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ABSTRACT

From Preschool to College: The Impact of Education Policies over the Lifecycle*

Across all education levels, policymakers are using the re-sorting of students to diversify the socioeconomic composition of student bodies. We study how these integration policies interact, using a heterogeneous agent overlapping generations model featuring multiple periods of human capital development. Households sort into public schools through housing location, and into college via a competitive admissions process. Quality of schools and colleges are endogenous through peer effects. At the public school level, we simulate an integration policy that randomly shifts students across schools. For college, we consider an income-based affirmative action policy. Public school integration weakens the link between residential location and school quality, increasing intergenerational mobility by 2.5%. On the other hand, the college policy decreases intergenerational mobility by 0.7%: when the high-quality college reserves seats for low-income students, it makes college more competitive, which increases sorting at the public school level. In fact, an integration policy that combines public school re-sorting and college affirmative action leads to minimal changes in upwards mobility.

JEL Classification: I2, R23
Keywords: intergenerational mobility, sorting, integration

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1 Introduction

In the United States, across all stages of child and young adult development, individuals face different education opportunities depending on their family socioeconomic status (SES). Preschool attendance rates are greater among children from higher SES families. (Cascio and Schanzenbach, 2014). There is large income segregation across public schools (Owens et al., 2016), and significant test score gaps between students of varying SES (Reardon, 2018; Hanushek et al., 2019). In addition, recent work on colleges and economic mobility highlight a stark relationship between family income and quality of college attended (Chetty et al., 2020a; Chetty et al., 2023).

In light of these inequities, there has been a growing emphasis on policies designed to diversify the socioeconomic composition of student bodies. We will refer to these policies as "integration policies". At the preschool level, the federal government recently updated Title I funding rules so districts can use these funds to expand preschool access.[1] For public schools, these policies involve re-sorting students across schools, within a district. At the college level, in response to the ban on race-based affirmative action, the U.S. federal government has advised colleges to instead consider applicants' family income and high school background during the admissions process.[2]

While the effects of integration policies have been studied in isolation (Agostinelli et al., 2024; Brotherhood et al., 2023; Chyn and Daruich, 2022), the interaction of these policies across human capital stages is less understood. This is an important issue to study, given that, in practice, these integration policies are being implemented by different levels of government across multiple education levels. As such, individuals are likely to be exposed to several of these treatments over time. Additionally, policies to create equitable education

[1] Title I funding is federal funding given to low-income school districts. See https://www.ed.gov/news/press-releases/biden-harris-administration-releases-resources-support-preschool-expansion-and-early-school-success

[2] See the press release here: https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/29/fact-sheet-president-biden-announces-actions-to-promote-educational-opportunity-and-diversity-in-colleges-and-universities/

opportunity may have unintended general equilibrium consequences.

This paper builds a novel framework to study the effects of integration policies across different stages of human capital development. Our main goal is to understand what combination of integration policies is most effective at improving intergenerational mobility. We begin with a standard lifecycle, heterogeneous agent model of incomplete markets.[3] We augment this model to include several additional features necessary to achieve our research objective: (1) intergenerational motives in the style of Becker and Tomes (1979), (2) multi-period dynamic human capital accumulation as in Ben-Porath (1967), and (3) all key phases of education over the lifecycle; preschool, elementary school, secondary school, and college.

When children graduate secondary school, they become independent adults and are heterogeneous in terms of ability, human capital, and wealth, the latter two being endogenous. They then decide whether to apply to college or not. Contingent on being accepted, they choose which college to attend. Colleges differ in terms of peer effects (average ability), tuition, and per-pupil expenditures. The high-quality college has a fixed supply of seats with an endogenous admissions cutoff score based on the human capital and ability of its applicants. At the elementary and secondary school level, our model features sorting and school quality through peer effects. We assume there are two school zones, each with a fixed housing supply, and house prices determined in equilibrium. Finally, at the preschool level, parents choose whether to pay and enroll their child in private preschool, or to care for the child themselves. At each education stage, the quality of education influences the level and growth rate of human capital. Given education decisions, adults endogenously choose the level to invest in their own human capital, their child human capital, and the size of inter-vivos transfers to leave.

Solving a model with endogenous human capital accumulation, intergenerational linkages, and endogenous education quality through sorting at the public school and college level is computationally challenging. In equilibrium, house prices must clear the housing market

[3]For the foundations of this class of models, see Bewley (1977), Imrohoroğlu (1989), Huggett (1993), and Aiyagari (1994).

in each school zone, and the college admissions score must clear the college market. In addition, the school and college qualities that agents use to solve their value functions must equal the realized qualities, and there is an additional fixed-point problem linking agents across generations. It is through such a framework that we are able to provide an analysis of how different integration policies affect sorting and human capital accumulation across the lifecycle: a novel contribution to the literature.

The model is disciplined using data on college characteristics, school quality, and human capital development. In particular, we use the Panel Study of Income Dynamics to gather moments on child human capital, child time investments and the identity of school attended. We map our high-quality college into elite colleges in the data, which enroll only nine percent of all college students. Our high-quality elementary school is mapped into the top 20% of schools in the United States. In our calibration, we target moments on parental income sorting across schools, time investment across schools, earnings growth by college quality, and the effect of school quality on human capital. Additionally, our model is able to match the aggregate Gini coefficient of income, the intergenerational elasticity of earnings, and the transfers to net-worth ratio.

We use our structural model to run several integration policies which have been considered or implemented by policymakers. First, we simulate an income-based affirmative action policy where the high-quality college implements a quota for low-income students. At the elementary and secondary school level, we study school integration policies that involve randomized re-sorting of students across schools. With some probability, students living in the high-quality school zone may be sent to the low-quality school and vice versa. We start with a conservative policy that shifts only four percent of the student population. Finally, we consider a preschool policy where there is extra funding to send low-income children to preschool for free. For each policy, we run three versions. First, the policy is unanticipated and agents cannot adjust their policy functions. Whether or not the policy is expected is of particular importance at the college level. Once children reach the college application phase of their lifecycle, key parental investments have already been decided. Second, the policy is anticipated but in partial equilibrium, leaving house prices and the college admission score fixed. Lastly, we solve for the general equilibrium, allowing house prices and the college admission score to adjust. These policies are studied in isolation and in concert with one another.

We now highlight the key findings of our policy analysis. As expected, the integration policies have, on average, positive human capital gains for children from low-income families. The preschool policy allows treated children to attend preschool without cost, which raises parental resources by allowing them to work more or to accumulate more of their own human capital. In the following period, parents can then use these additional resources to pay for housing in the high-quality school zone. Next, for children who are re-sorted from the low- to high-quality public school, their parents increase time investment in them and reduce transfers. In the case of the college policy, agents that are sent to the high-quality college subsequently increase monetary investments for their own child (preschool, public school, and transfers) rather than time, taking advantage of their more productive human capital to earn higher income.

Next, we outline the importance of policy anticipation. When the policies are unanticipated, there are limited changes in intergenerational income mobility because agents cannot adjust their decisions. For example, under a college income affirmative action program, low-income parents optimally increase time investment in their child relative to the baseline equilibrium. These parents know that that their child is more likely to get into the elite college and it is optimal to devote more to their human capital growth. This is only possible when the policy is anticipated. Similarly, an integration policy at the secondary school level has larger effects on upward income mobility when expected. Low-income parents in the low-quality school zone know that the expected value of the school quality at secondary school rises and they increase their time investment in the preceding period.

At the aggregate level, we find that an integration policy at the elementary school or the secondary school has positive effects on mobility: the intergenerational elasticity of income (IGE) decreases by 1.4% in the former case and 1.3% in the latter case.[4] While the effects on the IGE are similar, the secondary school policy reduces inequality between the two school zones by more. The price of the high-quality school zone declines by approximately 6% under secondary school re-sorting, but only by two percent under elementary school re-sorting. These price differences mirror the fact that the high-quality school zone experiences a larger fall in average ability during the secondary school policy. The difference arises from the model timing: under an elementary re-sorting policy, the high-quality school zone is more valuable because it still guarantees access to the high-quality secondary school. Parents can thus insure against a bad elementary school shock by increasing time investment during secondary school.

On the other hand, integration at the college level can have a negative effect on income mobility, with the IGE increasing by 1.6%. The reason is as follows: a quota for students from low-income families essentially restricts the supply of college seats. At the high-quality college, supply is fixed, and in response, the endogenous admissions score rises by eleven percent. This rise in college competition has effects on human capital development during the public school stage. More specifically, a higher admissions score drives up the price of the high-quality school zone by 1.6%. Parents know being admitted into the elite college is more difficult, so their valuation of a good school increases. This price increase prevents low-income families from accessing good schools, leading to a decrease in intergenerational mobility.

A result that follows from above is the importance of understanding how policies interact. For instance, an integration policy at both the elementary and secondary school reduces the IGE by 2.5%. However, if those policies are implemented in conjunction with a college integration policy, the IGE declines by just 1%. While the public school integration

[4] The intergenerational elasticity of income is the coefficient from a regression of logged child income on the logged income of their parent. A higher (lower) coefficient indicates lower (higher) intergenerational mobility.

policy creates more equality across the two school zones, the college policy counteracts this by driving up the value of the good school zone. Our work highlights the importance of policy coordination. Currently, colleges, school districts, and other forms of governments are independently implementing integration policies.

The remainder of our paper is organized as follows. In the next section we provide a literature review and discuss our contribution. *Section 2* begins by establishing important motivating facts highlighting the degree of income segregation across different stages of schooling. In addition, we summarize current integration policies at the public school and college level. *Section 3* lays out our quantitative framework, and *Section 4* describes our calibration strategy. The results of our policy analysis are presented in *Section 5*. Finally, *Section 6* concludes.

1.1 Related Literature

In terms of research question, our work is most closely related to two papers investigating the effectiveness of the timing of human capital policy interventions: Krueger et al. (2024) and Lee and Seshadri (2019). Krueger et al. (2024) studies the effectiveness of policies to improve schools versus making college more accessible. They investigate the effectiveness of different financing policies across the child development stages while we focus on re-sorting. Lee and Seshadri (2019) study the effectiveness of policies to increase child investment at different points in the lifecycle. We differ from these two works in that we explicitly model sorting across differing qualities at both the public school and the college stage. This allows us to have endogenous school and college qualities that are determined through peer effects. We follow Lee and Seshadri (2019) in modeling adult and child human capital in a Ben-Porath framework, incorporating the idea that investments in human capital during childhood affect the growth of human capital throughout the lifecycle. Furthermore, our calibration strategy closely mirrors Lee and Seshadri (2019) but we adapt it to target additional moments across schools and colleges.

The sorting features of our model are built off of several seminal works that studied the link between neighborhood residence and school financing (Benabou, 1996; Durlauf, 1996b; Durlauf, 1996a; Fernandez and Rogerson, 1996; Fernandez and Rogerson, 1998). More recently, work by Aliprantis and Carroll (2018), Chyn and Daruich (2022), Gregory et al. (2022), Fogli and Guerrieri (2019), and Zheng and Graham (2022) study spillover effects from neighborhoods in dynamic lifecycle models. Closely related to our work is Fogli and Guerrieri (2019), who study how an increase in the skill premium can amplify income segregation across neighborhoods, and Chyn and Daruich (2022), who analyze the effects of place-based policies in the form of housing vouchers and neighborhood wage subsidies. We differ from these works in that we study desegregation policies at public school in combination with policies to improve access to college. Also related is Agostinelli et al. (2024), who build a rich urban model of school zones to evaluate the effects of school choice policies and housing vouchers on access to quality education. While our model lacks their fine spatial heterogeneity, we instead incorporate a dynamic lifecycle model that captures policy interaction across time while still including sufficient spatial dynamics to answer our research question.

Our work is also related to the literature on child development (Cunha and Heckman, 2007; Cunha et al., 2010; Del Boca et al., 2014a; Caucutt et al., 2020) and to works studying the macroeconomic and intergenerational implications of child development policies (Lee and Seshadri, 2019; Daruich, 2018; Caucutt and Lochner, 2020). Our main distinction from this line of papers is modeling sorting during K-12 and college, with quality of these institutions determined through peer effects. In addition, we also include competitive college admissions.

Lastly, our work also ties into recent papers studying policies at the college level. Brotherhood et al. (2023) build a structural model investigating an income-based affirmative action policy in Brazil. Other quantitative models of college choice include Hendricks and Leukhina (2017), Leukhina et al. (2021), and Hendricks et al. (2021). We differ from these works by modeling K-12 schooling choices with endogenous sorting.

2 Institutional Context

We begin by discussing the institutional details that motivate our research question. For each schooling stage, we highlight the existing inequalities and give examples of recent policies.

To start, the high cost of childcare contributes to the significant gaps in preschool enrollment documented between low- and high-income families (Cascio and Schanzenbach, 2014). As a consequence, by the time children enter public school, there are differences in their cognitive skills by socioeconomic status (Duncan, Magnuson, et al., 2011). In recognition of the disparate preschool attendance rates by family SES, the U.S. federal government has given new directives to school districts on how to use their Title I funding to incorporate preschool programs into their schools.[5] Individual states are also taking initiatives to improve preschool access: for example, the state of Colorado created a universal free preschool program in 2023 (Schmike, 2024).

Within the elementary and secondary school system, two levels of public school institutions exist: school districts and individual schools. School districts are administrative bodies that are responsible for the management (including finances) of a group of individual schools.[6] Our focus is on studying economic segregation among schools within a single district, in line with the current state of integration policies (Potter and Burris, 2020).[7] Within a school district, assignment to public schools is mostly determined by residential address through school attendance zones. While school choice options, such as open enrollment, magnet schools, and charter schools, have become more common, the percentage of public school students who attended a school assigned based on their location of residence was nearly 70% in 2016 (Wang et al., 2019). The link between location of residence and

[5]Title I funding is provided by the federal government to low-income districts. For the official government guidance, see: https://www.ed.gov/news/press-releases/biden-harris-administration-releases-resources-support-preschool-expansion-and-early-school-success

[6]For example, Chicago Public Schools is the district that manages the public schools in the city of Chicago.

[7]School districts span large geographic areas (such as entire counties), and desegregation policies across districts would be logistically challenging.

school assignment implies that access to high-quality public schools is a function of real estate prices, and therefore, family socioeconomic status (Black, 1999). Owens et al. (2016) document that income segregation within school districts has increased since 1990.

We present statistics on income segregation for Chicago Public Schools and New York City Public Schools. *Figure 1* highlights economic segregation in the Chicago Public School District using free and reduced-lunch status; a program that provides no-cost or reduced-cost meals to children at school.[8] The maps indicate stark income segregation with clusters of higher-income areas at both the elementary (left map) and secondary school (right map) level. In *Figure 2* we highlight the relation between the share of free and reduced-lunch students and other covariates for New York City Geographic District #2. The top left map shows the share of free and reduced-lunch, which positively correlates with the share of white students in the top right map. In the bottom left map we plot the per-pupil expenditures in each school, showing that low-income schools actually have higher-spending. Lastly, the bottom right figure plots the share of students who score above proficiency on standardized tests. There is a strong correlation between income and test score performance. These figures emphasize that low-income students tend to attend lower-performing schools, despite these schools receiving more funding.

In terms of policy, since every child has access to a public school, policymakers focus on how to re-sort students across schools to reduce socioeconomic segregation. While some integration plans stem from the result of federal or state government grants, the majority are implemented at the local government level (Potter and Burris, 2020). A recent report by The Century Foundation identified 185 school districts that have student integration plans outlined in their district policies.[9] These 185 districts enroll about 14% of public school students, and about a quarter of their policies were implemented in 2017 or later (Potter and

[8]Eligibility requires that the family income of students must be below 1.30 (free) and 1.85 (reduced) times the federal poverty line, respectively. According to Owens et al. (2016), free and reduced lunch students represent roughly the bottom 20% of the income distribution.

[9]The report identifies another 722 districts who state that they aim to reduce segregation, but have no explicit language in their policies about detailing plans to do so (Potter and Burris, 2020).

Burris, 2020). Integration plans can take shape in the following ways: frequent redrawing of attendance zone boundaries to balance socioeconomic status, giving higher weight to transfer requests from low-SES students, and school choice programs that prioritize a balanced SES distribution. As a specific example, at the middle school level, in 2019, NYC Geographic District 15 in Brooklyn implemented a program to reduce segregation among low-income and English Language learner students by giving them priority seats at every school in the district (Meckler, 2019).

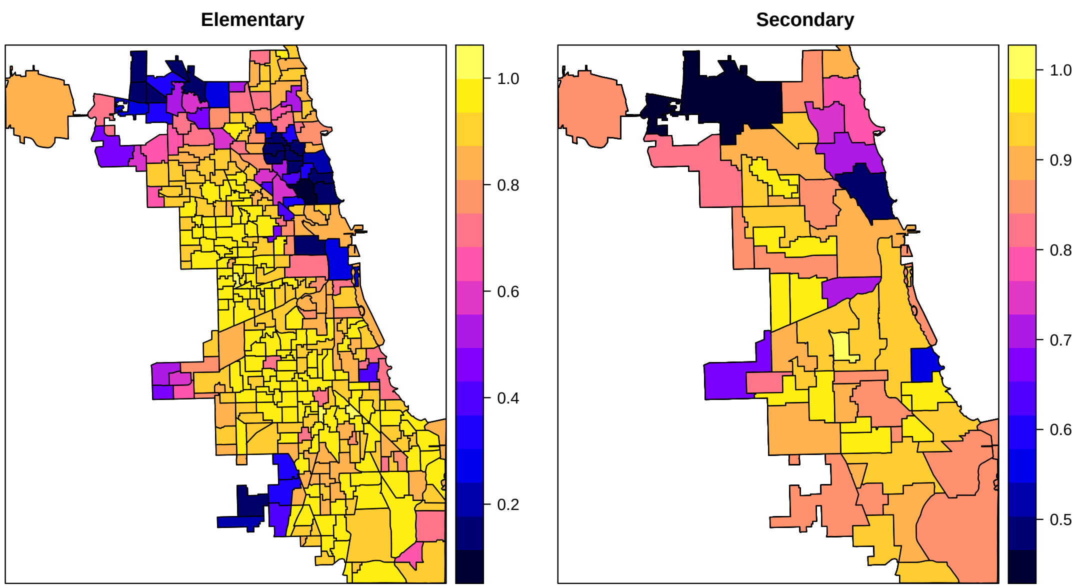
Finally, at the college level, recent work from Chetty et al. (2020a) finds family income segregation across colleges that is comparable in magnitude to that across neighborhoods. In addition, Chetty et al. (2020a) show that even conditional on the same SAT scores, students from higher-income families have a higher probability of attending selective colleges than those from lower-income families. The recent decision to strike down race-based affirmative action has left policymakers focused on continuing to improve access to good colleges for those from underrepresented backgrounds. The Biden-Harris Administration has issued directives to states and colleges to improve outreach to minorities and to consider financial hardship, secondary school, and neighborhood during admissions.[10] One such example is the Texas "Top 10%" rule, in which the top seniors of each high school in the state get admitted to public state schools. The states of Florida, California, and Illinois also have similar percentage plans.[11]

To conclude, there are a variety of integration policies across different stages of child development. A complete understanding of the effects of these policies requires studying how these policies interact with each other across the lifecycle. To this end, we turn to developing a structural model of human capital development.

[10]See https://www.ed.gov/news/press-releases/biden-harris-administration-outlines-strategies-increase-diversity-and-opportunity-higher-education.

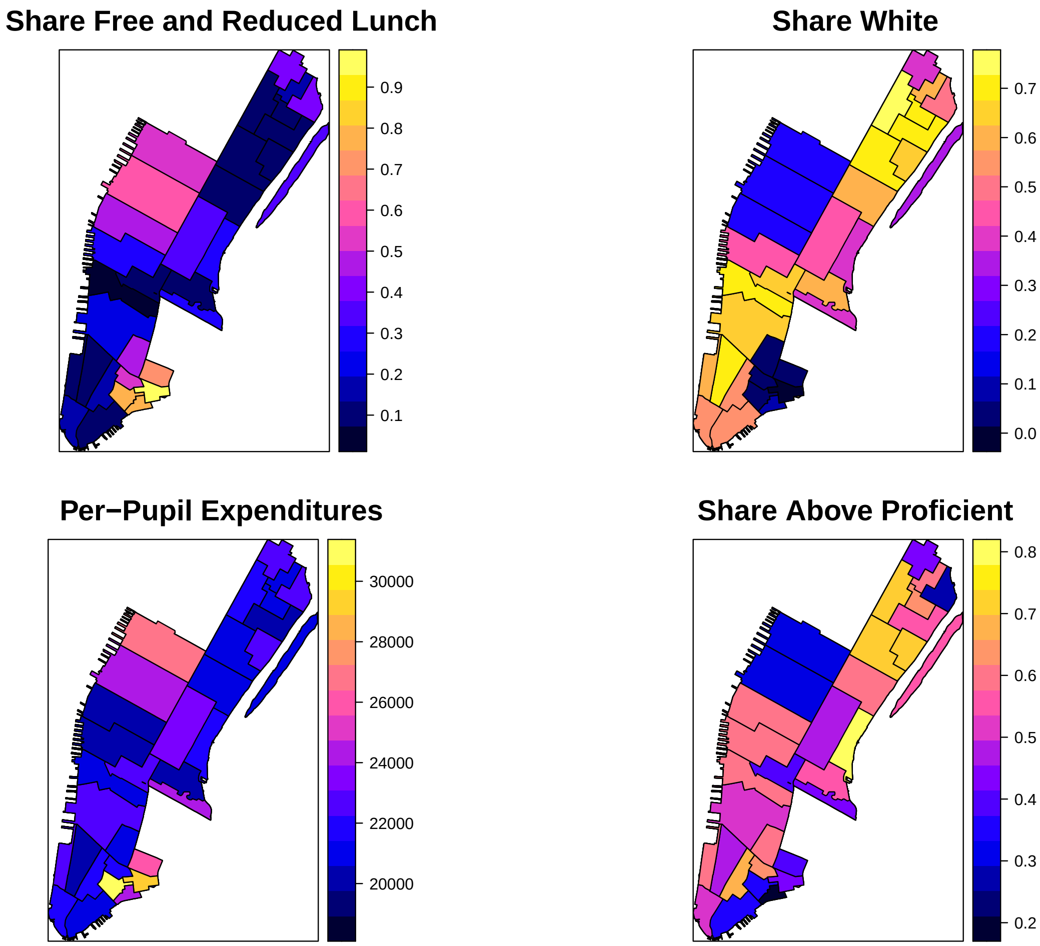
[11]See https://admission.universityofcalifornia.edu/admission-requirements/freshman-requirements/california-residents/statewide-guarantee/.

Figure 1: **Chicago Elementary School Zones**



Notes: These two maps present school zones in the Chicago Public School District 299 at the elementary level (left map), and high school level (right map). Each area is a school zone. School zones are shaded with the share of free and reduced lunch students. School attendance zone boundaries are from the School Attendance Boundary Survey (SABS) 2015-16. Free and reduced lunch statistics are from the National Center for Education Statistics.

Figure 2: **New York City Elementary School Zones**



Notes: These maps present different statistics for elementary school zones in New York City Geographic District #2. Each area is a school zone. The top left figure shows the share of free and reduced lunch students. The top right figure shows the share of white students. Per-pupil expenditures at each school are in the bottom left figure while the bottom right figure shows the share of students who score above proficient on standardized tests. School attendance zone boundaries are from the School Attendance Boundary Survey (SABS) 2015-16. Free and reduced lunch and race statistics are from the National Center for Education Statistics. Per-pupil expenditures are from the U.S. Department of Education. Standardized test scores are from the New York State Department of Education.

3 Model

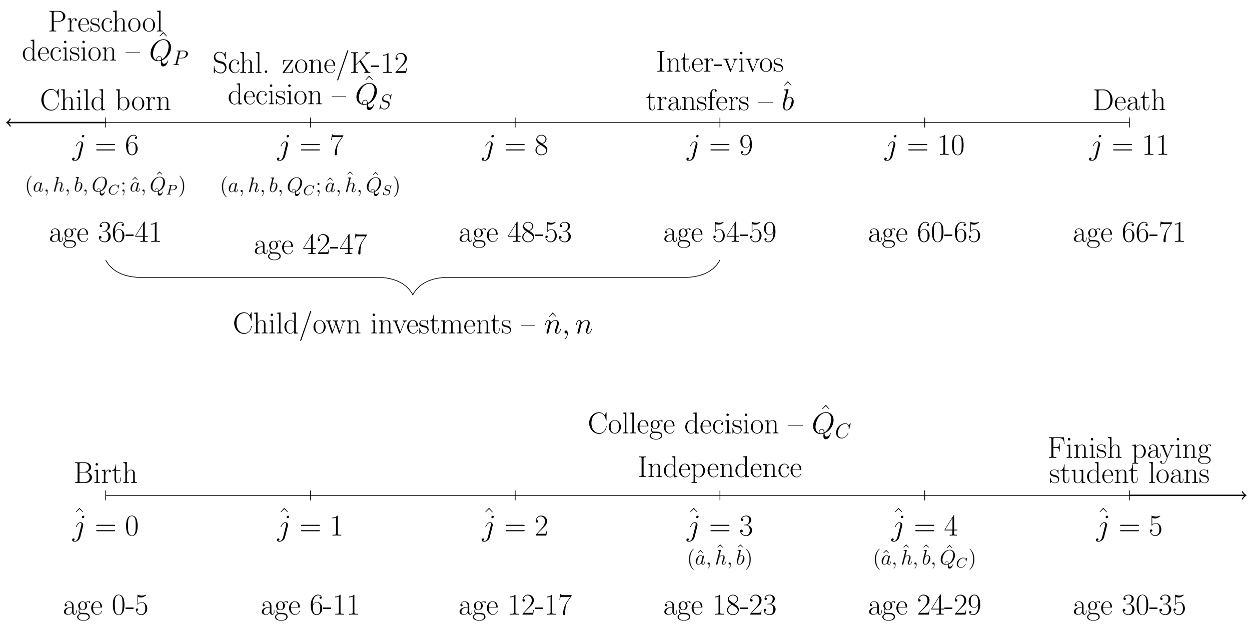
Time is discrete and has an infinite horizon. The economy is populated by a continuum of 11 overlapping generations with a uniform demographic structure. Agents are altruistic towards their children (Becker and Tomes, 1979; Becker and Barro, 1986) and dynasties are infinitely-lived. One model period represents six biological years and is denoted by j. Throughout, "hat" variables denote the next generation (i.e. the current generation's child) and "prime" variables will denote the next period in an agent's lifecycle. We occasionally use subscript j notation when "prime" notation would be otherwise unclear. *Figure 3* summarizes an agent's lifecycle.

A child is born in period $\hat{j} = 0$ with ability $\hat{a}$, stochastically inherited from their parent. For periods $\hat{j} = 0$ to $\hat{j} = 2$ children live with their parent and do not make independent decisions. The parent makes preschool $\hat{Q}_P$, school zone $\hat{Q}_S \in \{\hat{Q}_S^l, \hat{Q}_S^h\}$, and human capital investment $\hat{n}_j$ decisions for the child.

At the beginning of period $j = 3$ (biological age 19) the child becomes independent from their parent. In addition to ability a, the initial states for this adult include an endogenous level of human capital h, and inter-vivos transfers b. Upon independence, the agent chooses to attend college or not, and which quality of college to attend, $Q_C \in \{Q_C^l, Q_C^h\}$. If an agent attends college, they have access to government sponsored student loans. Otherwise, an agent may save but not borrow.

As an adult, agents are endowed with one unit of time in each period, which is divided between market work and human capital accumulation. Human capital determines labor market earnings and is subject to uninsurable idiosyncratic risk. For the remainder of the agent's lifecycle they supply labor, accumulate human capital (with and without children in the household) and solve a consumption-savings problem. At age $j = 11$ exogenous retirement/death is imposed. Only steady states are considered and so time scripts are omitted throughout.

Figure 3: **Lifecycle Timeline**



We assume that the period utility is valued by the CRRA function $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$. During periods $j = 6$ to $j = 8$ when the child is present in the household, period utility is maximized by solving a Pareto problem over child and parent consumption,

$$U(\tilde{c}_j) = \max \Big\{ u(c_j) + \theta u(\hat{c}_{j-6}) \Big\}$$

where $\tilde{c}_j$ is aggregate household consumption of parent and child, and θ represents altruistic motives of parents towards children. Given the CRRA form of period utility, we have:

$$U(\tilde{c}_j) = \xi u(\tilde{c}_j)$$

with $\xi \equiv (1 + \theta^{1/\gamma})^\gamma$ being interpreted as an adult consumption-equivalence.

3.1 Human Capital Development

In this section, we discuss details of human capital development for children, and then onwards into adulthood. We first introduce functional forms, and then describe the manner in which education affects human capital production at each stage.

3.1.1 Child Human Capital Production

The functional forms we use for child human capital production is similar to that of Lee and Seshadri (2019). At the beginning of period $j = 6$ each agent exogenously gives birth to one child, which begins its lifecycle in period $\hat{j} = 0$. Children differ by an initial ability $\hat{a}$ transmitted stochastically from the parent by some transition function $\mathcal{A}(a, \hat{a})$. The parent has complete information with respect to their child's ability, which remains a fixed state for the lifecycle.

From $\hat{j} = 0$ to $\hat{j} = 2$ the human capital of the child develops according to,

$$\hat{h}_{j+1} = \hat{a}\Big(\lambda_j \hat{n}_j^{\omega_j} + (1-\lambda_j)\hat{Q}_j^{\omega_j}\Big)^{1/\omega_j} + \hat{h}_j, \text{ where } \hat{h}_0 = 1 \tag{1}$$

where, $\hat{h}_{j+1}$ is the human capital stock in the next period, and $\hat{h}_j$ is current human capital. $\hat{Q}_j$ is school quality and $\hat{n}_j$ is the time investment adults make in their child. The parameters λ_j and ω_j capture the relative weights and complementarity between school quality and parental time investments. Throughout we refer to equation (1) as $g(\hat{h}, \hat{a}, \hat{n}, \hat{Q}_j)$.

Preschool – The parent begins period $j = 6$ by making a preschool enrollment decision. There is a single private preschool that has some exogenous quality $Q_0 = Q_P$ and cost t_P. Preschool quality affects how the child develops human capital during their first period. If the parent decides not to enroll the child in preschool they must spend $\hat{n}_0 = n_P$ of their time endowment investing in its human capital. The quality of no preschool is normalized to zero.

Elementary and Secondary School – At $j = 7$ the parent chooses a school zone $\hat{Q}_S \in \{\hat{Q}^l_S, \hat{Q}^h_S\}$. The school zone determines the school a child is sent to.[12] In order to live in a school zone parents must purchase one unit of housing at the equilibrium price P_S . Housing is supplied inelastically with measure $\mathcal{N}$ in school zone Q^h_S and $1 - \mathcal{N}$ in Q^l_S. Without loss of generality we assume that $P_{S^h} > P_{S^l}$ and normalize $P_{S^l} = 0$.

The quality of public elementary and secondary schools in each school zone S is given by,

$$Q_S = \bar{a}_S^{\alpha_S} \tag{2}$$

The term $\bar{a}_S$ is average ability of children living in school zone Q_S, and captures peer effects. In the baseline model, we do not allow agents to change schools between ages $j = 1$ and $j = 2$, and so Q_S is of a fixed level across both ages.

3.1.2 Adult Human Capital Production

Following Cunha et al. (2010), Del Boca et al. (2014b), and Lee and Seshadri (2019), at the beginning of the working phase of an agent's lifecycle a constant anchor ζ transforms children's human capital (proxied by test scores) to adult human capital (measured by labor earnings).

The adult human capital production function is,

$$h' = \epsilon'_m \Big(a \cdot (1 + Q_C) \cdot (nh)^\eta + (1 - \delta)h \Big) \tag{3}$$

where $n \in [0, 1]$ is time spent accumulating human capital, $\delta \in [0, 1]$ is period depreciation of human capital, ϵ'_m is a market luck shock, and $\eta \in (0, 1)$ is the elasticity of human capital production with respect to investment. The market luck shock is drawn from an i.i.d. ln-normal distribution with mean and variance μ_m and σ^2_m, respectively. Throughout we will use $h' = f(h, a, Q_C, n, \epsilon'_m)$ to denote equation (3). An agent's pre-tax labor market earnings

[12]This is in line with the main school assignment method in the United States.

in period j, are then given by $e_j = wh_j(1-n_j)$, where w is an exogenously given wage rate.

The non-standard addition to this Ben-Porath (1967) production function is Q_C, which represents college quality. Q_C is normalized to zero for agents who do not attend college. Chetty et al. (2020b) find that (controlling for observable characteristics) earnings levels and growth rates vary significantly across college qualities. Motivated by this finding, we model college quality as some factor which alters the growth of human capital over the agent's lifecycle. This is a similar modeling assumption to Leukhina et al. (2021) and Brotherhood et al. (2023).

College – Agents begin making their own decisions at the beginning of period $j = 3$ (biological age 19). Initial heterogeneity is with respect to ability a, human capital h, and parental inter-vivo transfers, b.

Upon becoming independent, agents must first decide whether or not to apply to college. There are two colleges in the economy, $Q_C \in \{Q_C^l, Q_C^h\}$. Each college charges an exogenous tuition price $\bar{r}_C$. We assume that $\bar{r}_{C^l} < \bar{r}_{C^h}$. There is a measure $\mathcal{C}$ spots available at Q_C^h and no constraint on the number of spots offered at Q_C^l. The selective college observes a noisy signal of an agent's admission score z, and sets the highest possible value of $\bar{z}$ to fill available spots. Following Brotherhood et al. (2023), admission scores are formed by combining innate ability and human capital,

$$z = \ln(ah^{\nu}) + \sigma_z \epsilon_z, \tag{4}$$

where ϵ_z is i.i.d standard normal and σ_z is a parameter governing noisiness of the admissions process. ν is the elasticity of admissions scores with respect to human capital investments made by parents prior to the agent's independence.

The probability that an agent with human capital h, and ability a, is admitted to college is given by,

$$p(z) = 1 - \Phi\Big(\frac{\bar{z} - z}{\sigma_z}\Big) \tag{5}$$

where $\Phi(\cdot)$ is the cumulative distribution function for the standard normal distribution.

Given the admission cutoff and tuition price, college quality is determined by,

$$Q_C = (\bar{r}_C)^{\alpha_C} (\bar{a}_C)^{1-\alpha_C} \tag{6}$$

where the term $\bar{a}_C$ is average ability of the student body. $\bar{r}_C$ is average expenditures per-student generated from tuition revenues. The elasticity of school quality with respect to expenditures per pupil is given by α_C.

Expenditures per student follows the exogenous tuition schedule,

$$\bar{r}_C = \frac{1}{n_C} \sum_{k=1}^{n_C} \{t(Q_C) - g(b_k, Q_C) - s(a_k) + f\} \tag{7}$$

where $t(Q_C)$ is the sticker tuition price for each college quality, $g(Q_C, b)$ is all needs-based (non-repayable) financial aid by an agent's wealth level and quality of college, $s(a)$ is a merit-based scholarships by the agent's ability, and f is a fixed cost of attending college. n_C is the number of students attending college of quality Q_C.

If an agent decides to attend college, they are given a government sponsored student loan of size $D(Q_C, b) = \min\{t(Q_C) - g(Q_C, b), \bar{D}\}$. While not all university attendees take on full student loans, we make this assumption in order to simplify computations, as in Matsuda and Mazur (2022). The modeling of student loans is designed to represent the current U.S. income-contingent college loan plan.

The interest rate on student loans is given by, $\bar{r} = r + \iota$, where ι is the premium paid on student loans above the market rate. Interest does not begin to accrue until after college, and repayments are made for two periods beginning in $j = 4$. Repayments depend on the loan size and an agent's current income level. No repayments are made for individuals with income below some threshold, $\hat{y}$. Agents with income above $\hat{y}$ make repayments proportional to a factor χ of their income. Proportional repayments are made up to the level $\bar{L}(D)$, at which point they make fixed repayments of size $\bar{L}(D)$. Fixed repayments are given by,

$$\bar{L}(D) = \begin{cases} D\left(\bar{r}\frac{(1+\bar{r})^2}{(1+\bar{r})^2-1}\right) & \text{if } 4 \leq j \leq 5 \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

and hence the loan repayment schedule is given by,

$$\bar{L}(D, y) = \begin{cases} \min\{\chi \cdot \max\{0, y - \hat{y}\}, \bar{L}(D)\} & \text{if } 4 \leq j \leq 5 \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

Fixed repayments are such that their present value over three periods equals the present value of student debt, inclusive of interest. If the student loan is not fully repaid within the two periods; it is assumed that the remainder is paid by the government. The repayment length of twelve years is in line with the standard 10-year federal student loans.

3.2 Recursive Decision Problems

All discrete school and college decisions made by agents in the model are subject to preference shocks. These shocks are distributed according to the Type I Extreme Value distribution.

3.2.1 Independence from Parent, $j = 3$

Agents become independent and begin making decisions at the beginning of period $j = 3$ (biological age 19). The states are, ability level a, human capital h, and inter-vivos transfers b. The first decision is whether or not to apply to college,

$$\max\left\{V^{not\ apply}(j = 3, a, b, h), V^{apply}(j = 3, a, b, h)\right\} \tag{10}$$

If the agent does not apply to college they immediately enter the workforce. This problem is given by equation (12). Contingent on being admitted, the agent chooses, consumption c, assets b', and college quality $Q_C \in \{Q_C^l, Q_C^h\}$ to solve,

$$V^{admitted}(j=3,a,b,h) = \max_{c,b',Q_C} \left\{ u(c) + \beta \mathbb{E}_{\epsilon_m} \left[V(j=4, Q_C > 0, a, b', h') \right] \right\}$$

$$\text{subject to,} \tag{11}$$

$$c + b' + \bar{r}_C = b + D(Q_C, b)$$

$$Q_C \in \{Q_C^l, Q_C^h\}$$

$$h' = f(h, a, Q_C, 1, \epsilon_m')$$

$$b' \geq 0$$

An agent who attends college is assumed to have chosen $n = 1$, which implies they cannot work while in college. They enter period $j = 4$ with the human capital level of setting $n = 1$ in equation (3).

Notice that agents use loan amount $D(Q_C, b)$ and initial wealth b to pay for college expenses while in college. This is an important assumption since agents do not have access to private borrowing. Needing to immediately pay for college in full prevents agents from attending college to gain access to borrowing and smooth consumption over their lifecycle. An agent who applied to college but is not admitted decides between attending the low-quality college Q_C^l or immediately entering the workforce.

3.2.2 Pre-child Working, $j = 3, 4, 5$

The problem of an agent who decides not to attend (or apply to) college, or an agent who has attended college but has not yet given birth to a child is given by the standard consumption saving problem with endogenous human capital accumulation. The agent chooses consumption c, human capital investment n, and savings b', to solve,

$$
\begin{aligned}
V(j, Q_C, a, b, h) = \max_{c,n,b'} &\Big\{ u(c) + \beta \mathbb{E}_{\epsilon_m} \big[V(j+1, Q_C, a, b', h') \big] \Big\} \\
\text{subject to,} & \\
& c + b' + L(D, y) = y(e, b) + b \\
& e = wh(1-n) \\
& h' = f(h, a, Q_C, n, \epsilon'_m) \\
& n \in [0, 1] \\
& b' \geq 0
\end{aligned}
\tag{12}
$$

Where, $L(D, y) = 0$ if the agent did not attend college. $y(e, b)$ is after-tax income. That is, defining $y = e + rb$ and for some arbitrary tax function $\tau(y)$, after tax income is given by,

$$
y(e, b) = \big(1 - \tau(y)\big) y \tag{13}
$$

For brevity we are suppressing an explicit formulation of the period $j = 5$ problem where agents will form expectations over the ability of their child to be born in the following period.

3.2.3 Child in Household

At $j = 6$ a child is born into each household. Then, at $j = 8$, the child graduates secondary school and receives independence from the parent.

Preschool, $j = 6$ – A parent with own states (Q_C, a, b, h) and child of ability $\hat{a}$ first makes the preschool enrollment decision,

$$
\max \Big\{ \underbrace{V(j = 6, Q_C, a, b, h; \hat{a}, 0)}_{\text{No Preschool}}, \underbrace{V(j = 6, Q_C, a, b, h; \hat{a}, \hat{Q}_P)}_{\text{Preschool}} \Big\} \tag{14}
$$

The agent then chooses consumption c, own human capital investment n, savings b', and child human capital investment $\hat{n}$ which solves,

$$V(j=6, Q_C, a, b, h; \hat{a}, \hat{Q}_P) = \max_{c,n,b',\hat{n}} \Big\{ U(\tilde{c}) + \beta \mathbb{E}_{\epsilon_m} \big[V(j+1, Q_C, a, b', h'; \hat{a}, \hat{h}, \hat{Q}_S) \big] \Big\}$$

$$\text{subject to,} \tag{15}$$

$$c + b' + \mathbb{1}\{\hat{Q}_P \neq 0\} t_P = y(e, b) + b$$

$$e = wh(1 - n - \hat{n})$$

$$h' = f(h, a, Q_C, n, \epsilon'_m)$$

$$\hat{h}' = g_0(\hat{a}, \hat{n}, \hat{Q}_P)$$

$$n \in [0,1], \quad \hat{n} \in [0, 1-n]$$

$$b' \geq 0$$

Elementary and Secondary School, $j = 7, 8$ – At the beginning of $j = 7$ ($\hat{j} = 1$) the agent chooses a school zone $\{Q_S^l, Q_S^h\}$ (that determines the elementary and secondary school quality of the child), by solving,

$$\max \Big\{ V(j, Q_C, a, b, h; \hat{a}, \hat{h}, \hat{Q}_S^l), V(j, Q_C, a, b, h; \hat{a}, \hat{h}, \hat{Q}_S^h) \Big\} \tag{16}$$

The agent now chooses consumption c, own human capital investment n, savings b', and child human capital investment $\hat{n}$, which solve,

$$
\begin{aligned}
V(j, Q_C, a, b, h; \hat{a}, \hat{h}, \hat{Q}_S) = \max_{c,n,b',\hat{n}} & \Big\{ U(\tilde{c}) + \beta \mathbb{E}_{\epsilon_m} \big[V(j+1, Q_C, a, b', h'; \hat{a}, \hat{h}, \hat{Q}_S) \big] \Big\} \\
\text{subject to,} & \qquad\qquad (17) \\
& c + b' + P_S = y(e, b) + b \\
& e = wh(1 - n - \hat{n}) \\
& h' = f(h, a, Q_C, n, \epsilon'_m) \\
& \hat{h}' = g(\hat{h}, \hat{a}, \hat{n}, \hat{Q}_S) \\
& n \in [0, 1], \quad \hat{n} \in [0, 1 - n] \\
& b' \geq 0
\end{aligned}
$$

Child Independence, $j = 9$ – At the beginning of period $j = 9$ ($\hat{j} = 3$) the agent's child becomes independent. The agent now chooses consumption c, human capital investment n, savings b', and an inter-vivos transfer $\hat{b}$, in order to solve,

$$
\begin{aligned}
V(j = 9, Q_C, a, b, h; \hat{a}, \hat{h}) = \max_{c,n,b',\hat{b}} & \Big\{ u(c) + \beta \mathbb{E}_{\epsilon_m} \big[V(j = 10, Q_C, a, b', h') \big] \\
& + \theta \mathbb{E}_{\epsilon_m, \epsilon_z} \big[\max \big\{ V^{not\ apply}(\hat{j} = 3, \hat{a}, \hat{b}, \hat{h}), V^{apply}(\hat{j} = 3, \hat{a}, \hat{b}, \hat{h}) \big\} \big] \Big\} \\
\text{subject to,} & \qquad\qquad (18) \\
& c + b' + \hat{b} = y(e, b) + b \\
& e = wh(1 - n) \\
& h' = f(h, a, Q_C, n, \epsilon'_m) \\
& n \in [0, 1] \\
& b', \hat{b} \geq 0
\end{aligned}
$$

The intergenerational transfer, $\hat{b}$ is subject to a non-negativity constraint, meaning that parents cannot borrow against their child's future income. Parents make the transfer before any uncertainty faced by the child at the start of period $\hat{j} = 3$ is realized.

3.2.4 Post-child Working, $j = 10, 11$

During periods $j = 10$ and $j = 11$ the individual's problem solved is identical to the problem defined by equation (12) with the exception of no term $L(y, d)$, as student loans are no longer being repaid. The terminal condition is given by $V(j = 11, Q_C, a, b, h) = 0$.

3.3 Government

Government revenues consist of tax proceeds and student loan repayments. The government levies taxes on labor earnings and returns to household savings using the tax function $\tau(y)$. Government expenditures consist of student loan disbursements, and expenditures on college. We assume that some government consumption G ensures a balanced budget in each period. Government consumption provides no utility to the household.

3.4 Equilibrium

Let $\mathbf{x}_j$ denote the state space of an adult in period j, $\mathbf{X} = [\mathbf{x}_3, ..., \mathbf{x}_{11}]$ the aggregate state space, and $\Lambda(\mathbf{X})$ its distribution.

A stationary recursive competitive equilibrium is a set of value and policy functions, house prices $\{P_S^l, P_S^h\}$, college admissions score cutoff $\bar{z}$, and distribution $\Lambda(\mathbf{X})$, such that, *(i)* households optimize, *(ii)* housing markets clear and school qualities are consistent, *(iii)* admissions markets clear and college qualities are consistent, and *(iv)* the distribution over the state space is stationary.

3.4.1 Equilibrium Selection

Given the presence of peer effects, multiple equilibria may arise in this model. At the college level we follow Epple et al. (2017) and Hendricks et al. (2021) and consider what are referred to as "hierarchical adherence" equilibria, which require that college quality follows tuition cost rankings $t(Q_C)$. Computationally, we find that a unique equilibrium exists in the relevant parameter region. At the K-12 level we again follow the literature (Aliprantis and Carroll, 2018; Fogli and Guerrieri, 2019; Zheng and Graham, 2022) and focus on the empirically relevant equilibrium where both school zones have positive populations.

3.5 Sources of Inefficiency

In this section we briefly discuss the four main sources of market inefficiency in our model. While the current version of this paper does not undertake a full welfare analysis, these inefficiencies suggest room for government intervention to increase aggregate welfare.

First, markets are incomplete. It is a standard result that borrowing constraints prevent agents who suffer adverse income shocks from smoothing consumption over their lifecycle. Additionally, borrowing constraints have implications for models featuring preschool, school zone, and college decisions. Agents would otherwise make different optimal decisions with respect to education decisions without the presence of financial constraints. That is, agents may choose lower quality education when experiencing negative earnings shocks. Borrowing constraints also affect the optimal time investments a parent may choose to make in their child. Finally, given borrowing constraints and the uninsurable shocks to human capital accumulation, agents will under-invest in adult human capital.

Second, and similar to the first inefficiency, parents may not borrow against their child's future income. This means that consumption cannot be smoothed across generations. In the context of our model, children cannot use their own (higher) later life earnings to compensate the parents for preschool, elementary school, or time investments. This causes parents to under-invest in their children both in time and monetary investments.

Third, noisy college admission scores interact with borrowing constraints. From the policy functions for problems (15) and (17), parental time investment in children is an increasing function of parental income. Therefore, for two college applicants with identical admissions scores, but different income levels, it must be that the lower-income student has higher ability. This has two effects: (1) these students' future income will differ and (2) their effect on college quality will differ. Both imply that the college admission process is inefficient.

Fourth, externalities exist at both the school zone and college level in our model. Individuals do not internalize the impact they have on elementary or college education quality. This arises in our model due to the presence of peer effects.

4 Calibration

In this section we describe our internal and external identification strategies. Externally calibrated parameters are taken directly from the data or literature. Internally calibrated parameters are determined using the simulated method of moments (SMM) approach to find 17 parameters which minimize the distance between 30 moments, simulated by the model and empirical counterparts. While SMM estimates all internal parameters jointly, we discuss which moments are most affected by each parameter.

All monetary values are reported as a fraction of real mean household income, from the 2015 American Community Survey (ACS). *Table 3* summarizes the parameters set externally and *Table 4* lists the parameters estimated internally.

4.1 Preferences

A time period in the model is six years. The annual discount factor is given by $\beta = {}^{1}/_{1.02}$, where the average risk-free rate in 2019 is 0.02. The wage rate w is normalized to 1.0. The relative risk aversion γ is set to 1.0, which implies $u(c) = \ln(c)$.

The altruism parameter, θ, is internally calibrated to match an aggregate share of transfers to net worth of 1.26 from the Survey of Consumer Finances (Feiveson and Sabelhaus, 2018). A higher value of θ increases the weight of a child's continuation value in its parent's value function and thus increases the incentive for parents to transfer wealth to their child.

4.2 Adult Human Capital

In this section we describe parameters governing the manner in which adults accumulate human capital. There is some overlap with child human capital accumulation, which will be discussed below in *Section 4.3*.

4.2.1 Production

Depreciation of human capital is taken to be 1.5% which is standard in the literature. Weber (2014) reviews the literature and finds a value in the range of 0.5% to 4.5%. We set the elasticity of investment in the human capital production function, η, to 0.5. Estimates of this parameter are reviewed in Browning et al. (1999) and range from 0.5 to 0.9. The value is chosen to be at the lower end of this range, as 0.5 is standard in more recent literature and similar models (see for instance Lee and Seshadri (2019)).

4.2.2 Earnings Volatility

The mean of the market luck shocks is set to zero. We follow Lee and Seshadri (2019) when estimating the variance of market luck shocks σ_{ϵ_m}. Their method relies on the fact that in Ben-Porath models, agents cease investing time accumulating human capital near the end of the lifecycle. Given that market luck shocks are i.i.d., we can estimate σ_{ϵ_m} by simply calculating the variance of old age ($j = 10$ and $j = 11$) household labor earnings using our PSID sample. This produces an estimated σ_{ϵ_m} of 0.17.

4.2.3 Earnings Taxation

Following Guvenen et al. (2014) and Herrington (2015) we estimated tax functions using data from the Organization for Economic Co-operation and Development (OECD). The data includes central and local government taxes, family tax benefits, and social security tax contributions, levied on income. The data is comparable across countries and publicly

Table 1: **Estimated Tax Function Parameters**

Parameter	Value
a_0	0.623
	(0.010)
a_1	-0.005
	(0.0003)
a_2	-0.516
	(0.010)
ϕ	-0.448
	(0.010)
R^2	0.998

Notes: This table reports the regressions results of equation (13). P-values are reported in brackets.

available. The net average tax function is estimated using the form,

$$\tau({}^{y}/_{AW}) = a_0 + a_1({}^{y}/_{AW}) + a_2({}^{y}/_{AW})^{\phi} \tag{19}$$

where AW denotes average earnings for the given country. Our estimated tax functions are reported in *Table 1*. We bound the tax function from below at -0.1 to ensure that some agents do not receive arbitrarily large transfers from the government.

4.2.4 Ability Transmission

We assume that the transmission of ability across generations, given by the function $\mathcal{A}(a, \hat{a})$, is a first-order auto-regressive process (AR(1)),

$$\ln(\hat{a}_i) = \rho_a \ln(a_i) + \epsilon_i^a \tag{20}$$

where $\hat{a}_i$ and a_i denote the ability of child and parent in family i, ρ_a determines the persistency of ability across generations, and $\epsilon_i^a \sim N(a, \sigma_a^2)$. ρ_a and σ_a^2 are calibrated internally.

ρ_a and σ_a affect the intergenerational elasticity of income of 0.34 (Chetty et al., 2014) and the Gini coefficient of income inequality (OECD, 2024), respectively. In the model, the intergenerational elasticity of income is the slope coefficient from a regression with the log of child income (age $j = 5$) on log of parental income (age $j = 8$). The Gini is taken for adults at ages $j = 4 - 11$.

4.2.5 Colleges

Student Loans – We set our repayment length to two periods as the statutory repayment length of student loans under Fixed Repayments is ten years in the United States. Following Matsuda and Mazur (2022) we set the student loan premium, ι, as 0.02. We do not allow agents to default on student loans.

There are several types of income-contingent loans (ICLs) in the United States, all with slightly different income repayment options. The plan modeled here is Pay-As-You-Earn (PAYE), which is the most common ICL. Under PAYE, agents making less than 150% of the federal poverty level make no repayments. This means that $\hat{y}$ is set to \$18,060. Someone making an excess of $\hat{y}$ pays 10% of discretionary income, i.e. $\chi = 0.1$.[13]

Loan limits are either: (1) total cost of attending college less expected financial contribution, or (2) the federal undergraduate loan limit of \$57,500. Together, these two components define the function governing loan levels, $D(Q_C, b) = \min\{t(Q_C) - g(Q_C, b), \bar{D}\}$.

Qualities – We must map our two college qualities in the model to the many colleges in the data. We use information from two sources, the College Mobility Report Card from Opportunity Insights (Chetty et al., 2020a) and the 2016 Undergraduates Survey from the National Post-Secondary Student Aid Study (NSPAS). In both sources there is a variable that describes the "selectivity" of each college. In Chetty et al. (2020a) we group colleges with the "Tier" variable valued at "Ivy Plus", "Highly selective private" ,"Highly selective

[13]Discretionary income is defined as after-tax income in excess of $\hat{y}$.

public","Other elite schools (public and private)" into Q_C^h, and the remaining 4 and 2-year colleges as Q_C^l.[14] In the NPSAS we group the colleges labeled as "Very Selective" into Q_C^h. From both sources, our Q_C^h college is composed of roughly nine percent of all college students.

College quality in the model is a function of the average ability of the student body and per-pupil expenditure. The parameter governing this function is the elasticity of school quality with respect to per-pupil expenditure, α_C. α_C moves the difference in earnings growth and earnings level for those who attend the high-quality versus the low-quality college. This moment is calculated in the data by taking the ratio of earnings for those who went to a certain college quality and are 30-35 versus those who are 24-29 (Chetty et al., 2020a). Note that Chetty et al., 2020a measure earnings at the same point in time so wage growths are obtained from separate cohorts.

Tuition Schedules – The function $t(Q_C)$ is calculated by taking the average sticker tuition price in 2013, weighted by college enrollment for each college group (Chetty et al., 2020a). Next, $g(b, Q_C)$ is set by computing the average needs-based grants from all sources across our two levels of Q_C and four income quartiles. In the NPSAS, income quartiles are classified for all students within the same dependency status (whether students depend financially on their parents' income or not).[15] Lastly, the merit-based grant, $s(a, Q_C)$, is set by calculating the average merit grant awarded by three ranges of SAT scores (400-800,801-1200,1201-1600) and by college quality Q_C, again using the NPSAS. All functions are near linear and are linearized using endpoint values.

Admissions – Q_C^h college enrolls nine percent of all college-going students, or 3.7 percent of the economy. Having Q_C^h represent these elite and highly selective colleges lines up with our

[14] We do not include institutions that provide less than 2-year degrees.

[15] Ideally, we would use wealth quartiles to line up with the model, but the NPSAS only reports income quartiles.

assumption that Q_C^h has a fixed supply of seats (Blair and Smetters, 2021).[16] In equilibrium, we solve for $\bar{z}$ so that college markets clear for Q_C^h. To represent the many "open-admissions" colleges, we do not set a capacity constraint at the low-quality college Q_C^l. However, we do match the total share of agents in college in 2016 at 0.45.[17]

Admissions are governed by two additional parameters which we internally calibrate. ν, the elasticity of admission scores with respect to human capital, and σ_z, the noisiness of the admission score. As in Brotherhood et al. (2023), ν moves the percentage of low-income people (calculated from Chetty et al., 2020a) in the high-quality college. σ_z also affects sorting and together with ν we target the parental income distribution across each college type.

Preference Shocks – In the model, preference shocks across college attendance and type of college affect the sorting into the post-secondary school options. We discipline the preference shocks using the share of individuals from different income quintiles in each college type (Chetty et al., 2020a).

4.3 Child Human Capital Development

We use the Panel Study of Income Dynamics (PSID), a longitudinal dataset tracking families since 1968, to discipline child human capital production. Our sample of interest consists of children who participated in the 1997, 2002, 2007, 2014, and 2019 Child Development Supplement (CDS) studies. The CDS gathered information on child care arrangements, school attended, child cognitive skills, and parental time investment in children. The study complements information in the main PSID study on parental income and hours worked. We follow Lee and Seshadri (2019) in cleaning and preparing the PSID sample. Furthermore, we

[16]Blair and Smetters, 2021 shows that elite colleges have increased their supply very little over the past decades.

[17]Since we do not consider dropouts in our model, this is also the share of people who graduated college in 2016. To get the total share in the economy, we take the college enrollment rate of 0.697 from the Bureau of Labor Statistics and multiply it by the graduation rate of 0.64 in 2016 from the National Center for Education Statistics.

must restrict our sample to those that have school identifiers. In all, we end up with 3,202 child-year observations. See *Appendix A* for details and sample summary statistics.

4.3.1 Time Investment

The CDS contains twenty-four hour time diaries that track child activities. Additionally, these diaries collect information on whether a parent was actively participating during the activity ("active investment") or if they were simply present ("passive investment)".[18] We focus on active hours invested per week, in addition to the opportunity cost of these hours, using hourly parental wages (Lee and Seshadri, 2019).

4.3.2 Human Capital

The CDS assesses child cognitive skills through Letter-Word questions. There are fifty-seven questions, which increase in difficulty and are each given a score of zero or one. We follow the methodology in Lee and Seshadri (2019) and adjust raw scores by difficulty to ensure that they are comparable over time. We also normalize scores to a scale of 100. We call these adjusted scores human capital in our model.

4.3.3 Preschool

The cost of preschool, t_P, is externally set as the population-weighted average of median preschool cost across counties from the National Database of Childcare Prices (US Dept of Labor 2016-2018). We assume if a parent does not send their child to preschool they must spend the equivalent of a full-time 40 hour work week caring for the child. This implies that $n_P = 0.24$.

We have three parameters governing human capital accumulation while of preschool age, which we internally calibrate to jointly match three moments from the data. The parameters are, the quality of preschool Q_P, and λ_0 and ω_0, the CES parameters for the first period of

[18]This activity classification follows Del Boca et al. (2014b) and Lee and Seshadri (2019).

human capital development.

The first moment we match is the share of children under five who are in some form of center-based care in 2019, using the National Center for Education Statistics. The higher the value of Q_P, and the lower the value of λ_0 and ω_0, the more parents will find it worthwhile to pay the cost of preschool. Our second moment, which these three parameters sharply affect, is the level of parental time investment made for children aged 0-5 ($j = 1$). For our third moment, we use the PSID sample and run an indirect inference exercise.

The 1997 and 2002 CDS waves collect information as to whether a child has ever been enrolled in preschool, up until the interview time. The 2007 and 2014 CDS ask the primary caregiver if preschool was the most often used child care arrangement in the last four weeks.[19] For each child in our sample of interest, we create an indicator variable that equals one if a child was ever in preschool up until the age of five. We use this variable to compare outcomes of children in elementary school who were in preschool versus those who were not.

We then run a regression which estimates the association between preschool attendance and child human capital upon entering elementary school. Using a subsample of children who have just entered elementary school (ages 5-7), we estimate the following regression,

$$h_c = \alpha_0 + \alpha_1 Preschool + \epsilon, \tag{21}$$

where h_c is the human capital of the child and $Preschool$ is the indicator variable that equals one if a child was ever in preschool up until the age of five.

We find a coefficient of 2.16 indicating that on average, children who attend preschool have 2.16 percentage points higher human capital than those who do not. We run a comparable regression in the model using children in $j = 1$.

[19] The 2007 CDS asks about daycare, not preschool.

4.3.4 Elementary School

Qualities – The restricted version of the PSID allows us to identify the school attended by the child through the National Center for Education Statistics school identifier. Next, we merge in information on school quality. While there is publicly available information on average test scores by schools, these test scores are not comparable across states due to different testing standards. Instead, we use the only comparable metric of school test scores nationwide from the Stanford Education Data Archive (SEDA). This metric is constructed using the National Assessment of Educational Progress (NAEP), a nationwide standardized exam, to correct for different testing standards across states. School level data is available as an average across 2009 to 2019.[20] To map the schools in the data to our model, we rank schools according to their average test score and group them into the top quintile (which we map to school Q_S^h in the model) and the bottom four quintiles (which represent school Q_S^l). In the model equilibrium we solve for the neighborhood price, P_S, which ensures that housing markets clear.

We have four parameters at the elementary school level which we internally calibrate. First, ζ, the anchor of child human capital to earnings, and the two parameters in the CES child human capital function, λ_1 and ω_1[21] discipline average parental investment by age, and ratios of parental income, time investment, and child human capital across elementary school qualities.

Next, we internally calibrate α_S, the curvature of elementary school quality. A larger value of α_S will create starker sorting patterns in the model and magnify the importance of peer effects. More importantly however, it directly affects the productivity (and hence growth rate) for which child human capital is produced. We pin down α_S using indirect inference. To do so, we estimate the relationship between human capital growth across

[20]Note that the SEDA test score data is primarily available for elementary and middle school levels, and so our merge is based on the school quality of a child's elementary or middle school.

[21]We assume that the CES parameters in $j = 1$ are the same as in $j = 2$.

$j = 1$ and $j = 2$, and the school attended in $j = 1$. The sample here is those from the PSID for which we have test scores at $j = 1$ and $j = 2$, which is just under a third of our overall sample. We control for parental time investment at $j = 1$, lagged test scores at $j = 1$, and the age difference in years between the two test observations. We run the following regression,

$$\Delta \log(test) = \beta_0 + \beta_1 Q_S^h + \beta_2 \log test_{j=1} + \beta_3 time + \beta_4 \Delta age + \epsilon \tag{22}$$

Table 2 presents the results from the above regression. We find that the coefficient on Q_S^h is 0.046 and significant at the 5% level. Controlling for ability (proxied by lagged test scores) and time investment, children in Q_S^h have test scores that grow 4.6% faster than those in Q_S^l. We run the same regression in the model.

Preference Shocks – In the model, preference shocks across elementary quality attendance affect the income sorting into qualities. We discipline the preference shocks using the share of individuals from different income quintiles for each elementary quality, from the PSID.

4.4 Model Fit

We report a summary of model fit in *Table 5*. Our model exactly matches moments on income inequality (Gini and standard deviation of earnings) as well as the intergenerational income elasticity. We slightly understate the share of transfers to net worth: our model generates 1.09 while it is 1.26 in the data (Feiveson and Sabelhaus, 2018).

Our model is able to closely generate the average household income ratio across school zones, as well as the ratio in active time investment. Our test score ratio is slightly higher (1.15) than in the data (1.11). We underestimate the average time investment for ages 6-11 (0.05 in the model and 0.09 in the data). However, we do well matching average time investment overall, 0.09. In addition, we match the effect of school quality on test score

Table 2: **Effect of School Quality on Human Capital Growth**

Variable	**Coefficient**
Q_S^h	0.0461
	(0.0145)
$\log test_{j=1}$	-0.730
	(0.0152)
$time$	0.000531
	(0.00029)
Δage	0.0758
	(0.009)
$Intercept$	2.73
	(0.093)
Number obvs.	805
Adjusted R^2	0.85

Notes: This table presents coefficient estimates from equation (22). The dependent variable is the logged difference in test scores for individuals from age $j = 1$ to $j = 2$. Q_S^h is an indicator for if the individual was in a high-quality school zone during $j = 1$. $\log test_{j=1}$ is the logged test score of the individual at $j = 1$. $time$ is active time investment at $j = 1$ and Δage is the difference in ages in years for when the two test scores were observed. Standard errors are in parentheses.

growth. Our indirect inference exercise gives us an estimate of 0.057, whereas it is 0.046 in the data. Our model also fits moments at the college level. 43% of our agents attain college compared to 45% in the data. We are also able to accurately match the earnings growth and levels by college quality.

Figure 4 plots sorting across elementary school quality by parental income quintiles, for both the model and the data. Blue (red) bars are for the low- (high)-school quality. The model does well in generating the observed patterns in the data, though sorting is starker in the model. We underestimate the share of families from the bottom quintile in the high-quality school zone and over-estimate the share of families from the top quintile there. *Figure 5* plots the corresponding figure for college qualities showing the proportion of the student body by parents of a given income level. Our model has more trouble matching the distribution of family income by college. For instance, there are very few people from the bottom two income quintiles in any college. A potential way of remedying this is to have taste shocks (or psychic costs) for college that are correlated across generations (Lee and Seshadri, 2019).

5 Policy Experiments

We use our model to assess the effects of education policies at four different stages: preschool, elementary, secondary, and college. Our model allows us to study the general equilibrium effects of these policies and how they interact with each other. Below we outline each policy and how it is implemented in the model.

Income Affirmative Action at College – We consider a permanent income-based affirmative action policy that gives students from low-income families an increased probability of attending the high-quality college. Children from families with below-median income receive extra bonus points when calculating their admission score. This is equivalent to a policy

Table 3: **Externally Calibrated Parameters**

Parameter	**Description**	**Value**	**Source**
(a) Preferences			
J	Model periods	11	Biological life, 0-72
β	Discount factor	0.98	Risk free rate, 0.02
σ	Relative risk aversion	1.0	Ln utility
(b) Prices			
r	Risk free rate	0.02	Risk free rate, 2019
ι	Student loan premium	0.02	Standard loan
w	Wage rate	1.0	Normalization
(c) Preschool			
t_p	Cost of preschool	0.18	NDCP
n_p	Time investment, no-preschool	0.24	Full-time care
(d) Tuition			
$t(q_l)$	Sticker tuition low-Q college	0.11	NPSAS
$t(q_h)$	Sticker tuition high-Q college	0.31	NPSAS
$g(\bar{b}, q_l)$	Needs aid, top quartile, & low-Q	0.07	NPSAS
$g(\underline{b}, q_l)$	Needs aid, bottom quartile, & low-Q	0.01	NPSAS
$g(\bar{b}, q_h)$	Needs aid, top quartile, & high-Q	0.19	NPSAS
$g(\underline{b}, q_h)$	Needs aid, bottom quartile, & high-Q	0.04	NPSAS
$s(\bar{a})$	Merit aid by college quality	0.06	NPSAS
$s(\underline{a})$	Merit aid by college quality	0.01	NPSAS
f	Fixed cost of attending college	0.10	Belley et al. (2014)
(e) Student Loans			
$\hat{y}$	No repayment threshold	0.35	PAYE terms
χ	Proportional repayment	0.10	PAYE terms
$\bar{D}$	Federal student loan limit	0.28	PAYE terms
(f) Adult Human capital			
δ	Depreciation	0.015	Weber (2014)
η	Production elasticity	0.55	Browning et al. (1999)

Notes: This table gives model parameters, a brief description of their role, the externally calibrated value, and the source. All monetary values are expressed as a proportion of average income.

Figure 4: **Share of Students Attending a K-12 Quality by Parental Income Ranks**

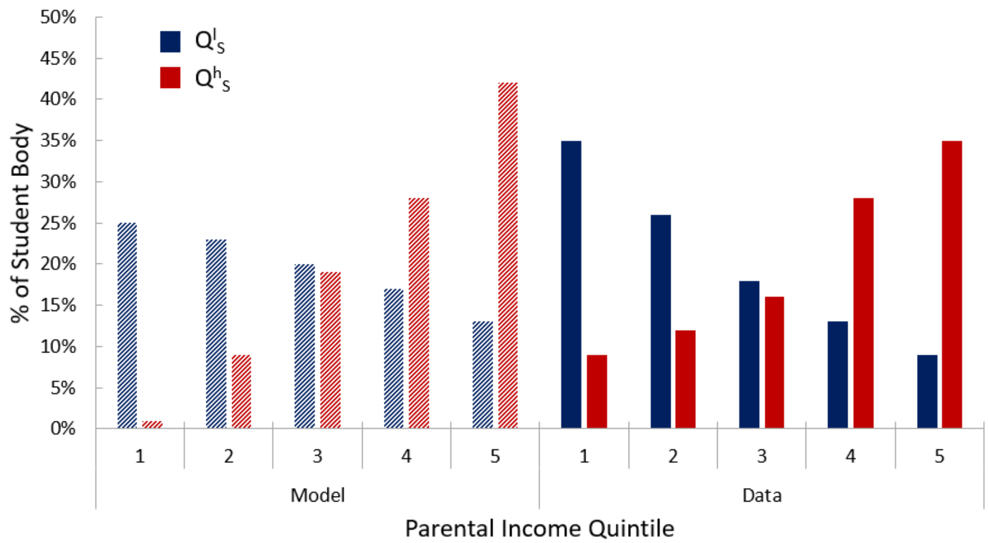


Figure 5: **Share of Students Attending a College Quality by Parental Income Ranks**

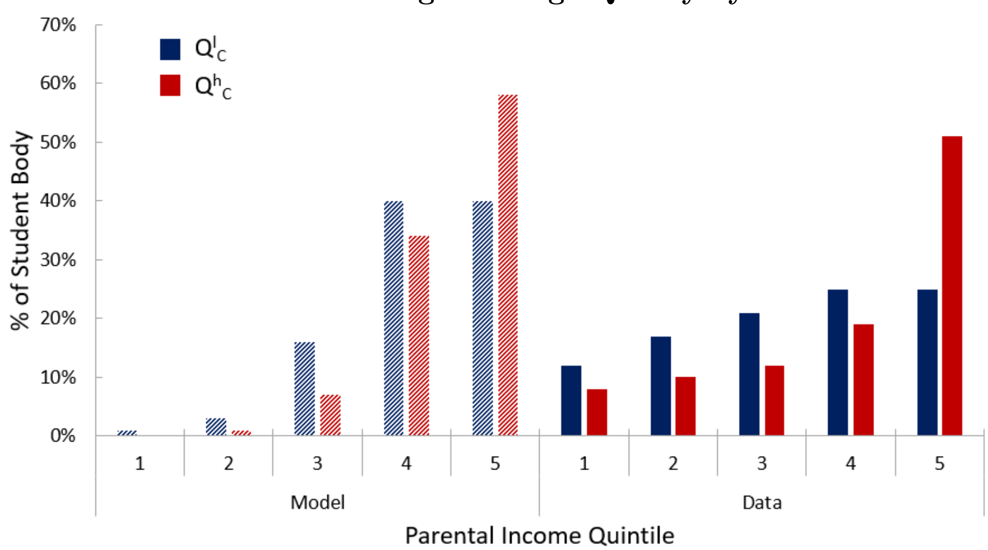


Table 4: **Internally Calibrated Parameters**

Parameter	Value	Description
θ	0.32	Parental Altruism
ρ_a	0.45	Persistence of abilities
σ_a	0.325	Variance of abilities
σ_ϵ	0.065	Variance of market luck shocks
q_p	0.25	Preschool quality
λ_0	0.25	CES productivity parameter – 0-5
ω_0	0.50	CES elasticity parameter – 0-5
λ_1	0.50	CES productivity parameter – 6-17
ω_1	0.25	CES elasticity parameter – 6-17
ζ	2.0	Anchor of child to adult human capital
α_S	7.0	Curvature of elementary quality
ν	0.40	Curvature of score production function
σ_z	0.60	Noisiness of admissions process
α_C	0.33	Elasticity of college quality to peer-effects
σ_e	0.40	Scale of elementary preference shocks
σ_c	0.25	Scale of college preference shocks

Notes: This table gives model parameters, the internally calibrated value, and a brief description of their role.

where the high-quality college has a quota of spots for low-income students, with a higher level of bonus points implying more spots allocated to low-income applicants.[22] We consider a conservative policy where low-income students receive an additional 20% of the admission score cut off required in the baseline equilibrium. Since colleges admit more low-income students, their per-pupil expenditure falls as they must pay out more in financial aid. However, college quality may increase or decrease depending on whether more high-ability students attend.

[22]See Brotherhood et al. (2023) for a proof of this equivalency. We use bonus points as they are more computationally tractable.

Table 5: **Model Fit**

Moment	Data	Model	Source
Aggregate			
Gini	0.396	0.396	OECD
Std. earnings	0.88	0.85	CPS
IGE	0.34	0.34	Chetty et al. (2014)
IGE transfer share	1.26	1.09	SCF
Preschool			
Attendance high	0.37	0.38	NCES
Time invest. – 0-5	0.13	0.16	PSID
Preschool growth effect	0.022	0.019	PSID
Elementary school			
Attendance	0.20	0.20	Normalization
Parental inc. ratio	1.72	1.79	PSID
Time invest. ratio	1.10	1.08	PSID
Opportunity time invest. ratio	1.94	1.83	PSID
Test score ratio	1.11	1.15	PSID
School growth effect	0.046	0.057	PSID
Time invest. – 6-11	0.09	0.05	PSID
Time invest. – 12-17	0.07	0.07	PSID
Mean time invest. 0-17	0.09	0.09	PSID
College			
Attendance	0.45	0.43	BLS, NCES 2016
Rel. attendance high	0.09	0.09	Normalization
Earnings growth low – 24-35	1.40	1.40	Chetty et al. (2020a)
Earnings growth high – 24-35	1.71	1.72	Chetty et al. (2020a)
Relative earnings – 24-35	1.82	1.69	Chetty et al. (2020a)

Notes: The columns compare the model to the data for selected targeted moments.

Integration at the Public School Level – In practice, the magnitude of integration policies varies across school districts. We consider a modest policy that amounts to moving 4% of the economy. The policy consists of randomly taking 2.5% of children living in the low-quality school zone and sending them to the high-quality school. Conversely, we randomly send 10% of children in the high-quality school-zone to the low-quality school. We do this at the elementary school level, and/or at the secondary school level. The realization of the elementary (secondary) school shock takes place at the start of period when the child is age $j = 1$ ($j = 2$) so that parents know the realized school quality when making time investment decisions.

Expanded Preschool Access – We assume that there exists some slack level of preschool supply and policymakers can increase the number of low-income students attending preschool without incurring any additional expenditures. This is in line with the current federal government policy of using existing Title I funds to expand preschool access. We randomly select 10% of those earning below median income and not attending preschool, and allow the agent to enroll their child in preschool for free. This amounts to an approximately five percentage point increase in the number of agents attending preschool.

Equilibrium – For each policy experiment, we run three versions. In the first version, the policy comes as a surprise; agents do not anticipate the change. We simulate a new stationary distribution of agents under the new policy experiment, using the same policy functions as in the baseline equilibrium. Second, we resolve the model when the policy is anticipated in a partial equilibrium setting. Agents update their choices in response to the policy, and spillovers from peer effects readjust, but the house price and college cutoff are held constant. Finally, we resolve the model when the policy is anticipated and allow all equilibrium objects to adjust.

5.1 Effects of Policy on the Treated

In this section we present the average effect of being treated by a given policy. For brevity, we focus on the effect of treatment for the expected partial equilibrium case. We find that the dynamics of treatment effects vary significantly depending on whether it occurs at the preschool, K-12, or college level. *Table 6* reports ratios of average moments for those in the treatment group relative to the control group. Columns (1) and (2) show the treated child's human capital, $\hat{h}$, changes and how time investment in children, $\hat{n}$, changes. Columns (3) and (4) present outcomes for the treated child once they become an adult: h is their own human capital, and $P(y > y_{parent})$ is the probability that the child earns more than their parent at age 55. Finally Columns (5), (6), and (7) present outcomes for the child of the adult who were themselves treated as a child. Q_S is the proportion living in the high-quality school zone, $\hat{h}$ is the child's human capital and $\hat{b}$ is the transfers that the child receives. All columns are broken down by the same fixed ability of the treated child. The treatment also affects the parent of the treated child, the treated child into adulthood and the subsequent child of the treated child when they are themselves in adulthood.

5.1.1 Preschool

The preschool access policy raises a child's human capital. This effect works directly through the more productive technology for producing human capital, as parents actually decrease time investments in their child (raising their own current income). The relative effect of preschool treatment on child human capital is decreasing in child ability: low-ability children benefit most from this policy.

The effect of preschool treatment is persistent as the child moves into adulthood, with the largest effects being for lower-ability children. In terms of absolute mobility, treatment significantly raises the probability of a child earning more than their parent. This effect is much smaller (larger) for high- (low-) ability children. Parents who received treatment as a child are significantly more likely to also enroll their own child in the high-quality elementary school and in preschool. While parents increase transfers to their child, they reduce child time investment and overall there is little change in the human capital for the treated child.

5.1.2 Elementary and Secondary School Integration

We now examine the treatment effect for moving from a low- to high-quality elementary and secondary school.[23] We consider the policy where the child is moved for both $j = 1$ and $j = 2$.

Again, treatment causes child human capital to rise. However, unlike the preschool case, the relative treatment size is now increasing in child ability. High-ability treated children have 1.24 times more human capital than those who were not treated. The corresponding value for low-ability children is 1.15. This difference results from complementarity between ability and education quality, as in fact parents of low-ability children actually increase time investment levels more (1.64 times) than that of high-ability children (1.60 times). Hence, parents sacrifice their own current (and future) income by taking advantage of the more productive human capital technology and invest more in their children. As a result of lowering their own income, they leave (on average) smaller bequests.

While we have so far discussed treatment effects broken down by the ability of treated children, treatment effects also vary by income levels of the parents of treated children. It is the children of middle-income parents who benefit the most from K-12 treatment.[24] Low-income parents are unable to sufficiently reduce own income in order to make the necessary investments to increase their child's human capital. Conversely, high-income parents (relatively) invest more in their child monetarily and less in terms of time investment. This causes a smaller overall increase in their child's human capital.

The treatment effect is strongest (weakest) for high- (low-) ability children. The same is

[23]In principle, there is also the treatment effect of moving from a high- to low-quality elementary school. We do not discuss those results here.

[24]In *Appendix C*, we report treatment effects by income tertile of the parent of a treated child, as opposed to ability of the treated child.

true for these children as they move into adulthood, in terms of later life earnings, as the income effect dominates later in life. However, the same is not true for the children of those who were treated as a child. Again, we see the strongest effects for middle-income parents.

Middle-income parents (who were treated as children) see the largest increase in the probability of sending their child to preschool or the high-quality elementary school. This is due to the fact that there are more middle-income parents on the margin that can now afford to spend money on a high-quality education. On average, low-income parents can still not afford high-quality education, and high-income parents were always able to afford it.

5.1.3 College

At the college level, we consider the model equivalent of a local average treatment effect (LATE). That is, we consider the effect of our affirmative action policy on agents who did not attend the high-quality college under the benchmark economy, but received the affirmative action in our counterfactual economy and were induced to attend the high-quality college as a result.

The effect of the policy now solely affects adult agents (and subsequent children), as it is implemented upon receiving independence from their parents. It is important to note, while parents know for certain whether their child will receive affirmative action or not, they do not know with certainty if their child will attend Q_C^h due to the noisiness of the admissions score.

Affirmative action policies have a large positive effect on later life human capital accumulation and earnings. The effect on later life earnings is largest (in relative terms) for middle-ability agents, and of similar size for low- and high-ability agents. This is due to a more productive technology for producing human capital across the lifecycle inducing both an income and substitution effect. However, in terms of absolute upwards mobility, it is low-ability agents who benefit the most from an affirmative action policy. This is because on average there are few low-ability parents who attended a high-quality college.

Unlike the elementary school policy which tended to increase time investment by parents in those treated, we observe the opposite for those treated by college affirmative action. In particular, those who were treated, invest less time in their children, but invest significantly more in monetary terms (inter-vivos transfers, preschool, and elementary school).

5.2 Unexpected versus Expected Policies

Next, we study how agents respond when the policy is unexpected versus expected. The unexpected case is only well defined in the partial equilibrium environment when P_S and $\bar{z}$ are fixed.

The right panel of *Figure 6* presents the percent change in average time investment in Q_S^l over ages $j = 1, 2$ in each policy experiment relative to the baseline steady state equilibrium. Red bars are when the policy is unexpected, and blue are when the policy is expected. Across the four policies, there are limited changes in average time investment in the unexpected case. However, when the policy is expected, there are larger changes. For example, under the college re-sorting policy, residents in Q_S^l, who are on average lower-income, know that their child has a better chance of being accepted to a high-quality college. Parents of children whose scores were close to the Q_C^h threshold find it worthwhile to invest more in their child's human capital. Average time investment increases by 2.5% in Q_S^l. We see similar patterns in the elementary and secondary school re-sorting case. When the elementary school policy is a surprise, average time investment in Q_S^l changes by -0.3%. However, in the partial equilibrium case, that same statistic increases by 2.8%, with parents again anticipating that their child has higher expected school quality. At the preschool level, the time investment response in the expected case is also larger. With more children getting free preschool, parents can either invest more human capital in themselves, or spend more hours working. As the parent has more resources, it can afford to invest more time in their child. However, note that the magnitude of the time investment change in the preschool case is lower than in the other policies.

Table 6: **Treatment Effects by Ability and Education Level**

	Treated, Child		Treated, Adulthood		Treated's Child		
	$\hat{h}$	$\hat{n}$	h	$P(y > y_{parent})$	Q_S	$\hat{h}$	$\hat{b}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Preschool							
Treated's Ability							
Low	1.24	0.69	1.11	1.74	1.62	1.02	1.71
Mid	1.18	0.64	1.08	1.15	1.15	1.01	1.14
High	1.10	0.52	1.02	1.01	1.02	1.00	1.01
K-12							
Treated's Ability							
Low	1.15	1.64	1.13	1.89	1.32	1.01	1.82
Mid	1.18	1.47	1.11	1.23	1.15	1.02	1.08
High	1.24	1.60	1.09	1.10	1.02	1.01	1.08
College							
Treated's Ability							
Low	-	-	1.64	23.58	1.07	1.03	8.37
Mid	-	-	1.73	2.53	1.10	0.96	3.19
High	-	-	1.63	1.05	1.05	0.99	1.95

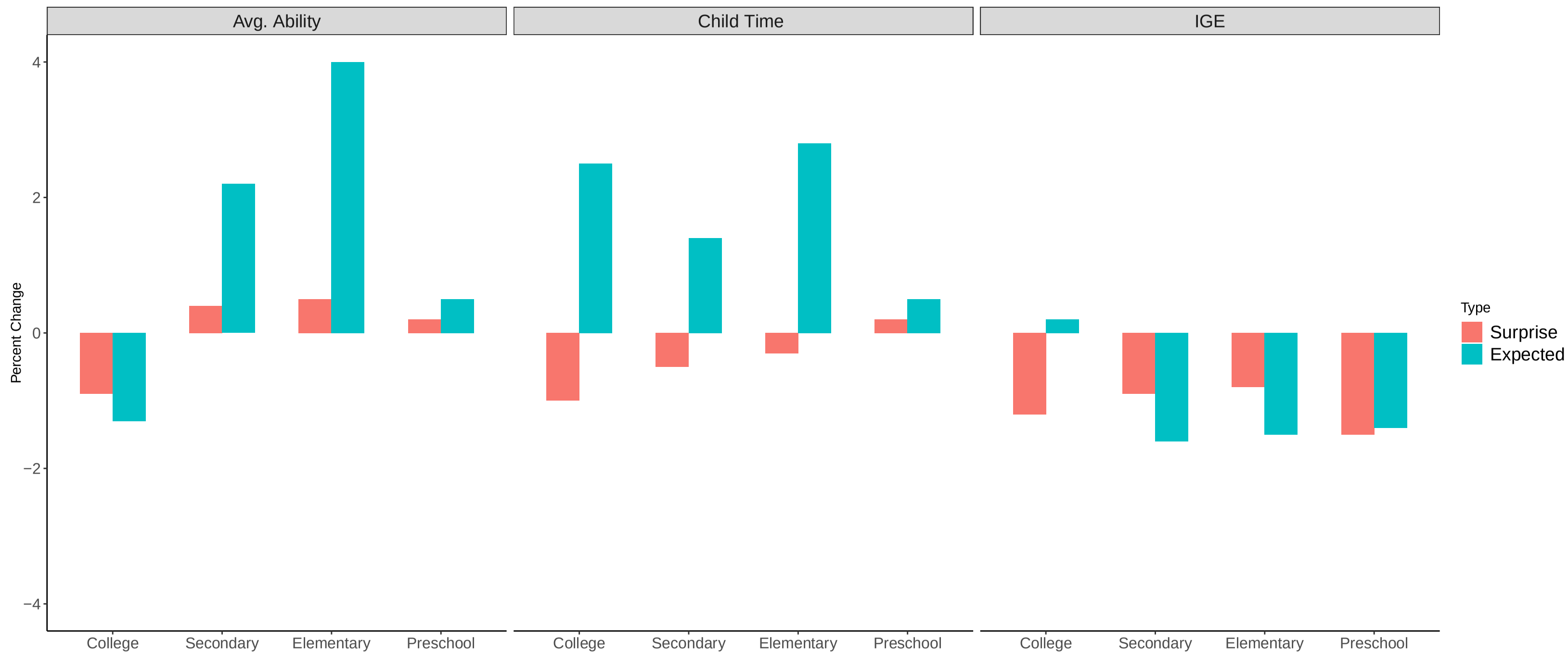
Notes: This table shows the effects of being treated by a policy at each education level and by the ability of the treated agent. Numbers show ratios between control and treatment group. Columns (1) and (2) report effects for children who are treated. Columns (3) and (4) report effects on adults who were treated (possibly as a child). Columns (5)-(7) report the effect on the children of adults who were treated.

The middle graph of *Figure 6* looks at the average change in school quality for Q_S^l, which is measured as the average ability of children in the school, across the four integration policies. When elementary integration is unexpected, average ability in Q_S^h rises by 0.5%; it rises by 0.4% in the unexpected secondary re-sorting case. On the other hand, the rise is four (two) percent when the elementary (secondary) re-sorting policy is expected. In anticipation of the policy, some agents with high-ability children on the margin of living between Q_S^l and Q_S^h in the baseline equilibrium will now choose to live in Q_S^l with the rise in expected school quality. For the preschool policy, parents have more resources and so those who have high-ability children can afford to live in Q_S^h. As was the case for time investment, the change in school quality is limited in the preschool case compared to policies in other time periods.

Lastly, the right graph of *Figure 6* presents the percent change in the IGE. Except for the preschool policy, there are large differences in these moments between the unexpected and the expected case. For the college policy, the IGE decreases by 1.2% in the unexpected case and rises by 0.2% in the expected case. In the unexpected case, parental investments do not adjust, and hence when unexpected IGE rises mechanically when sending more students to the high-quality college.

For high school and elementary school, the expected case has higher changes in mobility (larger fall in the IGE) as parents in the low-quality school zone increase their time investment in anticipation of the higher expected school quality. This increases upwards mobility as lower-income parents raise their child's human capital relative to the baseline equilibrium. The change in mobility for the preschool policy is not different due to the small changes we saw in time investment and school quality in Q_S^l. These results highlight the importance of expectations in creating effective policies to improve mobility. Agents cannot optimally change their decisions when policies are a surprise, which limits the increases in intergenerational mobility.

Figure 6: **Expected versus Unexpected Policies**



Notes: This figure presents effect of the unexpected (red bars) and the expected policies (blue bars) in partial equilibrium. The left graph is for average time investment in the low-quality school zone. The middle graph is average ability in the low-quality school zone. The right graph is the intergenerational elasticity of earnings. All moments are presented as percent changes relative to the baseline steady-state equilibrium.

5.3 General Equilibrium Effects

In this section, we study the effect of our policies on the aggregate economy and disentangle partial versus general equilibrium effects. *Table 7* presents the percent changes relative to steady state in the following variables: Q_C^h, the share who attend the high-quality college; Q_S^h, the share who live in the high-quality school zone, IGE, the intergenerational elasticity; the Gini coefficient of income; $\bar{z}$, the admissions score that clears the high-quality college; and P_S^h, the price of the high-quality school zone. We highlight some specific results and then discuss key takeaways in the next section.

Panel (a) presents the preschool expansion policy. Row (i) contains the partial equilibrium results: there is a rise of 1.6% in Q_C^h, as individuals acquire more human capital and can attend the high-quality college. There is also a rise in demand for the high-quality school zone as individuals accumulate more human capital through preschool. As the preschool policy helped low-income families, the IGE decreases by 1.4%, implying an increase in economic mobility. However, in general equilibrium, presented in row (ii), the IGE only decreases by 0.7%; half of the decrease in the partial equilibrium case. One of the reasons is that both $\bar{z}$ and P_S^h must increase to clear the housing and college market. Their increase makes the high-quality school zone and college less accessible.

Panel (b) presents results for the college affirmative action policy, which helps low-income families with children whose test scores were just below the baseline admission cutoff. Row (i) contains the partial equilibrium results, which show college attendance at Q_C^h increasing by 21% as more people have enough points to be admitted. Average income rises as more people go to college and this allows a larger share of families to live in school zone Q_S^h. There are limited changes in the IGE and the Gini. Row (iii) presents the general equilibrium effects, when $\bar{z}$ and P_S^h are allowed to adjust. Since Q_C^h has a fixed supply of seats and is now accepting more low-income children, the admissions score that clears the college market, $\bar{z}$, increases by ten percent. As college becomes more competitive, the value of a guaranteed good elementary and secondary school increases, which is reflected in a 1.6% increase in P_S^h. In general equilibrium, the IGE increases by 1.6% (lower income mobility) due to the increase in sorting at the elementary and secondary level. Stepping back, this policy experiment highlights how policies to promote socioeconomic diversity at the college level can have unintended consequences that affect earlier stages of human capital development.

Next, we study how the integration policy unfolds throughout public school. Panels (c) and (d) of *Table 7* present our findings for the secondary school and elementary school policy change, respectively. When the policy is expected and in partial equilibrium - row (i) of Panels (c) and (d) - the demand for Q_S^h falls substantially more in the secondary school policy case (6.7% decrease) than in the elementary school policy case (2.2% decrease). The smaller response to the elementary school policy is also reflected in the general equilibrium cases (rows (ii) of Panels (c) and (d)). P_S^h falls by 5.7% in the secondary school policy, but only by 2.1% in the elementary school policy. When a parent must choose between Q_S^h and Q_S^l, there is more uncertainty in the case of the secondary school policy. When their child is aged $j = 2$, the parent faces uncertainty both in terms of school quality and the income shock. However, in the elementary school policy, the parent can insure against a bad school shock in $j = 1$ by adjusting time investment in $j = 2$. In fact, we see that the partial equilibrium changes in Q_S^l and Q_S^h are starker in Panel (d) than in Panel (c).

Panel (e) contains results for the combined K-12 policy. In general equilibrium, the policy produces the largest decrease in the IGE (highest increase in mobility) with a 2.5% drop. There is a large fall in P_S^h as the expected value of the school zone's quality decreases. School qualities become more similar across the two zones (not shown). In Panel (f), we add the college affirmative action policy to the K-12 policy. In the general equilibrium case, the fall in the IGE is cut by nearly half compared to Panel (e). The reason is that while the desegregation at K-12 improves upwards mobility, the college policy increases competition, pushing up the admission score. There is also a smaller reduction in P_S^h.

5.4 Discussion

We now summarize a few key takeaways. First, integration policies from low- to high-quality schools/colleges increase human capital for those who are treated. The types of parental investments differ by policies. For elementary school integration policies, parents increase time investment and help their child build more human capital before becoming an adult. On the other hand, college affirmative actions tend to increase monetary investments by parents through transfers or school zone choice.

Second, unanticipated policies have smaller effects since parents cannot adjust their investments optimally in response to them. This is of particular interest to policy makers, as the introduction of new policies tends to be unexpected, and occurs after key child investments and decisions have already been made.

At the aggregate level, we found that integration policies are effective in improving intergenerational mobility at the public school levels but not at the college level. At elementary and secondary school, a re-sorting policy reduces the inequality between the two school zones. The average ability of those in Q_S^l rises, increasing the school quality there. Since lower-income children are more likely to live in Q_S^l, intergenerational mobility rises as these children now accumulate higher levels of human capital. At the college level, a policy that aims to re-sort students has minimal effects on the IGE in partial equilibrium, and actually decreases mobility in general equilibrium. The reason is that the re-sorting policy makes college more competitive and this increases inequality in the earlier stages of human capital development.

The key assumption driving this result is the capacity constraint at the high-quality college. It follows that improving opportunity at the public school versus the college stage requires different policy levers. While integration works for public schools, it does not increase intergenerational mobility at the college level. In both cases, the supply of seats at the high-quality school/college is limited but the difference is that the college admissions process

Table 7: **Effect of Policies on Population**

	Q_C^h pop. (1)	Q_S^h pop. (2)	IGE (3)	Gini (4)	$\bar{z}$ (5)	P_S^h (6)
Panel (a): Preschool						
(i) Partial Eqm.	1.6	1.0	-1.4	-0.5	–	–
(ii) General Eqm.	–	–	-0.7	-0.6	1.5	0.5
Panel (b): College						
(i) Partial Eqm.	21.2	1.2	0.2	0.8	–	–
(ii) General Eqm.	–	–	1.7	0.9	10.8	1.6
Panel (c): Secondary School						
(i) Partial Eqm.	-2.4	-6.7	-1.6	-0.7	–	–
(ii) General Eqm.	–	–	-1.3	-0.5	-0.9	-5.7
Panel (d): Elementary School						
(i) Partial Eqm.	-0.8	-2.2	-1.5	-0.7	–	–
(ii) General Eqm.	–	–	-1.4	-0.7	-0.3	-2.1
Panel (e): K-12:						
(i) Partial Eqm.	-2.3	-7.7	-2.5	-0.9	–	–
(ii) General Eqm.	–	–	-2.5	-1.0	-0.9	-8.8
Panel (f): K-12, College:						
(i) Partial Eqm.	31	-8.0	-3.6	-0.6	–	–
(ii) General Eqm.	–	–	-1.1	-1.7	21.5	-7.8

Notes: This table presents results for our policy experiments in partial and general equilibrium. Each panel lists a different policy experiment. Columns (1) through (6) present different moments. Q_C^h pop. is the share of agents in the high-quality college. Q_S^h pop. is the share of households living in the high-quality school zone. IGE is the intergenerational elasticity of income. Column (4) presents the Gini coefficient of income. $\bar{z}$ is the admissions score to get into the high-quality college. P_S^h is the price of the high-quality school zone. The last two variables are held fixed in partial equilibrium. Moments are presented in percent changes relative to the baseline steady-state equilibrium.

Figure 7: **Income Sorting for High-Quality Elementary School, by Counterfactuals**

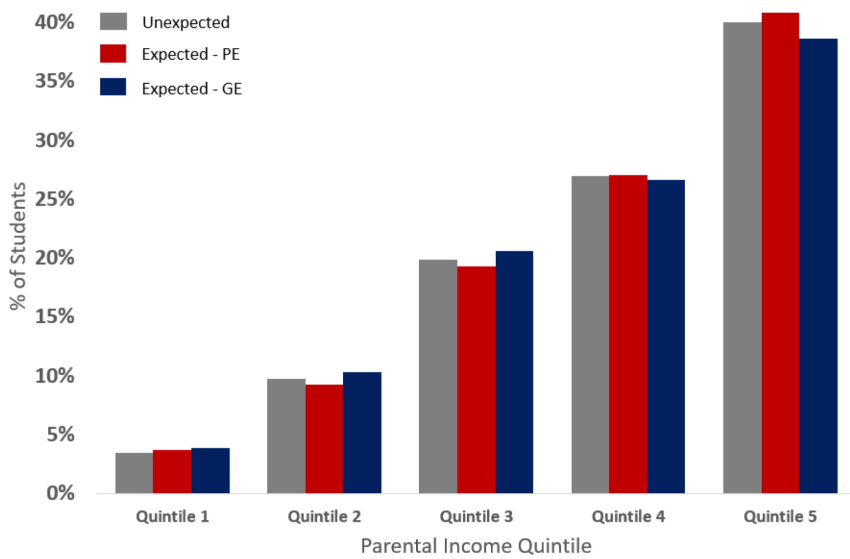
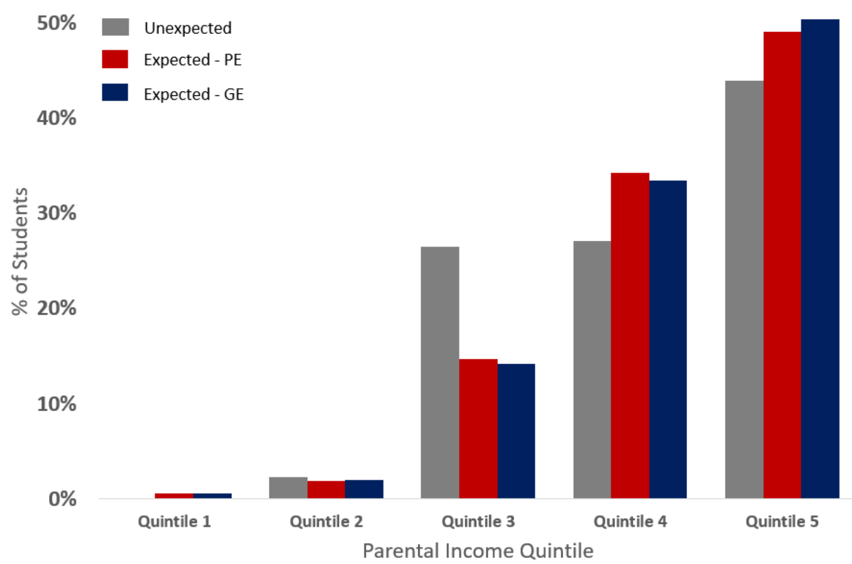


Figure 8: **Income Sorting for High-Quality College, by Counterfactuals**



has a human capital floor. Instead, colleges can improve mobility by increasing supply.

Furthermore, our model highlights the importance of understanding the timing and the interaction between policies. An elementary school integration policy reduces inequality between school zones less than the same policy at secondary school. The reason is that the elementary school policy still guarantees access to a quality secondary school, which keeps the price of that school zone elevated. In terms of policy interactions, our results show that implementing a college affirmative action policy along with a public school re-sorting may not be effective. In fact, the college affirmative action policy cancels out some of the positive intergenerational mobility gains from the public school re-sorting policy. In addition, our work shows that preschool re-sorting policies may not be as effective as policies at the elementary and secondary school level. The preschool policy moved roughly the same share of agents as the K-12 policies, but had smaller effects.

To get a broader view of the effect of policies on sorting, we present the shares of different income quintiles at the high-quality elementary and college across different experiments. *Figure 7* shows the share of households from each of the five income quintiles in the high-quality school zone. The policy shown is elementary school integration and the gray bars are for the unexpected case, the red bars for the partial equilibrium case, and the blue bars for the general equilibrium case. Next, *Figure 8* presents the share of parental income quintiles in the high-quality college under the college integration policy. It is worth noting two points here. First, all three versions of the policy do not increase the representation of low-income children in colleges. In the unanticipated case, the policy brings the share of individuals from the third quintile to almost thirty percent. However, this share drops by more than half in the partial equilibrium case. One reason for this is that when the policy is expected, despite having higher human capital and being eligible for the high-quality college, middle-income students do not find it worthwhile to pay the higher tuition costs for the college and instead go to the lower-quality college or no college at all. At the elementary level, we see more representation from the bottom income quintile, however this does not translate into higher representation later on at the college level.

The results suggest that these policies are not "effective" in improving outcomes at the college level for the very lowest income agents. For instance, *Figure 8* shows that most changes work through the middle quintile agents, and minor changes (in levels) occur for those at the lowest income quintile. It warrants more research to determine if this is specific to these policies (perhaps financial policies are more effective) and model assumptions, or if it is simply that low-ability (and usually low-income) agents are simply behaving optimally.

6 Conclusion

Recently, policymakers have begun to consider a variety of education opportunity policies that involve the integration of students. This paper studies the effect of these integration policies across different stages of human capital development. We build an overlapping generations model of heterogeneous agents featuring sorting into school zones and colleges of different qualities. These education qualities are endogenously determined through peer effects. School zones have limited housing supply while the high-quality college has a fixed supply of seats; both of these markets clear in general equilibrium. The model is calibrated to match differences in household income, human capital, and time investment across school zones, along with differences in earnings growth and level by colleges.

Our work is the first in the literature to feature a dynamic lifecycle heterogeneous agent model with endogenous sorting and peer effects at both the public school and college level. The key advantage of our model is that we can consider integration policies across preschool, public school, and college. This allows us to simulate the current patchwork of policies being put forth by policymakers aiming to improve education opportunity across several stages.

At the elementary and secondary school level, these policies involve re-sorting students across schools. At the college level, we model an income-based affirmative action policy. A key result of our policy analysis is that having both public school integration and college income-based affirmative action policy may not be effective. While public school re-sorting increases intergenerational mobility by breaking the link between residential location and school quality, the college affirmative action policy reduces intergenerational mobility. When that college reserves seats for students from low-income families, it drives up competition for the remaining seats and increases sorting at the public school level. With the high-quality public school becoming costlier, intergenerational mobility falls. Our work highlights that improving education opportunity needs coordination of policies.

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Appendix

Appendix A Data

This appendix provides additional details on data sources, empirical methods, and provides additional empirical results.

A.1 Panel Study of Income Dynamics

The primary data source we use is the Child Development Study (1997, 2002, 2007, 2014) from the Panel Study of Income Dynamics. In the main PSID sample, we extract information on all family heads and their partner (using the "relation to head" variable) including age, marital status, labor and taxable income, and hours worked. We deal with top-coding as in Lee and Seshadri (2019).

The Child Development Study raw data comes in multiple files. We merge the "Assessment" file (child test score information), the "Demographics" file (child age) and the "Time Diary' file. For each child-year observation, we link the child to their primary caregiver (in some waves there is also an "other" caregiver) from the main study. For each child-year we have the following information : age, human capital scores, time per week with parent, and caregiver information and earnings.

There are fifty-seven letter-word questions in the Child Development Study, which are increasing in difficulty. The raw scores are out of fifty-seven, and we normalize them to being out of one hundred. These raw scores only allow us to account for differences in cognitive skills among children of the same age. In order to compare test scores across ages, we use the adjustment mechanism in Lee and Seshadri (2019), where each of the fifty-seven questions is given a weight equal to the inverse of the share who got that question correct.

Table A.1: **PSID Sample Summary Statistics**

	Full Sample (1)	Human Capital Scores (2)	School Information (3)
Age	10.10	10.85	10.51
log Household Income	10.76	10.77	10.76
Active Hours	28.22	26.31	26.33
Age of Household Head	38.20	38.80	38.35
% Head: Male	70	69	69
Adjusted score	–	46.08	45.70
Number of Unique Children	4,673	4,490	2,201
Number of Child-Year Obs.	7,612	6,877	3,202

Notes: Column (1) presents the full sample of children in the Child Development Study. Column (2) conditions on children with human capital scores. Column (3) conditions on those with school information.

A.1.1 Sample Selection

We make the following refinements to the sample. First as in Lee and Seshadri (2019), we drop children who are noted as not being in the household (seqno greater than 50). We only keep caregivers who are listed in relation to the child as begin either a parent or a stepparent. Next, we drop families where the caregiver is not in the household or the caregiver is not listed as either the "Head" or the "Wife". The reason for the latter is we need to know the caregiver's labor market earnings in order to account for opportunity cost of time when investing in children.

Appendix B Computation

The dynamic programming problem is solved by backwards induction beginning with the terminal condition $V(j = 11, Q_C, a, b, h) = 0$. Given that ability and college quality are static over an individual's lifecycle, the problem is broken apart and solved separately. This is done to easily facilitate parallelization of the computer code. The model is solved with three college qualities (including no college option). The model can be solved for a larger number of qualities, however distinguishing between many more college qualities in the data becomes difficult.

The AR(1) process for abilities is approximated using five ability levels and the Rouwenhorst discretization method. The model solution is invariant to the number of abilities used. The distributions for market luck shocks are discretized using the equal-mass approach of Kennan, 2006.

For all periods where the child is present in the household an expanding rectangular grid is set over continuous variables $(h_j, \hat{h}_j, b_j)$ and a uniform grid is set over discrete variables $(a, \hat{a}, Q_c)$, with an additional state variable for either preschool, Q_P, or elementary school, Q_S. During period $j = 7$ there is an additional continuous choice variable $\hat{b}_j$. When solving for optimal policies we interpolate using cubic splines over next periods value functions. We solve for policy functions using a modified Nelder-Mead algorithm to allow for rectangular box constraints.

Given the altruistic motives of parents to children a single round of backwards induction is insufficient to solve the model. Solving the model proceeds by guessing a value function V_3, a mean income level $\bar{y}$, elementary school quality Q_S, and college qualities Q_C. Additionally, guesses for the price of the high quality neighborhood, P, and the high quality college admission cut off, $\bar{z}$, are given. The model is then solved via backwards induction, obtaining a new guess for V_3. Once a convergence criterion is satisfied on V_3, we simulate to solve for the additional three fixed points of $\bar{y}$, Q_S, and Q_C, then updating guesses. The new guesses are then fed into the model, and the model is solved by backwards induction until once more achieving convergence on V_3. This process is repeated until we obtain convergence on $\bar{y}$, Q_S, and Q_S. Finally, we then update guesses for P and $\bar{z}$ and proceed again as above, until convergence is achieved for all five fixed points.

To simulate moments from the model we take some arbitrary vector of parameters Θ and solve the model to obtain all decision rules. we then simulate $N = 1,000,000$ agents for $T = 20$ generations and discard all but the last two generations. The model converges to a steady state quickly and increasing the number of generations to $T = 100$ has no effect on results. Similarly, simulating $N = 2,000,000$ agents has negligible effects on results.

Appendix C Additional Figures and Tables

Table C.1: **Treatment Effects by Parental Income**

Parent Income	$\hat{h}$	$\hat{n}$	$\hat{b}$	y
Low	1.14	1.39	0.26	0.99
Mid	1.22	1.59	0.50	0.95
High	1.20	1.74	0.84	0.98

Notes: This table shows the effects of being treated by the income of the parent, of the treated child for the K-12 policy.