child will become independent and enter the labor force immediately. As a result, the labor productivity shock (ϵ) is realized in the same period.

Next, I present a problem in which parents decide whether to support their children to take the College Entrance Examination. Since the public college has a limited capacity, the probability of admission depends on the government's admission policy $\chi(h_c)$, which is a function of children's human capital (h_c). For a parent with education level s, before the exam outcome is realized, the ex ante value of supporting her child taking the exam $\widehat{V}_j^s$ is obtained by taking the expectation over the value of passing the exam $V_j^s(\cdot|c)$ and the value of failing in the exam $V_j^s(\cdot|nc)$, which is given by

$$\underbrace{\widehat{V}_j^s(h_p, \epsilon, a, h_c)}_{take\ exam} = \chi(h_c)\underbrace{V_j^s(h_p, \epsilon, a, h_c|c)}_{success} + (1 - \chi(h_c))\underbrace{V_j^s(h_p, \epsilon, a, h_c|nc, 1)}_{failure}$$

where $\mathbf{1_e} = 1$ indicates that her child took the College Entrance Examination but ended up with a failure result.

Let V_j^s denote the value of an individual who can choose between have their children skip the exam (enter the labor force), and have their children take the exam. The discrete choice problem is given by

$$V_j^s(h_p, \epsilon, a, h_c) = max\left\{\underbrace{V_j^s(h_p, \epsilon, a, h_c|nc, 0)}_{skip\ exam}, \underbrace{\widehat{V}_j^s(h_p, \epsilon, a, h_c)}_{take\ exam}\right\}$$

where $\mathbf{1_e} = 0$ indicates that the child skips the college entrance exam.

Note that by choosing to have their children skip the exam, parents can avoid paying the upfront cost of the test. As a result, the value of skipping the exam is strictly greater than the value of taking but failing the exam. However, every parent who chooses to have her child take the exam (strictly) prefers to support her child attending college than skipping the exam. Therefore, failing the exam will lead to a deviation from the optimal decision path. To increase the probability of passing the test, parents have incentives to invest in their children's human capital. This channel only exists in the environment where the college attainment is constrained by the capacity of the college.

Problem at $j = 9, 10, 11$ Starting from period 9 all of the children leave their family. Thus, before exiting the economy at period 11, parents only choose consumption and savings. The dynamic problem will be the same as the that in periods 1 and 2.

3.8 Definition of Equilibrium

Let $x_j \in X_j^s$ denote the vector of state variables of an individual in period j and completed education s. Let μ_j^s be the corresponding measures over Borel sigma-algebras defined using those state spaces. A stationary recursive competitive equilibrium for this economy is a collection of (i) value functions $\{V_j(x_j)\}$ and $V_8^{exam}(x_8)$; (ii) policy functions for consumption and savings $\{c_j(x_j),\, a'_j(x_j)\}$, education expenditure $\{m_j(x_j)\}$ and exam choice $\{\mathbf{1_e}(x_8)\}$; (iii) aggregate capital and labor inputs $\{K, H_c, H_{nc}\}$; (iv) tax policy $\{\tau, d\}$ and admission policy χ; (v) measures for parents $\mu = \{\mu_j^s\}$, such that:

1. Given prices, the policy functions solve the dynamic programming problems described in subsection 3.7 and $\{V_j(z_j)\}$ and $V_8^{exam}(z_8)$ are the associated value functions;

2. Given prices, aggregate capital and labor inputs solve the representative firm's problem;

3. Labor market for each education group clears:

$$H_c = \sum_{j=2}^{11} \int_{X_j^c} \epsilon_j h_{c,j} d\mu_j^c$$

$$H_{nc} = \sum_{j=1}^{11} \int_{X_j^{nc}} \epsilon_j h_{nc,j} d\mu_j^{nc},$$

   where H_s denotes the aggregate effective labor supply of education level s.

4. Capital market clears:

$$K = \sum_{j=2}^{11} \int_{X_j^c} \epsilon_j a'_j(x_j) d\mu_j^c + \sum_{j=1}^{11} \int_{X_j^{nc}} \epsilon_j a'_j(x_j) d\mu_j^{nc},$$

   where the first term is the aggregate savings of college-educated parents, and the second term is the aggregate savings of non-college-educated parents.

5. Good market clears;

6. The distribution of μ is stationary:

$$\mu(x) = \int \Gamma(x) d\mu(x),$$

   where $\Gamma(\cdot)$ denote the aggregate law of motion of $x = \{x_j\}$, which is derived from the individuals' policy functions.

4 Data

This section presents three sets of evidence. First, how parental education expenditures towards children are associated with their parents' characteristics. Second, how education outcomes of children are associated with their parents' characteristics. Third, how test scores in the College Entrance Examination are linked with individuals' education attainments and labor earnings. The evidence will be used to construct moments for the model's estimation and validation.

4.1 Education Investments and Outcomes

One of the key elements of the model is the intergenerational human capital investment. Therefore, before moving on to the calibration, it is essential to examine the patterns of education expenditures empirically. From 2002 to 2009, the Chinese Urban Household Survey (UHS2002-2009)[11] collected detailed information about individual and household income, consumption expenditure (including education expenditure), and demographic characteristics. I have access to the portion covering nine provinces, representing over 14,000 households and 60,000 individuals per year.

With the UHS, I can inspect how household education expenditures towards children depend on the parents' characteristics (e.g., income and education level), and children's developmental stages. This evidence is useful to construct moments for estimating the skill formation technology. Besides, the rotating structure of UHS does not allow me to track parental expenditures towards children's education and their outcomes over a long period. However, the UHS does allow me to observe children's terminal education attainments and their associated parents' education levels. The simulated model will be calibrated to reproduce the intergenerational persistence in education that can be observed in the data.

4.1.1 Descriptive Statistics

Table 1 displays a summary of statistics on the variables that are useful for the following empirical analysis. I restrict the sample to households with one child since this is the most common family structure of Chinese urban households[12]. All the following results are robust if I relax this restriction.

Household education expenditures and disposable income both increased very rapidly

[11] I do not have access to earlier issues since UHS is a restricted dataset. The rotating structure of the UHS enables the construction of a two or three-year panel. One can also treat the UHS as a repeated cross-section survey. Ding and He (2018) discuss more details about UHS's design.

[12] More details about sample selection are provided in Appendix A.1.

Table 1: Descriptive Statistics (UHS)

Variable	2002	2009
Education expenditure (RMB)		
All households	1,345	1,575
All with positive expenditure	1,996	2,747
Disposable income (RMB)		
Households, all	22,334	42,038
Households, tercile 1	10,408	18,619
Households, tercile 2	19,078	35,244
Households, tercile 3	37,518	72,257
Variable	1993-1998	2001-2005
Percentage of college attainment		
Child, four-year institution	18.04	38.21
Child, three- and four-year institution	51.63	71.50
Parent, four-year institution	6.57	8.77
Parent, three- and four-year institution	30.24	25.95

Note: Data source: UHS2002 and 2009. This table shows unweighted averages of selected characteristics. All RMB amounts are deflated to 2002 values. Sample restricted to urban households with an only child. UHS2002 contains the information about the children whose education outcome is realized during 1993-1998. Similarly, from UHS2009, I obtain the information about the children whose education outcome is realized during 2001-2005.

during 2002-2009. In particular, the average real disposable income increased by 188 percent, while the real college tuition only increased by 51 percent. College, in turn, became substantially more affordable for Chinese families. Moreover, the average education expenditures increased by 38 percent for households that made positive spending on children's education. This pattern indicates that the share of education expenditure in household income declined during this period.

The UHS2002 is the earliest dataset available to me. However, the college expansion policy was implemented in 1999. To overcome this time discrepancy, when I calculate the percentage of college attainment before college expansion, I only focus on the households whose children were above age 22 (and below age 26) in 2002 since they took the College Entrance Examination between 1993-1998 and hence are unaffected by the college expansion program.

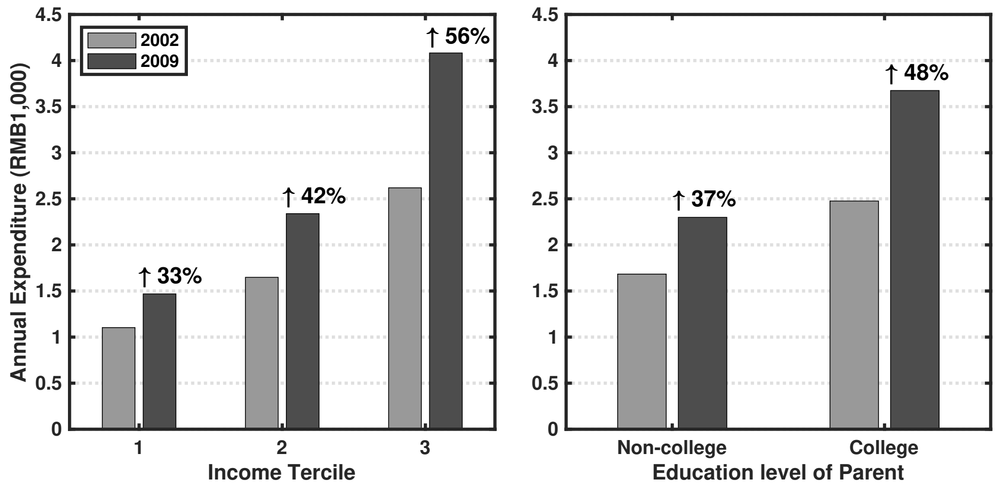
The last four rows of the Table 1 show that, as a result of the college expansion policy, the fraction of children who entered college between 2001 and 2005 increased by approximately 20 percentage points, relative to those who took entered college between 1993 and 1998[13]. Besides, immediately after college expansion, over 70 percent of children went to three-year or four-year institutions. This evidence reflects that college was no longer very selective in urban areas.

4.1.2 Education Expenditures and Parent Characteristics

The evidence presented in this subsection highlights two important features of educational expenditures on children. First, the education investment is associated with parents' socioeconomic background. For example, the light bars in Figure 3 (left panel) shows that high-income parents (top income tercile) spent about RMB1,500 (144%) more on their children than low-income parents (bottom income tercile) in 2002. The light bars in the right panel shows that college-educated parents spent approximately RMB860 (54%) more than non-college educated parents in 2002. Second, the gap in education expenditures became larger between 2002 and 2009. The high-income parents increased their education expenditure towards children by 56% (vs. a 33% rise for low-income parents), and college-educated parents increased their education expenditure by 48% (vs. a 37% rise for non-college-educated parents).

[13]Since the dataset does not cover rural households, the numbers displayed in the table are not nationally representative, and thus will not be targeted when I calibrate the model.

Figure 3: Education Expenditures by Parent Characteristics



Note: Data source: UHS2002 and 2009. This figure plots education expenditures on children in relation to parent's income and education level. The light bar shows the information from observations in 2002, and the dark bar displays the information from the observations in 2009. The numbers on the graph display the change in the fraction of college-educated children from 2002 to 2009 for each income or education group. Sample restricted to urban households with an only child.

4.1.3 Education Expenditures and Developmental Stages

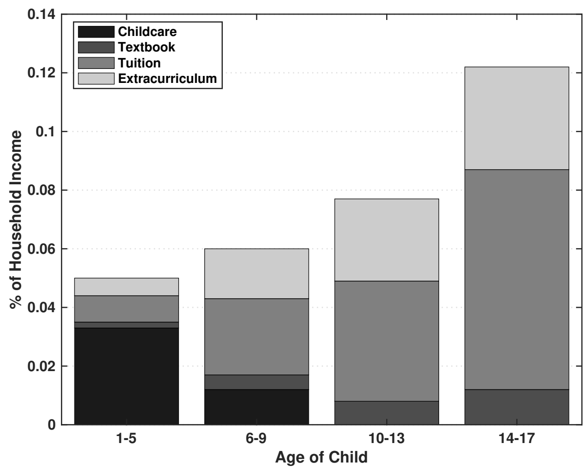
Share of education expenditure in income. Figure 4 displays education expenditures (in % of household income) in relation to the age of the child[14]. It increases from 5% (preschool age) to 12% (high-school age). The spending on tuition as well as extracurricular training are increasing most rapidly as the child ages, especially for children above age 14. This is mainly due to the fact that Chinese children enjoy nine-year compulsory (almost free) education. Additionally, extracurricular trainings for preparing the College Entrance Examination are incrementally important as children reach the high-school stage.

Effect of income on education expenditures. In this subsection, I estimate the effect of household income on education expenditures and how does that relationship vary across the developmental stages of children. To do so. Using the subscripts i and t to index the individual household and year, I run the following regression

$$log(EXP_{i,t,j}) = \alpha + \beta log(INC_{i,t,j}) + Year_{t,j} + HH_{i,j} + \epsilon_{i,t,j}$$

[14]Since this paper focuses on the pre-college educational investment decisions, I do not report the statistics for children above age 17. Choukhmane, Coeurdacier, and Jin (2017) use the data from CHIP2002 and plot a similar graph which contains the information about educational spending towards post-college children.

Figure 4: Education Expenditures by Developmental Stage



Note: Data source: UHS2002. This figure plots the average education expenditure (as a share of household income) across education categories (childcare, textbook, tuition and fees, and extracurricular trainings) by the age of the child. Sample restricted to urban households with an only child.

respectively for each stage j[15]. INC is the household disposable income, and EXP is the household education expenditure. The fixed-effect $Year_{t,j}$ controls for time effects, and $HH_{i,j}$ controls for the time-invariant household characteristics, and ϵ is the error term. The regression coefficient β captures the impact of within-household deviations in disposable income.

Table 2 summarizes the estimation of β at stage j in various regressions. In the first two specifications, I construct a two- and three-year short-panel, respectively, and include the year and household dummies. In the last specification, I run a cross-sectional regression using 2002 household data.

The coefficient of interest is β, which reports how household income impacts education spendings on children. The results presented in Table 2 show that education expenditures are more elastic to the change in household disposable income at the early childhood developmental stages. For example, column (1) shows that, from 2002 to 2004, a one percent increase in household income increases the predicted education expenditures by approximately 0.75 percent at the first and second developmental stages, by only 0.55 percent at the last stage. The result is robust in the two-year panel and cross-sectional regressions, as shown in column (2) and (3).

[15]For each household, I can observe its information for three consecutive years. If the child age jumps across two developmental stages during this time span, I drop them from the fixed-effect estimation.

Table 2: Effect of Household Income on Education Expenditure

Dep. variable: log-education expenditures			
	(1)	(2)	(3)
Indep. variable	2002-2004	2002-2003	2002
log-income (stage 1)	0.747***	0.953***	0.858***
	(0.282)	(0.214)	(0.073)
log-income (stage 2)	0.756***	0.557***	0.649***
	(0.140)	(0.130)	(0.047)
log-income (stage 3)	0.689***	0.645***	0.617***
	(0.118)	(0.117)	(0.040)
log-income (stage 4)	0.551***	0.457***	0.563***
	(0.128)	(0.107)	(0.047)
FE	Y	Y	N

*Note: Data source: UHS2002-2004. Table gives estimates from a regression of natural logarithm of the education expenditure on natural logarithm of the disposable income, year dummies, and household dummies. Separately for each developmental stage I run a regression. The first two specification uses sample from the three-year and two-year panel data covering the observations from 2002 to 2004, and 2002 to 2003, respectively. Sample restricted to urban households with an only child. The last column uses the sample from cross-section data covering the observations in 2002. Standard errors are reported in parentheses. *, **, *** denotes statistical significance at 10, 5, and 1 percent, respectively.*

4.1.4 Education Outcomes and Parent Characteristics

The Panel (A) of Figure 5 shows the education outcomes of children (proxied by the probability of earning a terminal degree from a four-year college[16]) in relation to the parent's income and education level. Prior to the college expansion policy[17], the light bars in the left graph show that the children of the high-income (top tercile) parents are about 10 percentage points more likely to earn a college degree than those of the middle and low-income parents. The light bars in the right graph shows that the children of the college-educated parents are about 19% more likely to earn a college degree than the children of non-college-educated parents. After the college expansion, it is notable that for middle-income and high-income parents, their children's probability of attending college increases by over 24 percentage points (vs. an 8 percentage point rise for low-income parents). For college educated parents, their children are 39 percentage points more likely to earn a college degree (vs. an 18 percentage point rise for non-college educated parents). The empirical evidence

[16] In UHS, the in-school college students and college dropouts are both classified as college-educated individuals.

[17] Here I am referring to the people who took the College Entrance Examination between 1993 and 1998 (derived from UHS2002). For comparison, I also display the statistics for those who took the between 2001 and 2005 (derived from UHS2009).

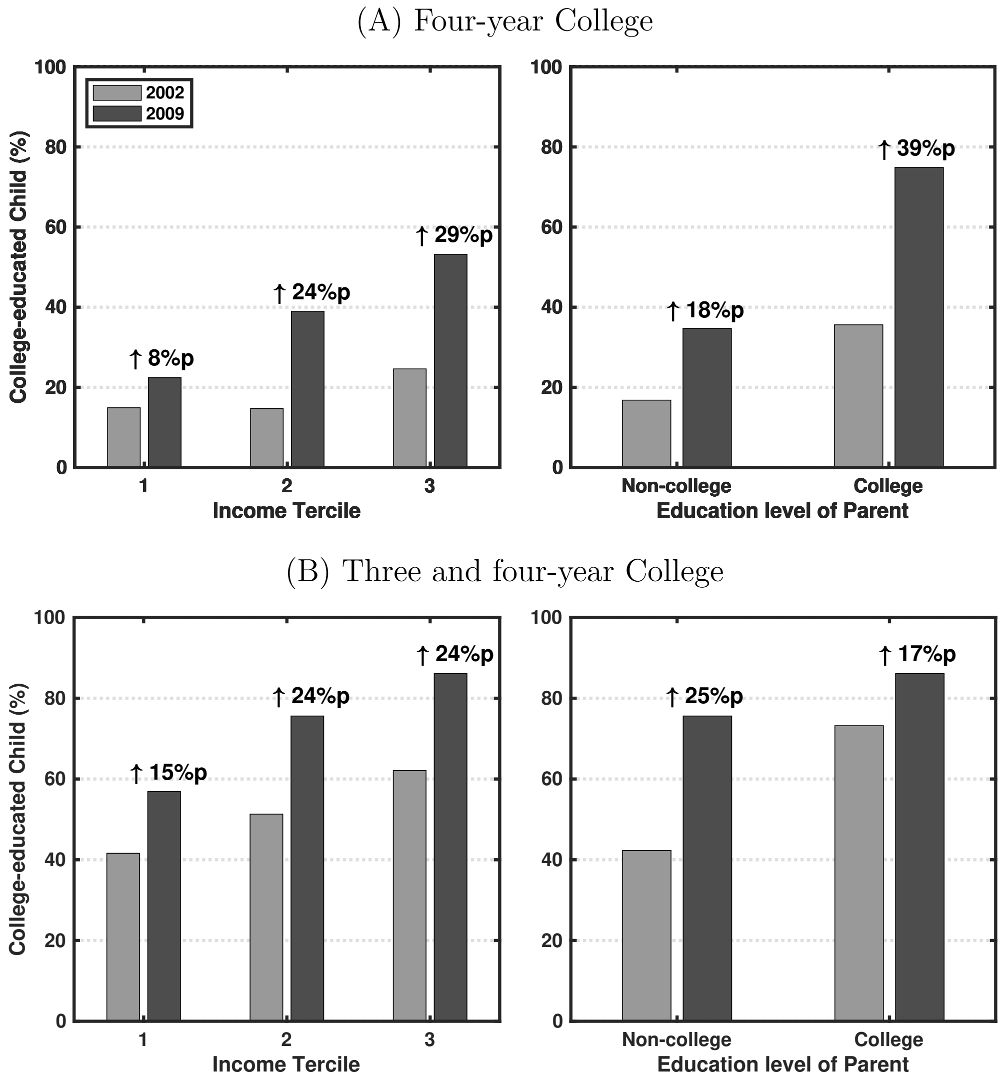
suggests that the children of the low-income and non-college educated parents benefit least from the college expansion policy.

The data shows that the changes in children's college attendance rate vary significantly across the income and education groups. As made clear in the model, whether a child can attend college depends on the exam choice and the level of human capital[18]. Accordingly, two theories can explain the empirical patterns. First, among the parents who would let their children skip the College Entrance Examination in the absence of college expansion and the decline in tuition-to-income ratio, high-income and college-educated parents, under the current circumstances, are more likely to support their children taking the test. Thus, the fraction of college-educated children from those families increases more remarkably. Second, high-income and college-educated parents make more human capital investments in their children than low-income (and non-college-educated) parents do. Therefore, the exam passing probability of the children from rich families increase more significantly since their human capital is higher. Because the main aim of this paper is to quantify the second channel, here I provide some evidence to support it.

Panel (B), Figure 5 displays the same information as shown in Panel (A) except adopting a new definition of college. Specifically, both the graduates from three- and four-year institutions are considered to be college-educated individuals. Since three-year colleges in China mainly accept students with low test scores, the college admission will be far less competitive under the new definition. Consequently, the associated education outcomes should largely reflect families' education choices instead of mirroring children's level of human capital. Panel (B) shows that, in contrast to the previous results, the changes in children's education outcomes vary modestly across income and education groups. In particular, for non-college educated parents, their children are 25 percentage points more likely to earn a college degree (vs. a 17 percentage point rise for college-educated parents). These patterns suggest that college expansion and a decline in tuition-to-income ratio considerably incentivize parents to support their children attending three- or four-year college, regardless of their socioeconomic background. The discrepancy in the change of education outcomes, measured by the probability of earning a terminal degree from a four-year college, is mainly due to the unequal changes in the accumulation of human capital across the socioeconomic groups.

[18]The former determines whether a child can take the college entrance exam, while the latter determines her passing probability.

Figure 5: Education Outcomes by Parent Characteristics



Note: Data source: UHS2002 and 2009. This figure plots education outcome of child (proxied by the probability of earning a terminal degree from a four-year college) in relation to parent's income and education level. The light bar shows the information about the households in which the children took College Entrance Examination *before 1999, and the dark bar displays the information about the households in which the children took the test after 1999. Panel (A) defines college as four-year institutions, while panel (B) define college as three and four-year institutions. The numbers on the graph display the change in the fraction of college-educated child (from pre-reform to post-reform era) for each income or education group. Sample restricted to urban households with an only child.*

4.2 Test Scores

To inspect to what extent the probability of passing the College Entrance Examination depends on children's skill and to what extent wages are associated with human capital, I construct a dataset derived from the 2013 Chinese Household Income Project (CHIP2013) survey. This cross-sectional survey follows a nationally representative sample of over 18,000 households, and 64,000 individuals living in urban and rural areas of China. It collects detailed information on a range of economic and demographic indicators. In particular, one crucial feature of the survey is the availability of test score (in the college entrance exam) data.

4.2.1 Descriptive Statistics

Table 3 displays summary statistics on variables that are useful for the empirical analysis of estimating the admission policy function and return to skill. The average exam scores are almost identical before and after the college expansion despite the rapid changes in the human capital distribution of test takers[19]. This fact suggests that the same test score does not necessarily imply the same skill if test takers took the exam in different years, which may lead to a biased estimation of return to human capital. I discuss how to deal with this problem in the subsection 4.2.3.

Additionally, although the dataset records information on rural households, the rural test takers who took the exam between 1989 and 1998 are underrepresented in the sample. Consequently, the actual national admission rate of four-year college before college expansion is substantially below the number (34%) shown in the table.

4.2.2 Test Scores and College Admission Rate

The goal of this exercise is to examine how each test score is associated with the probability of four-year college graduation[20]. To do this, I first normalize the raw scores by calculating their log difference from the mean score of the exam-taking year. This exercise is motivated by the consideration that the level of difficulty of the exam may vary across test-taking years. With the normalization, the same adjusted score will correspond to the equal probability of college admission in different years.

[19]There are at least two driving forces. First, since the tuition-to-income ratio is declining, and admission possibility is rising, more individuals with low human capital may decide to take the test. This force will lower the average student quality in the national admission pool. Second, the same situations can also incentivize more intergenerational human capital investment, which can improve the average student quality in the admission pool.

[20]The college dropout rate in China is below 3% over a long period. As a result, throughout this paper, I assume everyone who passes the College Entrance Examination will earn a college degree.

Table 3: Descriptive Statistics (College Entrance Exam)

Variable	All years	1989-1998	2008-2012
Raw test score (out of 750)			
Mean	469.35	474.73	471.70
Standard deviation	85.05	88.73	79.57
Percentage of college admission	40.80	34.14	43.75
Variable	**All years**	**1989-1998**	**1999-2008**
Annual disposable income (in RMB)			
All	43,771.00	49,846.26	40,403.39
College graduates	51,797.95	61,141.90	47,118.22
No-college graduates	37,635.54	42,145.84	34,939.09
Working experience	11.52	18.67	7.56

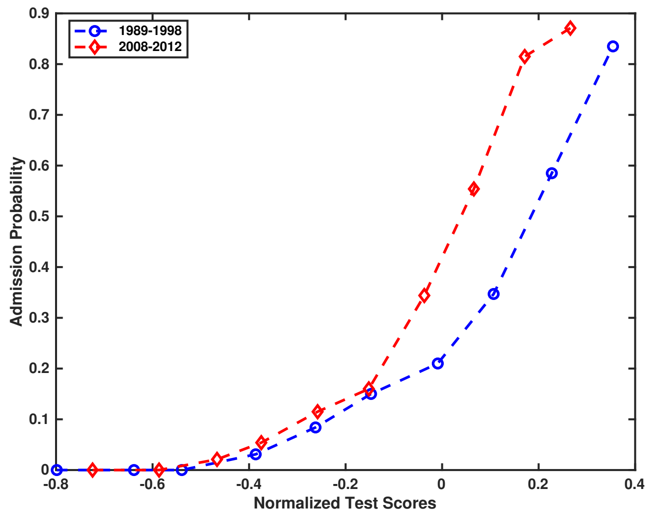
Note: Data source: CHIP2013. This table shows unweighted averages of selected characteristics. College is defined as four-year institutions. The fraction of test takers who enters the four-year college shown in table only reflects the situation in sample.

Next, I divide the scoring support into ten equal-length intervals and calculate the mean score for each interval. For the samples in each range, I compute the fraction of test takers who have a four-year college degree. I repeat this exercise for the test takers who took the College Entrance Examination between 1989 and 1998, and between 2008 and 2012, respectively. This is because I assume that the government has adopted a new admission policy after the implementation of the college expansion program. I provide more details about sample selection and score adjustment in Appendix A.1.

Figure 6 plots the admission probability of passing the College Entrance Examination against the normalized test score in the college entrance exam[21]. The figure displays that with a test score below the mean score, one has very little chance to pass the exam. Once the test score reaches the average, the probability of admission sharply increases. This empirical observation suggests that the return to human capital investment is increasing at a faster rate within the sensitive region, where the admission chance grows more rapidly. Additionally, the college expansion policy gives test takers whose score is 0.1 to 0.2 log point above the average a significantly higher probability of attending college. However, the policy is unhelpful for the test takers whose score is below the average score.

[21]Since the admission policy function displays a strong non-linearity, I cannot adopt a linear probability model (Donovan and Herrington, 2019) to estimate the probability of passing the college entrance exam.

Figure 6: College Entrance Examination Admission Policy Function



Note: Data source: CHIP2013. This figure plots the probability of passing the College Entrance Examination *against the normalized test score. A circle or diamond marker represents the admission probability among individuals in a scoring bin. Blue and red dashed line reflects the admission policy function before (1989-1998) and after (2008-2012) the implementation of the college expansion policy, respectively.*

4.2.3 Test Scores and Return to Skill

In this subsection, I estimate the impact of human capital on labor incomes. I assume that a test score can measure an individuals' human capital exactly. However, as I made clear in subsection 4.2.1, as the number of test takers rapidly grows, the distribution of human capital in the admission pool can vary across years. As a result, test scores may not be comparable across cohorts. To overcome this problem, I run a fixed effect regression to control the cohort-invariant test takers' characteristics.

I first filter out experience effects from the log wage observations in the CHIP2013. Here I assume that any residual unobserved error term is uncorrelated with human capital. Next following Hendricks and Schoellman (2014), I estimate an OLS regression of log individual wages on log test scores, a school dummy, and a cohort dummy. The estimation equation is given by

$$log(Income) = \lambda log(Score) + School + Cohort + \epsilon$$

where $Income$ is individual's labor income, $Score$ is individual's adjusted test score, $School$ is an indicator variable that takes a value of one if the individual is college-educated, $Cohort$ is the cohort dummy indicating the year of test, and λ captures the return to human capital (skill gradient).

The estimating results are reported in Table 4. A one standard deviation rise in human capital (i.e., test score) raises log-wages by 51 percent. Besides, college wage rate is 23 percent higher than non-college wage rate.

Table 4: Estimate Return to Skill

Dep. variable: log-wages		
Indep. variable		
Test score	0.512^{***}	0.525^{***}
	(0.083)	(0.083)
College education	0.228^{***}	0.225^{***}
	(0.034)	(0.033)
Cohort effect	Y	N
Observations	2,089	2,089
R-squared	0.111	0.06

*Note: Data source: CHIP2013. Table gives estimates from a regression of natural logarithm of the wages on school dummies and natural logarithm of the normalized test score. The omitted school category is non-college graduate. Standard errors are reported in parentheses. *,**,*** denotes statistical significance at 10, 5, and 1 percent, respectively.*

Recent literature, such as Meghir, Abbott, Gallipoli, and Violante (forthcoming) and Daruich (2018), has exploited a similar method by using the US Armed Forces Qualification Test (AFQT) score to proxy individual's skills. Different from this paper, they estimate the skill gradient separately for individuals with different educational backgrounds. This strategy is motivated by the fact that the return to skill is higher among college-educated individuals than among other groups. In other words, the education level and human capital investment are complementary. I do not adopt their approach because there is an apparent selection bias associated with the observations of test scores in CHIP2013. Since the College Entrance Examination is a knowledge-based test requiring a lengthy learning period, a large fraction of individuals with low human capital never takes the exam because the passing probability for them is extremely low. As a result, the estimation of skill gradient for non-college graduates will be biased since the sample does not include those who skip the exam.

5 Calibration

In this section I describe how I parametrize the model. Some parameters are calibrated externally or taken from other literature, others are jointly estimated from the simulation of the model. To do so, I numerically solve the decision rules of individuals, approximate the distribution of this economy, and then adjust parameters to minimize the distance between model moments and the data counterparts. After calibrating the model, I check the performance of the model by comparing the non-targeted model moments with the data.

5.1 Model Parameterization

The benchmark model is calibrated to the China data. The model period is four years. Individuals enter the economy at period 1 [age 18], give birth to child at period 4 [age 30], make college choice for their children at period 8 [age 46] and exit from the economy at the end of period 11 [age 61].

Table 5: Model Parameters

Parameters Calibrated outside the Model		
Parameter		**Value**
Risk aversion	σ	1.50
Capital share in production	Λ	0.41
Labor elasticity of substitution	Ω	0.74
Skill-biased technology	A_c	1.00
Depreciation rate of physical capital	δ	0.11
Intermediation cost in financial sector	ξ	0.12
Government subsidy on college tuition	θ	0.78
Persistence of labor productivity shocks	ρ_z	0.86
Variance of labor productivity shocks	σ_z^2	0.06
Return to human capital	λ	0.51
College admission policy	$\chi(\cdot)$	see text
Parameters Calibrated (Jointly) Inside the Model		
Preference		
Annual discount rate	$\overline{\beta}$	0.98
Altruism parameter	ν	0.26
Aggregate production function		
Share of skill labor	Φ	0.41
Tuition and fees		
Tuitions paid by parents	$\overline{\kappa}$	0.62
Upfront cost of test	κ_e	0.04
Tax system		
Labor income tax deductibles	d	2.60
Labor tax rate	$\bar{\tau}_y$	0.22
Human capital formation technology		
Total factor productivity of skill formation	ψ	1.28
Self-productivity of child's human capital	$\alpha_4, \alpha_5, \alpha_6, \alpha_7$	0.60, 0.81, 0.91, 0.95
Complementarity parameter	$\rho_4, \rho_5, \rho_6, \rho_7$	0.17, -0.16, -0.66, -1.18
Parent's human capital share	ω	0.18

5.1.1 Preference

I specify the period utility over parent and child consumption as

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

I choose a coefficient of relative risk aversion of $\sigma = 1.50$, and an adult consumption equivalence scale $\zeta = 0.33$ following the standard literature[22]. Then the discount rate β is chosen to generate an annual real interest rate of 4 percent, and a capital-output ratio (in 1998) of 1.57, which is calculate by Bai, Hsieh, and Qian (2006). This requires an annual discount rate $\overline{\beta} = \beta^{1/4} = 0.97$. In addition, I choose ν to match that 29.6% of children whose parents are college-educated attend four-year colleges in 1998, which requires $\nu = 0.26$. Besides, 1_c takes the value of 1 in period 4 to 7 for all parents, and in period 8 for parents whose children attend college.

5.1.2 Aggregate Production Function

An representative firm combining capital and labor produces consumption good according to a technology $Y = K^{\Lambda}H^{1-\Lambda}$, where H is a CES aggregator of the total efficiency units supplied by two education groups

$$H = (\varPhi(A_cH_c)^{\Omega} + (1-\varPhi)H_{nc}^{\Omega})^{\frac{1}{\Omega}}.$$

I choose a capital share to be $\Lambda = 0.41$, following Bai and Qian (2010), which combines the China's labor share computed with GDP by income approach at provincial level into one series. The elasticity of substitution between college and non-college labor efficiency units is set to be $\Omega = 0.74$[23]. At the initial steady state equilibrium, I normalize the skill-biased technology parameter $A_c = 1$. The depreciation of physical capital is set to be $\delta = 0.11$, and the intermediation cost is set to be $\xi = 0.12$ following Bai, Hsieh, and Qian (2006)[24]. The share parameter $\varPhi$ is chosen to target the college wage premium of 0.50, which requires $\varPhi = 0.41$.

[22] This paper implicitly assumes a two-parent and one-child family structure. The scales from Organization for Economic Cooperation and Development (OECD) assign a value of 1 for the first adult, and 0.5 for the subsequent adults. By setting $\zeta = 0.33$, I assume a child is equivalent to 0.5 of the first adult in terms of consumption expenditure following Doesey, Li, and Yang (2019).

[23] The estimation strategy is following Katz and Murphy (1992). Related literature has estimated the elasticity of substitution between college and non-college labor in China (e.g., Ge and Yang, 2014; Feng, 2019).

[24] The cost is chosen so that the net rate of return to capital is 16 percent in China since the long-run real interest rate is 4 percent.

5.1.3 Admission Policy

My estimation strategy for college admission probability has been discussed in the subsection 4.2.2. Each level of child's human capital h_c is corresponding to a probability of admission. When I solve the model and compute the stationary distribution, I use the method of linear interpolation to approximate the admission probability off the known data points. Column (1) of Table 12 in Appendix C displays the normalized test scores and their corresponding admission probability in the baseline economy.

5.1.4 Tuition and Fees

The tuition paid by parents for their children's college education $\overline{\kappa}_0 = (1-\theta)\kappa$ and the share of expenditure borne by the household $1-\theta$ in the benchmark model is chosen to match the tuition to average household income ratio, $\frac{\overline{\kappa}_0}{\overline{y}}$, and as a fraction of average per student costs of college education, $\frac{\overline{\kappa}}{\kappa}$.

To calculate the corresponding numbers from the data, I turn to the China Statistical Yearbook (CSY), and the China Statistical Yearbook of Education Fundings (CSYEF). CSYEF reports that the average yearly tuition for a four-year college in 1998-2001 is RMB3,114. I assume that miscellaneous fees (textbook, supplies, room, and transportation) tied to college is 30% of out-of-pocket tuition. According to CSY, the average household income during this time span is RMB10,719. Thus, I have

$$\frac{\overline{\kappa}_0 \times 1.30}{\overline{y}} = \frac{3,114 \times 1.30}{10,719} = 0.38$$

and the cost parameter $\overline{\kappa} = 0.62$ is calibrated at the equilibrium of the benchmark model.

Furthermore, CSYEF reports that the average yearly per student costs of college education in 1998-2001 is RMB13,963. Therefore,

$$(1-\theta) = \frac{\overline{\kappa}_0}{\kappa} = \frac{3,114}{13,963} = 0.22,$$

which requires $\theta = 0.78$.

5.1.5 Tax System

Labor income tax is the only tax in my model since it can distort college attendance. The labor income tax function is

$$T(y) = \bar{\tau}_y max(y-d, 0),$$

which means there are two parameters to be calibrated. In practice, I choose the income tax deductible $d = 2.58$ to capture the fact that the labor income tax only applies on 15% of workers. Then I choose the income tax rate $\bar{\tau}_y = 22.4\%$ to match the total labor income tax revenue to GDP ratio (1.5%).

5.1.6 Labor Earnings

The labor income depends on skill wage (w_s), human capital (h_p), and labor productivity shock (ϵ). The idiosyncratic labor efficiency process $\eta(h_p, \epsilon)$ is specified as

$$log(\eta(h_p, \epsilon)) = \lambda log(h_p) + \bar{\epsilon}$$

$$\bar{\epsilon}' = \rho_\epsilon \bar{\epsilon} + z, \ \sigma_z \overset{iid}{\sim} N(0, \sigma_z)$$

where $\bar{\epsilon} = log(\epsilon)$, and λ is a parameter controlling the wage-skill gradient.

Skill gradient. I set the skill gradient to be $\lambda = 0.51$, which is consistent with the estimation in subsection 4.2.3.

Labor income shocks. The $AR(1)$ process has a yearly persistence of 0.86 and an yearly innovation variance of 0.06, which is consistent with estimation of Yu and Zhu (2013), and İmrohoroğlu and Zhao (2018). Since one period is four years in my model, I can recover $\rho_z = 0.55$, and $\sigma_z = 0.42$. I follow Kopecky and Suen (2010) and use the method of Rouwenhorst (1995) to approximate this process with a discrete Markov transition matrix.

5.1.7 Human Capital Formation

Following Cunha, Heckman, and Schennach (2010), I assume that child's next-period human capital depends on her current stock of human capital, parent's human capital, and parental investment. Also I assume that there is a CES aggregator that combines current human capital of child and investment made by her parent

$$X = \left[\alpha_j h_c^{\rho_j} + (1 - \alpha_j) m^{\rho_j}\right]^{\frac{1}{\rho_j}}$$

where α_j indicates the share of self-productivity of child's human capital, and ρ_j represents elasticity of substitution at the developmental stage j.

Next, I assume X is combined with parent's human capital to produce next period child's human capital according to a Cobb-Douglas technology

$$h_c' = \psi h_p^{\omega} X^{1-\omega}$$

where the anchor parameter ψ and share parameter ω are independent from child's age.

Child's self-productivity. I choose a set of α_j to target the average education expenditure to household income ratio in period j, which requires $\alpha_4 = 0.60$, $\alpha_5 = 0.81$, $\alpha_6 = 0.91$, and $\alpha_7 = 0.95$. This estimation result reflects children's current-period human capital is more productive as they age. In other words, it is more difficult for parents to raise their children's human capital using monetary investment at the later developmental stages.

Dynamic complementarity. Since the household-level data available to me does not record any information about children's education outcomes during their early childhood, it is impossible to adopt the approach employed by S. Y. Lee and Seshadri (2019), which recovers the dynamic complementarity parameters by directly estimating the skill formation technology. Instead, I estimate these parameters via indirect inference, where I design an auxiliary model to highlight data patterns that are key for identification.

The auxiliary model is displayed in subsection 4.1.3, where I estimate the effects of household income on education expenditure for each developmental stage by running a set of fixed-effect regressions. To estimate the dynamic complementarity parameters, I repeatedly simulate the life-cycle model and search for ρ_j for four different stages respectively to ensure that the model-predicted income elasticities of education expenditures can match their data counterparts.

Now I explain the identification strategy in an intuitive way. The crucial argument is that the stage-dependent effects of household income on education expenditure towards children can inform me of the degrees of the complementary relationship between investments in period $j-1$ and j. This observation can be illustrated clearly using a two-period model described in the Appendix C. Here I summarize the key reasoning steps.

First, with a more substitutable (complementary) relationship between the current stock of children's human capital and parental investment, the optimal investment in human capital is lower (higher) when the household income is low. However, as household income increases, the optimal human capital investment grows more rapidly (slowly) in the substitutable (complementary) case. Therefore, if I find in the developmental stage j that household education expenditure grows at faster (slower) rate with the increase of household income, it implies that the skill formation technology at this stage features a more substitutable (complementary) relationship between current-period skill of children and monetary investment. Putting this theory into practice, the auxiliary regression will generate a larger (smaller) regression coefficient in the stage where the current human capital of children is more substitutable (complementary) to the parental investment.

I estimate that $\rho_4 = 0.17$, $\rho_5 = -0.16$, $\rho_6 = -0.66$, and $\rho_7 = -1.19$. The main finding is that it is easier to shape children's skill through money investment at the early stage of the human capital development, because the elasticity of substitution determined by ρ_j is larger the younger the children. Meanwhile, high early childhood investment in human capital will induce a larger amount of investment at the late developmental stages due to the complementary effect. This finding is consistent with the estimation implemented by Cunha, Heckman, and Schennach (2010).

Parent's human capital share. I choose $\omega = 0.18$ to target the correlation coefficient between parent's human capital and education investment $corr(h_p, m) = 0.17$. Lastly, the anchor parameter is calibrated jointly with other parameters to ensure that the average human capital (exam taker) is normalized to 1, which requires $\psi = 1.28$.

Table 6: Table – Key Moments: Model v.s. China Data

Description	**China Data**	**Model**
Aggregates		
Capital-output ratio	1.57	1.57
Share of exam taker	0.17	0.17
College wage premium	0.50	0.50
College tuitions to household income ratio	0.38	0.38
Taxation		
Fraction of labor income tax payer	0.15	0.12
Labor income tax revenue to GDP	0.02	0.02
Skill formation		
Average human capital (exam taker)	1.00	1.00
Interg. correlation of college education	0.30	0.29
Average investment to labor income ratio	0.06, 0.07, 0.09, 0.13	0.05, 0.07, 0.089, 0.13
regression coefficient $log(m_j)$ on $log(y_j)$	0.74, 0.75, 0.68, 0.56	0.74, 075, 0.68, 0.57
correlation coefficient between m and h_p	0.17	0.17

Table 5 summarizes the parameters that I calibrate independently (top panel) and those that are calibrated jointly in equilibrium (bottom panel) to match the moments shown in Table 6.

5.2 Performance of the Benchmark Model

Before moving on to the education policy analysis, I discuss whether the parameterized model provides an acceptable description of the China economy along the dimensions relevant for the current analysis.

Table 7: Non-targeted Moments

	Data	Model	Source
Inequality			
Income (std. dev. of log)	0.60	0.53	UHS
Consumption (std. dev. of log)	0.61	0.42	UHS
Skill of exam takers (std. dev. of log)	0.20	0.17	CHIP
Education Expenditure			
Income tercile Q1	-0.47	-0.49	UHS
Income tercile Q2	-0.11	-0.05	UHS
Income tercile Q3	0.39	0.37	UHS
College-educated parents	0.33	0.40	UHS
Non-college-educated parents	-0.07	-0.02	UHS

Note: All moments are computed using the estimated model in steady state. Skill of exam takers is proxied by their test scores in college entrance exam. Education expenditures include the spending on textbook, compulsory tuition and extracurricular activities. College-educated parents refers to those who have earned a four-year college degree.

Inequality. Since one of the main focuses of this paper is inequality, I first check if the estimated model can reproduce the qualitative features in those dimensions as shown in data. Table 7 reports various non-targeted moments generated from the baseline model.

First, the upper panel of Table 7 reports that the household income and consumption inequality measured in the standard deviation of log earnings is 0.60 and 0.61 in the data, respectively. The model produces a slightly lower income inequality, but a significantly lower consumption inequality. As pointed out in Ding and He (2018), one of the puzzling observations in Chinese micro-level data is that the consumption inequality closely tracks with income inequality over time.

Second, Table 7 displays that the standard deviation of log human capital of test takers (proxied by test scores) in China is 0.20. The model counterparts are slightly lower but still reasonably close to the empirical values. The model generates a lower dispersion in test scores because it does not capture that in the real world, a small number of children with zero probability of admission still take the College Entrance Examination by paying an upfront cost[25].

Education expenditure. The next set of moments I need to check is how education expenditures vary across parents in different income and education groups. The lower panel Table 7 reports that households in the bottom income tercile spend 49% log points less than the average on education expenditure, and the model counterpart is 47%. It also reports that college-educated households spend 33% more than the average, and the model counterpart is 40%. Therefore, the simulated model does a good job of matching the variation of education expenditure across income and education groups.

Human capital distribution. To see whether the simulated model can reproduce the patterns of human capital distribution, I compare the model-generated distribution with the Chinese data. Table 8 reports the statistics reflecting the distribution of log test scores, which is used as a proxy for human capital.

Table 8: Human Capital (Test Scores) Distribution

	Test Scores of Top X%				
X:	50	20	10	5	1
China Data	0.04	0.17	0.23	0.27	0.38
Model	-0.08	0.09	0.20	0.29	0.41

Note: Data source: CHIP2013. This table compares the distribution of human capital (proxied by test scores) generated by the baseline model with that in the data. The test scores are normalized by taking their log differences from the average score.

In the data, a test taker within the top 5% of the human capital (h_c) distribution (among test takers) should at least have a test score of 27% better than the average. The model counterpart is 29%, which means model-generated human capital distribution of the top percentiles is quite close to the data. In the data, test takers with a median score should have a human capital level of 4% better than the average. The model counterpart is -8%. This implies that the required human capital for being a top 50% test taker is below the data.

[25]This puzzle can be reconciled if I incorporate some uncertainties to the test performance, which means that the test score may not be perfectly correlated with children's human capital. In that case, some children with low human capital may set to gamble on the test.

6 Policy Evaluations

With estimates of the skill formation technology, wage function, and admission policy, I turn to examine the impact of various policy environments. By feeding the existing college expansion policy to the calibrated model, I can compare the model-generated long-run household behaviors with the short-run evidence shown in the data. Furthermore, to better understand the mechanisms that contribute to the effects of college expansion on macro variables, I quantify the impact of each channel through a sequential decomposition. Finally, I propose a counterfactual policy and ask the following question: can government expenditures on education be implemented in a more efficient way to improve social welfare and reduce inequality? To address this question, I divert a part of the government subsidy on college tuition to support early childhood development for disadvantaged children and compare its aggregate and distributional implication with the existing policy.

6.1 Description of Policies

This subsection describes how I incorporate the existing policy as well as the counterfactual policy into the calibrated model framework. Let $\mathbb{P} = \{0, 1, 2\}$ denote the policy introduced, with $\mathbb{P} = 0$ being the baseline economy, $\mathbb{P} = 1$ being the economy with the current college expansion policy, and $\mathbb{P} = 2$ being the counterfactual economy with the childhood education subsidy program.

Current college expansion policy. To evaluate the impacts of the current reform and provide a benchmark for the counterfactual experiment, I analyze the aggregate and distributional effects of the existing college expansion program ($\mathbb{P} = 1$). There are three main differences between the benchmark Chinese economy and the current reform economy: (i) due to rapid income growth, the tuition-to-income ratio declines dramatically, (ii) the government adopts a new admission policy function, and (iii) a skill-biased technological change increases the demand for college-educated workers.

To capture the decline in tuition to household income ratio, I feed in a new tuition parameter $\bar{\kappa}_1 = 0.26$. As the average household income goes up due to college expansion, $\bar{\kappa}_1$ is endogenously pinned down to match the tuition-to-income ratio (0.14) in 2015. I assume that the share of college costs borne by the government is fixed at $\theta_1 = \theta = 0.78$. The per student costs of college in the model therefore is

$$\frac{\bar{\kappa}_1}{1 - \theta_1} = \frac{0.26}{1 - 0.78} = 1.19,$$

and the amount of government spendings on college education under the current policy is

$$EX_1 = 1.19\theta_1 \int_{\mathbf{1_e}=1} \chi_1(h_c) d\mu_8,$$

where $\mathbf{1_e}$ denotes an indicator function taking the value one if the child takes the college entrance exam.

Furthermore, as shown in column (2) of table 12 in Appendix C, the government adopts a new admission policy function $\chi_1(h_c)$. Relative to the pre-reform economy, the new policy primarily increases the admission opportunity for test takers whose scores are above the average.

Finally, there is a skill-biased technological change that affects the demand side of labor. Of course, it is difficult to predict the magnitude of technical change in the long run. In this exercise, I choose $A_c = 1.54$ to ensure that the existing college expansion policy generates the same college wage premium (0.50) at the final steady state as the baseline economy.

Early childhood subsidy program. In this case, I analyze an economy in which the government implements a targeted early childhood intervention ($\mathbb{P} = 2$). The aim of this experiment is to explore a more efficient way for the government to implement education policies.

The subsidy is targeted at children whose parents are in the bottom quartile of the distribution of income. I do not use parent or child's human capital as an eligibility criteria because it could be private information of individuals in practice. However, since income level largely depends on parent human capital, I can still use this rule to identify disadvantaged families. Additionally, the program only targets children at the first and second developmental stages ($j = 4, 5$). This is motivated by the fact that educational intervention at the early developmental stages is more effective since human capital investment is more complementary to children's human capital at the later stages. I assume that the government subsidizes 60 percent of the education expenditures made by the parents of disadvantaged children. The subsidizing program is financed by increasing the college tuition. Additionally, I assume that the admission policy function and technological change are identical to those in $\mathbb{P} = 1$.

Let $\mathbf{1_g}$ denote an indicator function taking the value one if the parent is eligible for the child education subsidy. The budget constraint of parents becomes

$$c + a' + \mathbf{1_g} 0.4m + (1 - \mathbf{1_g})m = (1 + r)a + y - T(y).$$

I assume the government expenditures on college subsidy and early childhood subsidy equals the total amount of college subsidy under the existing education policy. To do so, I search for the out-of-pocket tuition $\bar{\kappa}_2$ that can balance the government budget in this economy. Since the tuition is adjusted, the new share of college costs borne by the government is

$$\theta_2 = 1 - \frac{\bar{\kappa}_2}{1.19}$$

where 1.19 is the per student cost of college.

The government expenditures are given by EX_2, where:

$$EX_2 = 0.6 \sum_{j=4}^{5} \int_{\mathbf{1_g}=1} m_j(x_j) d\mu_j + 1.19\theta_2 \int_{\mathbf{1_e}=1} \chi^1(h_c) d\mu_8,$$

where the first term aggregates the government spending on the early childhood development subsidy, and the second term aggregate the subsidy for college education with a new level of tuition in place.

In the steady state equilibrium, the new tuition is such that the government budget is balanced:

$$EX_2 = EX_1,$$

which requires $\bar{\kappa}_2 = 0.50$.

6.2 Results

When evaluating the aggregate impact of policies, I am interested in the following three outcomes in particular. First, how does human capital investment respond to the policy change? Second, how do the education outcomes, including the human capital of children and the education level of children, change as the result of the policy change? Third, to what extent can the welfare of households improve due to the policy change? When analyzing the distributional effects of policies, my attention will be devoted to the distribution of the increase in human capital, college attainment, and welfare gains across children with different socioeconomic backgrounds.

The welfare changes at the individual level are expressed in terms of consumption-equivalent variation, which allows me to quantify the gains and losses experienced by different groups in the population. Specifically, for a parent whose human capital is h_p and education level is s, before any realization of income shocks, I compute the expected lifetime welfare for her child, which is denoted by $V_{\mathbb{P}}^{\widetilde{s}}(\widetilde{h}_p)$[26]. The conditional welfare change of children in

[26] Although $V_{\mathbb{P}}^{\widetilde{s}}(\widetilde{h}_p)$ measures the ex-ante welfare of a child, the notation $\sim$ indicates that the state variable h_p and s reflect the human capital and education level of her parent.

the economy $\mathbb{P}$ relative to the baseline economy can be expressed as:

$$\Delta W_{\mathbb{P}}^{\widetilde{s}}(\widetilde{h}_p) = \left[\frac{V_{\mathbb{P}}^{\widetilde{s}}(\widetilde{h}_p)}{V_0^{\widetilde{s}}(\widetilde{h}_p)}\right]^{\frac{1}{1-\sigma}} - 1.$$

In this way, I can compute the heterogenous impacts of policy on the welfare of children whose parents are different in their human capital h_p and education level s.

Next, I also calculate the aggregate-level welfare changes under the veil of ignorance by assuming that the planner weights every agent in the stationary distribution equally. The ex ante welfare changes in consumption-equivalent units are computed as follows:

$$\Delta W_{\mathbb{P}} = \left[\frac{\int V_{\mathbb{P}}^{s}(h_p) d\mu_{\mathbb{P}}^{s}}{\int V_0^{s}(h_p) d\mu_0^{s}}\right]^{\frac{1}{1-\sigma}} - 1.$$

The social welfare in the economy $\mathbb{P}$ is obtained by integrating over the stationary distribution of human capital and education levels of parents. The total social welfare changes come from two sources: (i) changes in the expected welfare at each state and (ii) changes in the distribution over different states due to policy changes.

6.2.1 Macro Outcomes

In this subsection, I analyze the effects of the existing college expansion policy and the counterfactual childhood development subsidy program. I compare the aggregate outcomes in the stationary equilibrium of these two economies with those in the benchmark, the results of which are reported in Table 9.

With respect to the effects resulting from the current policy, column (2) of Table 9 shows that aggregate quantities increase across the board. Starting with the most direct effect of the reform, due to the expansion in college capacity and decline in tuition-to-income ratio, the fraction of test takers and college graduates increases by 17.1 and 10.1 percentage points[27], respectively. Furthermore, the existing policy induces parents to spend 16.5% more on their children's education. The 16.1% rise in aggregate human capital is due partly to the rise in parent investments and partly to the parents' increased human capital, which makes them develop children's skills more efficiently. Finally, the reform leads to a 29.0% increase in output and a 17.2% improvement in en-ante welfare, which are primarily driven by the

[27]In the data, the fraction of test takers and college graduates increased by 45% and 21%, respectively, in 2015, which implies that the existing college expansion policy and explain about half of the rise in the exam-taking rate and college attendance rate from 1998 to 2015. Other factors, including the changes in family structure, job-specific skill requirement, and college wage premium, can also affect exam choices and college attainments. However, this model does not take those driving forces into account.

Table 9: Aggregate Effects of Education Policies

	(1) Baseline	(2) Current Policy	(3) Childhood subsidy
	Level	*Change*	*Change*
(a). ***Aggregate***			
Test taker share	17.19%	17.1pp	20.0pp
College share	4.73%	10.1pp	11.1pp
College wage prem.	0.50	0.0%	5.5%
Edu. expenditure	0.14	16.5%	29.4%
Human capital	0.72	16.1%	30.0%
Labor income	1.62	17.9%	25.3%
Output	0.60	29.0%	44.1%
Welfare	-13.51	17.2%	26.1%
(b). ***Std. Deviation***			
Edu. expenditure	0.63	3.6p	-7.4p
Human capital	0.28	5.2p	-2.6p
Labor income	0.53	1.2p	-0.4p
(c). ***Persistence***			
Human capital	0.80	5.3p	-0.4p
College education	28.91%	25.0pp	18.5pp

Note: The table shows the baseline and simulated results related to the macroeconomic variables. Column (1) corresponds to the level in the baseline economy. Column (2) and (3) correspond to the percentage or point changes after implementing the existing and counterfactual policy relative to the baseline economy. The welfare in entry (a) is measured by consumption-equivalent units. All the variables in entry (b) are in log scale. The persistence in human capital in entry (c) is measured by computing the correlation coefficient between parents' and children's human capital (in log).

higher aggregate human capital and labor income, respectively.

Meanwhile, because the education expenditure becomes more dispersed (3.6 log points) than the baseline economy, the standard deviation in human capital and income increases by 5.2 and 1.2 log points, respectively. Additionally, the correlation between parents' and children's human capital increases by 5.3 points. These results suggest that although the existing college expansion program generates substantial human capital and welfare gains, it also raises inequality and reduces intergenerational mobility across generations.

With respect to the effects induced by the childhood development subsidy program, column (3) of Table 9 shows that the counterfactual reform leads to additional gains in all the aggregate quantities relative to the existing policy. In particular, the rise in the share of test takers is going from 17.1 to 20.0 percentage points. This change results from two opposing forces. First, the college tuition increases by 92% for financing the childhood subsidy program, which makes college less appealing for poor parents. However, low-income parents, incentivized by the subsidy policy, increase their education expenditure spendings on children. As for disadvantaged children, since their human capital, as well as the exam passing probability, go up, their parents are more likely to choose to have their children take the exam.

Moreover, compared to the existing college expansion policy, the childhood subsidy program proposed in this paper can additionally promote the growth in aggregate human capital (going from 16.1% to 30.0%), output (going from 29.0% to 44.1%), and en-ante welfare (going from 17.2% to 26.1%). More importantly, as the subsidy policy exclusively targets the human capital investment in disadvantaged children, the standard deviation of education expenditures drops by 7.4 log points. Since the parents with low human capital and low education level are induced to spend more on their children's education, the dispersion in human capital and intergenerational correlation in human capital drops by 2.5 and 0.4 log points, respectively. These results suggest that supporting the childhood development of disadvantaged children can not only raise social welfare but also mitigate inequality and improve social mobility in the long run.

Results decomposition. The existing college expansion policy affects aggregate variables through four main channels: (i) college becomes more affordable for parents, (ii) admission probability given a human capital level is higher, (iii) general equilibrium effect moves prices, and (iv) skill-biased technological change affects demand side. Although these four channels interact with each other and cannot be perfectly disentangled, this exercise aims to gain some insights into their relative importance through a sequential decomposition. Table 10 reports a decomposition of these four effects on the change of macro variables with the current college expansion policy.

Table 10: Results Decomposition (Current Policy)

	Total chg.	**Due to:**	(1) Decline in tuition	(2) Rise in capacity	(3) G.E. effect	(4) Skill-biased tech. chg.
(a). ***Aggregate***						
Test takers share	17.1pp		-4.2pp	22.2pp	-17.9pp	17.0pp
College share	10.1pp		0.0pp	10.4pp	-7.9pp	7.5pp
College wage prem.	0.00%		18.5%	-10.3%	-31.3%	23.1%
Edu. expenditure	16.5%		3.3%	9.5%	-13.1%	16.9%
Human capital	16.1%		3.1%	9.2%	-12.6%	16.5%
Labor income	17.9%		1.2%	7.4%	-7.7%	17.0%
Output	29.0%		3.4%	9.1%	-12.2%	28.8%
Welfare	17.2%		0.8%	6.2%	-5.6%	15.8%
(b). ***Std. Deviation***						
Edu. expenditure	3.6p		1.5p	2.1p	-4.0p	4.0p
Human capital	5.2p		2.8p	3.5p	-7.5p	6.4p
Labor income	1.2p		0.5p	1.7p	-2.6p	1.6p
(c). ***Persistence***						
Human capital	5.3p		3.1p	3.1p	-7.9p	7.1p
College education	25.0pp		16.9pp	6.5pp	-26.1pp	24.5pp

Note: This table presents the results from the decomposition exercise. Column (1) reports the effects of a 22 percentage points drop in tuition-to-income *ratio, fixing the college capacity, equilibrium prices, and skill-biased technology. Column (2) reports the incremental effects from column (1) when the college capacity constraint is relaxed, while still fixing the prices and technology. Column (3) reports the incremental effects from column (2) when prices are adjusted, while the technology remains unchanged. Column (4) reports the incremental effects from column (3) when a calibrated skill-biased technological change is fed in to the model.*

Column (1) shows that a decline in tuition-to-income ratio on its own (fixing college capacity[28], prices, and technology) would have little impact on most aggregate variables. In particular, the share of test takers goes down by 4.2 percentage points even though college is significantly cheaper. The reason for this decrease can be explained as follows: if the college education supplies elastically, a more affordable college can induce more parents to support their children to attend college. However, due to the college capacity constraint, an increase in demand for college only makes the college admission more competitive. A lower probability of admission, in turn, leads to a lower return from exam-taking. As a result,

[28] Here, I adopt a counterfactual admission policy function $max(\chi_1(h_c) - \Xi, 0)$, where $\Xi = 0.066$ is endogenously determined to ensure that the share of college individuals is fixed. This is a reduced-form way to mimic a more selective admission process when college is more affordable.

more parents avoid paying the upfront cost (κ_e) by choosing to have their children skip the test.

Furthermore, the modest rise in aggregate human capital is mainly driven by behavioral education expenditures response of wealthy parents. As the test becomes more selective than the baseline economy, rich parents have to increase their parental investments to secure their children's college attendance. Finally, the college wage premium substantially rises by 18.5%. Under the partial equilibrium environment, the relative skill price remains unchanged. Therefore, the increase in college wage premium is only accounted for by the increased human capital sorting between college and non-college individuals.

Column (2), together with column (1), presents the aggregate effects of college expansion with fixed prices and technology. The dramatic rise in test takers share (22 percentage points) is not surprising given the substantial relaxation in college capacity constraint. Moreover, a comparison between column (1) and (2) clearly shows that the rise in aggregate quantities, including human capital, labor income, and welfare, is mainly due to the capacity expansion and not the lower tuition-to-income ratio. In addition, these two shocks are equally important in explaining the rise in inequality and intergenerational persistence in human capital.

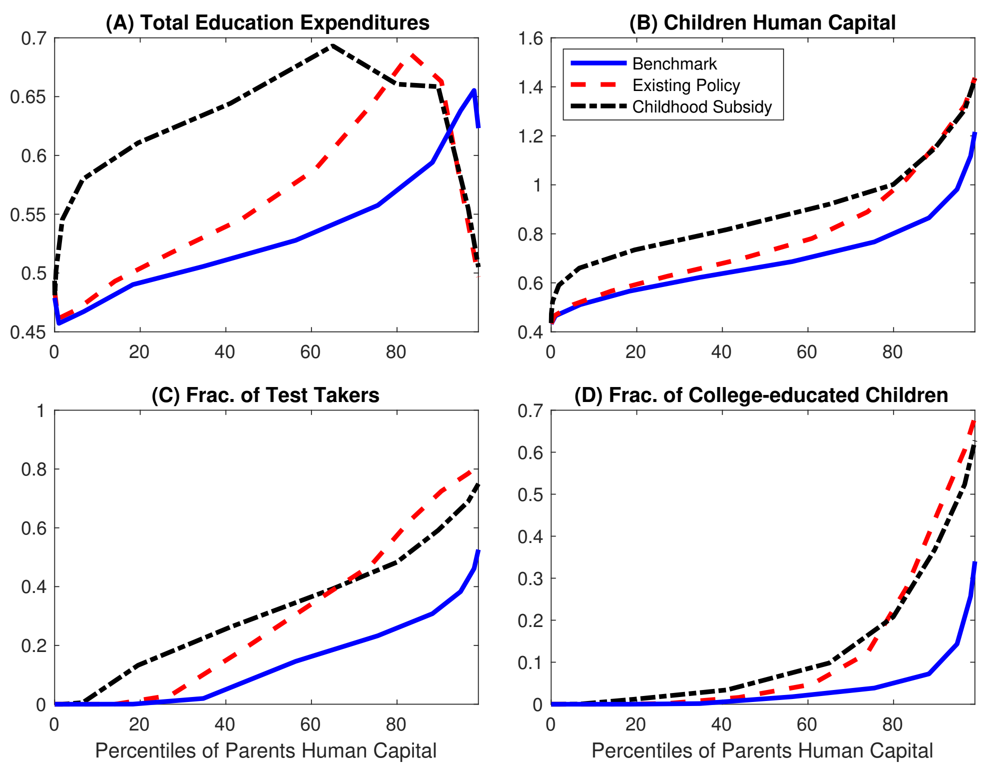
Column (3) shows that if equilibrium prices are adjusted, most of the gains in aggregate variables will be offset by the general equilibrium effect. As the college wage premium falls by 31.3 percent, parents are disincentivized to invest in their children's skill development and college education. Column (4) shows that with a skill-biased technological change that perfectly counterbalances the three effects as mentioned above on college wage premium, the exam-taking rate and college attendance rate rise back to the levels with prices fixed. Furthermore, aggregate education expenditure and human capital are slightly higher than those under the partial equilibrium exercise. Lastly, due to the rising demand for labor inputs, the increase in skill prices leads to substantial gains in labor income and welfare.

6.2.2 Distributional Effects

The aggregate statistics reveal that the current college expansion policy can contribute to rising inequality, while the childhood subsidy program can mitigate this effect. However, the channel through which the education policies affect inequality and intergenerational mobility is not clear. To illustrate the mechanism, in this subsection, I show how changes in educational investments and outcomes vary across parents heterogeneous in their human capital and education levels.

Figure 7 plots the simulated results related to parental investments and education outcomes against the percentiles of the human capital of parents. Specifically, Panel (A) and (B) of Figure 7 plots the average lifetime education expenditures and the average human

Figure 7: Education Investments and Outcomes in Relation to the Human Capital of Parents



Note: This figure presents how life-time education expenditures (panel (A)), average human capital of children (panel (B)), fraction of test takers (panel (C), and fraction of college-educated children (panel (D)) depend on parents' human capital. The horizontal axis corresponds to the human capital percentiles of parents. The blue solid line shows the results in the baseline estimation, the red dashed line shows the results under the existing college expansion policy, and the blacked dashed-dotted line shows the results under the counterfactual childhood subsidy program.

capital of children, respectively, against percentiles of the distribution of parent human capital. Panel (C) and (D) of Figure 7 plot the fraction of the associated children who take the college entrance exam, and fraction of the associated children who pass the test, respectively, against percentiles of the distribution of parent human capital. The blue solid line displays the results in the baseline economy, the red dashed line displays the results under the current policy, and the black dashed-dotted line displays the results under the childhood development subsidy program.

Panel (A) of Figure 7 reveals that the existing college expansion policy (red dashed line) significantly raises the educational investment of parents whose human capital is above the 50th percentile. In contrast, parents whose human capital is below the median level only slightly increase their human capital investment towards children. Consequently, as shown in Panel (B) of Figure 7, the increments in children's human capital resulting from the current policy increases with the human capital of parents. Panel (C) of Figure 7 shows that since the college is more affordable than the baseline economy, most parents (except for the bottom 20%) are more likely to choose to have their children take the exam. However, Panel (D) of Figure 7 reveals that the education outcome measured by the probability of college admission varies substantially across the human capital groups, with the children of low-skill parents gaining the least. The reason for the uneven outcomes can be explained as follows: the children of low-skill parents only have a slight gain in their human capital compared to the baseline economy. As a result, their admission possibility is still slim. The children of parents with high human capital, in contrast, take full advantage of the college expansion as their human capital as well as admission probability dramatically increases.

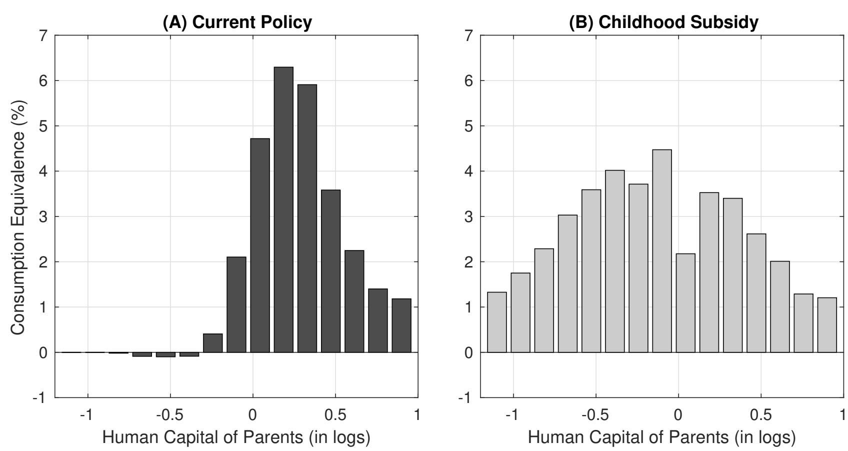
It is worth noting that the implications from the simulated model are consistent with the empirical evidence documented in subsection 4.1.4. The quantitative exercise as mentioned above illustrates the channel through which the college expansion policy leads to heterogeneous impacts on children with different socioeconomic backgrounds. For disadvantaged children whose human capital is far below the average of test takers, additional investments in human capital do not create an immediate rise in the probability of admission. The college expansion policy does not change this situation either[29]. Consequently, low-skill parents, facing the new admission policy function, are disincentivized to spend more on their children's education. In contrast, for high-skill parents, their children's human capital can reach the average level before the reform. College expansion rewards additional skill accumulation for children with above-average human capital by increasing the admission probability.

[29]The key observation from the estimation of college admission policies in subsection 4.2.2 is that only test takers whose scores are above the average have a significantly higher probability of passing the exam following college expansion.

In the economy with a childhood subsidy (black dashed-dotted line), as shown in Panel (A) of Figure 7 , the key difference is at the bottom: low-skill parents significantly increase their education expenditures towards children. As a result, as shown in panel (B) of figure 7 , the increments in children's human capital are more evenly distributed across parents with different human capital. The college attendance rate of disadvantaged children, in turn, goes up relative to that in the economy with the current policy in place. Meanwhile, Panel (C) of Figure 7 also shows that fewer children of high-skill parents take the exam, which is a result of the higher college tuition.

Figure 8 plots the changes in the expected welfare of children across the associated parents' human capital groups. Note that the welfare gains in this particular exercise are computed by fixing the prices and technological growth. The reason for this is that with skill-biased technological changes, the increase in wage rates will lead to welfare improvement for all socioeconomic groups. In this case, it is difficult to disentangle the contribution of policy changes.

Figure 8: Welfare Changes of Children Conditional on Parents' Skill



Note: This figure shows how the welfare changes of children measured in consumption equivalence depend on the associated parents' human capital (in logs). Panel (A) reports the welfare gains due to the existing college expansion policy relative the baseline steady state. Panel (B) reports the welfare gains due to the counterfactual childhood subsidy program relative the baseline steady state.

Panel (A) of Figure 8 shows that the welfare gains are concentrated among the children of high-skill parents[30]. Children of low-skill parents do not gain from these changes. Panel (A) of Figure 8 reveals that the childhood subsidy program redistributes the welfare gains away from the children of high-skill parents to the children of parents with low human capital. Figure 7 indicates that low-skill parents underinvest in their children's human capital

[30]In the simulation ($\mathbb{P} = 1$), $log(h_p) = -0.1$ is corresponding to the 73rd percentile of parent's human capital.

in the baseline economy, as well as in the economy with the current policy. In contrast, disadvantaged children have significant welfare gains with the childhood subsidy program since it exclusively targets low-income parents who underinvest in their children's early childhood education. Additionally, since the human capital investments at the subsequent stages are complementary to the early childhood investment, the subsidy program further raises the human capital as well as the welfare of disadvantaged children.

Table 11 reports how education outcomes and welfare changes are distributed across the children whose parents differ in their education levels. Column (1) corresponds to the baseline implications of the model. Column (2) and (3) presents the change in education outcomes and welfare due to the introduction of the current college expansion policy, and the counterfactual childhood subsidy program.

Table 11: Distributional Implications of Policies

	(1) Baseline		(2) Current Policy		(3) Childhood subsidy	
Parent edu.	Non-college	College	Non-college	College	Non-college	College
	Level		*Change*		*Change*	
Child						
Test taker share	15.16%	58.01%	11.9pp	18.4pp	16.2pp	10.3pp
College share	3.53%	28.91%	4.5pp	25.0pp	6.3pp	18.5pp
Human capital	0.70	1.10	8.5%	15.2%	25.0%	13.9%
Welfare	-12.35	-11.76	2.8%	21.7%	13.4%	19.4%

Note: This table displays how children's education outcomes and welfare depend on the associated parents with different education levels. Column (1) corresponds to the initial steady state. Column (2) and (3) corresponds to the percentage points or percentage changes after implementing the existing and counterfactual policies relative to the baseline economy.

Column (2) of Table 11 indicates that the children of college-educated parents increase college attendance rates, human capital, and welfare by more relative to the children of non-college-educated parents in the economy with the existing policy in place. Therefore, the policy gives rise to more persistent schooling across generations. Column (3) of Table 11 shows that the childhood subsidy program redistributes the human capital and welfare gains away from the children of college-educated parents to the children of non-college-educated parents. The reason for this is in line with the previous explanations since college-educated parents are associated with high human capital.

7 Conclusion

In this paper, I quantitatively investigate how China's college expansion program impacts human capital investment and inequality in the long run. To this end, I present a heterogeneous-agent overlapping generations model in which altruistic parents invest in their children's education and estimate the model using Chinese household-level data. I use the model to examine the aggregate and distributional effects of the higher education reform. The main finding is that the increase in college attainment, human capital, and ex ante welfare is substantial but unevenly distributed, with disadvantaged children benefiting least from the existing policy. The numerical exercise reveals that high-skill parents' education expenditures are more elastic to the policy change following the college expansion. As a result, their children can accumulate higher human capital, and hence more likely to gain access to college, which leads to a widening income gap and more persistent schooling across generations. Next, I use the model to conduct a counterfactual policy exercise. Specifically, I analyze an economy in which the government implements a targeted early childhood intervention, which subsidizes 60% of the education expenditures made by the eligible parents. The additional spending is financed by raising college tuition. I show that the remediation policy can generate substantial welfare gains and a decline in inequality relative to the existing policy, which suggests that government expenditures on education subsidies can be implemented more efficiently.

References

Agostinelli, Francesco and Matthew Wiswall. “Estimating the Technology of Children’s Skill Formation”. In: *Working paper* (2016).

Aiyagari, S Rao. “Uninsured idiosyncratic risk and aggregate saving”. In: *The Quarterly Journal of Economics* 109.3 (1994), pp. 659–684.

Bai, Chong-En, Chang-Tai Hsieh, and Yingyi Qian. “The Return to Capital in China”. In: *Brookings Papers on Economic Activity* 2006.2 (2006), pp. 61–88.

Bai, Chong-En and Zhenjie Qian. “The factor income distribution in China: 1978–2007”. In: *China Economic Review* 21.4 (2010), pp. 650–670.

Becker, Gary S and Nigel Tomes. “An equilibrium theory of the distribution of income and intergenerational mobility”. In: *Journal of political Economy* 87.6 (1979), pp. 1153–1189.

Bewley, Truman. “Stationary monetary equilibrium with a continuum of independently fluctuating consumers”. In: *Contributions to mathematical economics in honor of Gérard Debreu* 79 (1986).

Bohácek, Radim and Marek Kapicka. “Tertiary Educational Choices: the United States versus Europe”. In: *Working paper* (2016).

Caucutt, Elizabeth and Lance John Lochner. “Early and Late Human Capital Investments, Borrowing Constraints, and the Family”. In: *Journal of Political Economy* (forthcoming).

Choukhmane, Taha, Nicholas Coeurdacier, and Keyu Jin. “The one-child policy and household savings”. In: *Working paper* (2017).

Cunha, Flavio. “Investments in children when markets are incomplete”. In: *Working paper* (2013).

Cunha, Flavio, James J Heckman, and Susanne M Schennach. “Estimating the technology of cognitive and noncognitive skill formation”. In: *Econometrica* 78.3 (2010), pp. 883–931.

Daruich, Diego. “The macroeconomic consequences of early childhood development policies”. In: *FRB St. Louis Working Paper* 2018-29 (2018).

Ding, Haiyan and Hui He. “A tale of transition: An empirical analysis of economic inequality in urban China, 1986–2009”. In: *Review of Economic Dynamics* 29 (2018), pp. 106–137.

Doesey, Michael, Wenyi Li, and Fang Yang. “Demographic Aging, Industrial Policy, and Chinese Economic Growth”. In: *Working paper* (2019).

Donovan, Kevin and Christopher Herrington. “Factors affecting college attainment and student ability in the us since 1900”. In: *Review of Economic Dynamics* 31 (2019), pp. 224–244.

Feng, Yun. “The Labor Market Impact of China’s Higher Education Expansion Reform”. PhD thesis. UCLA, 2019.

Garriga, Carlos and Mark P Keightley. “A general equilibrium theory of college with education subsidies, in-school labor supply, and borrowing constraints”. In: *Working paper* (2007).

Ge, Suqin and Dennis Yang. “Changes in China’s wage structure”. In: *Journal of the European Economic Association* 12.2 (2014), pp. 300–336.

Hendricks, Lutz and Todd Schoellman. “Student abilities during the expansion of US education”. In: *Journal of Monetary Economics* 63 (2014), pp. 19–36.

Huggett, Mark. “The risk-free rate in heterogeneous-agent incomplete-insurance economies”. In: *Journal of economic Dynamics and Control* 17.5-6 (1993), pp. 953–969.

İmrohoroğlu, Ayşe and Kai Zhao. “The Chinese saving rate: Long-term care risks, family insurance, and demographics”. In: *Journal of Monetary Economics* 96 (2018), pp. 33–52.

Jia, Ruixue and Hongbin Li. “Access to elite education, wage premium, and social mobility: the truth and illusion of China’s College Entrance Exam”. In: *Stanford Center for International Development, Working Paper 577* (2016).

Katz, Lawrence F and Kevin M Murphy. “Changes in relative wages, 1963–1987: supply and demand factors”. In: *The quarterly journal of economics* 107.1 (1992), pp. 35–78.

Kindermann, Fabian. “Welfare Effects of Privatizing Public Education When Human Capital Investments Are Risky”. In: *Journal of Human Capital* 6.2 (2012), pp. 87–123.

Kopecky, Karen A and Richard MH Suen. “Finite state Markov-chain approximations to highly persistent processes”. In: *Review of Economic Dynamics* 13.3 (2010), pp. 701–714.

Krueger, Dirk and Alexander Ludwig. “On the optimal provision of social insurance: Progressive taxation versus education subsidies in general equilibrium”. In: *Journal of Monetary Economics* 77 (2016), pp. 72–98.

Lee, Sang Yoon and Ananth Seshadri. “On the intergenerational transmission of economic status”. In: *Journal of Political Economy* 127.2 (2019), pp. 855–921.

Lee, Soohyung and Benjamin A Malin. “Education’s role in China’s structural transformation”. In: *Journal of Development Economics* 101 (2013), pp. 148–166.

Li, Hongbin, Pak Wai Liu, and Junsen Zhang. “Estimating returns to education using twins in urban China”. In: *Journal of Development Economics* 97.2 (2012), pp. 494–504.

Li, Hongbin, Lingsheng Meng, et al. “Does attending elite colleges pay in China?” In: *Journal of Comparative Economics* 40.1 (2012), pp. 78–88.

Li, Shi, John Whalley, and Chunbing Xing. “China’s higher education expansion and unemployment of college graduates”. In: *China Economic Review* 30 (2014), pp. 567–582.

Ma, Shihui. “China’s College Expansion Policy: Ability Selection and Labor Market Effects”. In: *Job Market Paper* (2014).

Meghir, Costas et al. “Education Policy and Intergenerational Transfers in Equilibrium”. In: *Journal of Political Economy* (forthcoming).

Moschini, Emily. “Child Care Subsidies with One- and Two-Parent Families”. In: *Job Market Paper* (2019).

Mullins, Joseph. “Designing Cash Transfers in the Presence of Children’s Human Capital Formation”. In: *Working paper* (2019).

Rouwenhorst, Geert. “Asset Pricing Implications of Equilibrium Business Cycle Models”. In: *Chapter 10, Frontiers of Business Cycle Research, ed. by T. Cooley* (1995).

Song, Zheng, Kjetil Storesletten, and Fabrizio Zilibotti. “Growing like china”. In: *American economic review* 101.1 (2011), pp. 196–233.

Yu, Jihai and Guozhong Zhu. “How uncertain is household income in China”. In: *Economics Letters* 120.1 (2013), pp. 74–78.

Zhang, Junsen et al. “Economic returns to schooling in urban China, 1988 to 2001”. In: *Journal of comparative economics* 33.4 (2005), pp. 730–752.

A Data

A.1 Test Scores

Test scores in the college entrance exams are used to estimate the admission policy function in subsection 4.2.2, and the return to skills in subsection 4.2.3. In other words, I use test scores to predict an individual's probability of the four-year college admission, as well as to approximate her human capital. The data is obtained from CHIP2013.

Sample Selection I start with all the individuals for which I can observe the test scores. I only keep the individuals who took either social-science-oriented or natural-science-oriented exams [31]. I drop individuals who took the College Entrance Examination in Jiangsu province[32], and drop individuals who took the College Entrance Examination before 1989[33]. I restrict the sample to individuals who at least complete junior high school before taking the college entrance exam. Furthermore, I restrict the sample to individuals who took the College Entrance Examination between the age 16 and 22. For the individuals who took the College Entrance Examination between 1989 and 1992, I convert their raw scores to scaled scores consistent with the current scoring system [34]. Finally, I drop all the individuals whose test score is below 100 or above 700[35].

[31] Some test takers took the uni-category exam or took the special exam for the students with arts or sports talent. Due to the complexity of interpreting the observed scores, I drop them from the sample.

[32] The College Entrance Examination in Jiangsu province uses a different scoring system from other provinces. As a result, it is difficult to convert the raw scores to the scaled scores for individuals who took the test in Jiangsu province.

[33] China resumed the National Higher Education Entrance Examination in 1977. However, the scoring and admission system in the early years can be different from the status quo. So for estimating the admission policy function before the reform, I only keep the individuals who took the exam between 1989 and 1998.

[34] In the current scoring system, the full score is 750. However, between 1989 and 1992, the full score can be either 640 or 710 depending on the orientation of test takers.

[35] These scores are extremely rare in the college entrance exam. Individuals are likely to misreport their test scores in this case.

B Admission Probability

Table 12: Estimation of Exam Admission Probability

(1) Baseline		(2) Existing Policy		(3) Without Expansion	
Test Score	Adm. Prob.	Test Score	Adm. Prob.	Test Score	Adm. Prob.
-0.80	0.00	-0.72	0.00	-0.72	0.00
-0.64	0.00	-0.59	0.00	-0.59	0.00
-0.54	0.00	-0.47	0.02	-0.47	0.00
-0.39	0.03	-0.37	0.05	-0.37	0.01
-0.26	0.08	-0.26	0.12	-0.26	0.05
-0.15	0.15	-0.15	0.16	-0.15	0.07
-0.01	0.21	-0.04	0.34	-0.04	0.08
0.11	0.35	0.07	0.55	0.07	0.14
0.23	0.59	0.17	0.82	0.17	0.36
0.35	0.84	0.27	0.87	0.27	0.80

Note: Data source: CHIP2013. This table presents the estimated results of admission policy function. The test scores are normalized by taking their (log) difference from the the average test score. The probability of admission is estimated using the observations on individuals' test scores and education outcomes (whether or not they have eared a four-year college degree). Column (1) corresponds to the estimation for the baseline economy, which reflects the pre-reform admission policy. Only individuals who took the College Entrance Examination *between 1989 and 1998 are in the sample to obtain the policy function. Column (2) corresponds to the estimation for the post-reform admission policy. Only the individuals who took the* College Entrance Examination *between 2008 and 2012 are in the sample to obtain the policy function. Column (3) displays a counterfactual admission policy function when the* tuition-to-income *ratio declines but the capacity constraint of college is not relaxed.*

C Calibration

C.1 Description of Environment

Consider a single parent and single child problem. In the morning, the parent whose human capital is (h_p) chooses her consumption (c_p) and human capital investment (education expenditure) in child (m). The income depends on human capital as follows

$$y = h^{\gamma}$$

where γ controls the return to human capital. So the budget constraint of the parent reads as

$$c_p + m = h_p^{\gamma}.$$

Her child is endowed with human capital (h_1) in the morning. The following technology combining the endowment (h_1), parent's human capital (h_p) and investment (m) to produce new human capital h_2.

$$h_2 = h_p^{\omega}[\alpha h_1^{\rho} + (1-\alpha)m^{\rho}]^{\frac{1-\omega}{\rho}},$$

where ω controls the share of parent's human capital in skill production, α controls the self productivity of child's current human capital, and σ controls the elasticity of substitution between child's endowment of human capital and monetary investment.

In the evening, the child earns income depending on her human capital (h_2). The child will consume everything she has. So the budget constraint reads as

$$c_c = h_2^{\gamma}.$$

The altruistic parent is the one who makes consumption and investment decision. She cares about her child's consumption in the evening. The preference of the parent is given by

$$log(c_p) + \nu log(c_c)$$

where ν captures the degrees of altruism.

C.2 Household Problem

The household solves the following problem based on the description in the previous subsection

$$\max_{c_p, m} \; log(c_p) + \nu log(c_c)$$

$$s.t.\ c_c = [\alpha h_1^\rho + (1-\alpha)(y_p - c_p)^\rho]^{\frac{\gamma}{\rho}}.$$

I solve this problem using standard algorithm. The solution can be characterized by the following Euler equation

$$\underbrace{\frac{1}{c_p}}_{\substack{marginal \\ return\ to\ c_p}} = \underbrace{\nu\gamma(1-\alpha)(1-\omega)\frac{(h_p^\gamma - c_p)^{\rho-1}}{\alpha h_1^\rho + (1-\alpha)(h_p^\gamma - c_p)^\rho}}_{\substack{marginal \\ return\ to\ m}},$$

which implies the parent at optimality should equalize the marginal return to her own consumption, and marginal return to human capital investment in child.

C.3 Analytical Solution

Cobb-Douglas $\rho = 0$ There Euler equation is simplified as

$$\frac{1}{h_p^\gamma - m} = \nu\gamma(1-\alpha)(1-\omega)\frac{1}{m}.$$

Then the relationship between parent's income h_p^γ and human capital investment m can be written as

$$m = \underbrace{\frac{\nu\gamma(1-\alpha)(1-\omega)}{1+\nu\gamma(1-\alpha)(1-\omega)}}_{slope} h_p^\gamma.$$

Perfect substitute $\rho = 1$ There Euler equation can be simplified as

$$\frac{1}{h_p^\gamma - m} = \nu\gamma(1-\alpha)(1-\omega)\frac{1}{\alpha h_1 + (1-\alpha)m}.$$

Then the relationship between parent's income h_p^γ and human capital investment m can be written as

$$m = \underbrace{\frac{\nu\gamma(1-\alpha)(1-\omega)}{1+\nu\gamma(1-\alpha)(1-\omega) - \alpha}}_{slope} h_p^\gamma - \frac{\alpha h_1}{1+\nu\gamma(1-\alpha)(1-\omega) - \alpha}.$$

Link to calibration It is clear that if the current child's human capital is more substitutable to the education investment, the change of education expenditure will be more responsive to a change in income (h_p^γ). The magnitude of difference (in income elasticity of education expenditure) between the Cobb-Douglas world and the perfect substitute world is determined by self-productivity share (α). As a result, when I estimate ρ, I should first pin down α and other parameters. Then I can simulate my model and internally search for the parameter ρ through matching model-predicted auxiliary coefficients to the data counterpart.

C.4 Link to the Full Model

In the quantitative life-cycle model, parent's skill investment decision will be complicated by the heterogeneity in the current human capital of child, and in financial wealth. However, the numerical exercise shows that the full model's implications on income elasticity of education expenditure are consistent with that implied by the static problem.

Figure 9: Calibration of Dynamic Complementarity Parameters

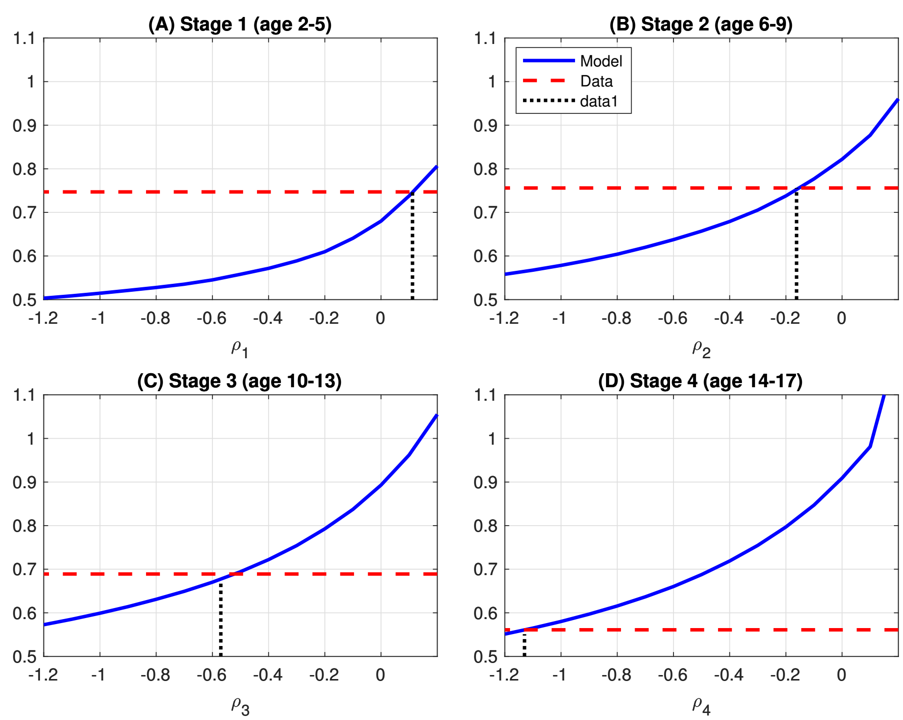


Figure 9 plots the data- and model-predicted effects of household income on education expenditure towards children for each childhood developmental stage, respectively. The red dashed lines are obtained from the estimation results (column 1) as displayed in subsection 4.1.3. The blue solids lines are obtained from repeatedly simulating the model by varying the dynamic complementarity parameters ρ_j[36]. It is clear that more substitutable relationship

[36]To obtain this figure, for each panel, I only vary one parameter each time and fix other parameters. In my calibration exercise, this set of parameters are jointly determined.

between current child's human capital and parental investment implies a stronger effect of household income on education expenditure. With this feature in mind, I can search for the four parameters that minimize the weighted distance between model-predicted coefficients and their data counterparts.