9-2023

Self-financing, parental transfer, and college education

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September 26, 2023

Abstract

We show that financial constraints can affect the human capital accumulation of college students by influencing students' labor supply. We document that many college students work a substantial number of hours at low-skill jobs, and students who have fewer financial resources (in particular, parental transfer) tend to work more. We develop a model that incorporates college students' labor supply and its interaction with parental transfer in the presence of financial constraints. By estimating the model, we quantify the trade-off between self-financing and human capital accumulation and discuss the implications of a wage subsidy policy.

Keywords: College Education, Parental Transfer, Labor Supply, Intergenerational Mobility, Financial Constraints

JEL classification number: I22, I23, I24

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1 Introduction

College education in the economics literature is often considered a lumpy investment. Decisions made during the college period, which could generate different trajectories of post-college labor outcomes, are abstracted in many economics models. One such decision is college students' labor supply. Besides financial resources, going to college requires time. This time can be used for studying or for working to finance educational investment or consumption. Table 1 illustrates a possible trade-off of working during college. Students who work more hours are less likely to earn more credits or a higher GPA, less likely to meet with their academic advisor or participate in a school club, and more likely to withdraw from enrollment in college for a period of time.[1]

In this paper, we show that financial constraints can impact human capital accumulation among college students by influencing their labor supply decisions. We also highlight the significant role played by endogenous parental transfer in determining the extent to which financial constraints affect human capital accumulation through self-financing. Using the National Longitudinal Survey of Youth 1997 (NLSY97) and the Survey of Income and Program Participation (SIPP), we first document facts that suggest financial necessity, rather than career development, is an important motive for college students' labor supply. First, a large number of college students work a substantial number of hours at low-skill jobs. In our data, college students work 1,775 hours, on average, for the first two years after college enrollment. The most common job is cashier, followed by retail salesperson, waiter or waitress, and nanny. Second, students who have fewer financial resources during college tend to work more. In particular, students from low-income families tend to work longer hours. Using a father's job-loss shock as an instrumental variable (IV), we show lower parental income leads to more working

[1] College students' working hours have increased substantially over the past 50 years. The proportion of full-time students at four-year colleges who work more than 20 hours per week was 5% in 1961, 17% in 2003, and 30% in 2012. Over the same time period, the average number of hours that full-time students at four-year colleges spent in class and studying decreased: 40 per week in 1961, 27 per week in 2003, and 15 per week in 2012. (Sources: Babcock and Marks [2011], the National Postsecondary Student Aid Study (NPSAS) 2012, and the American Time Use Survey (ATUS) 2012).

hours by students.

To quantify how easily a constrained student can substitute the lack of parental support with working while in college, we develop a theory that specifies the trade-off involved in students' decision to work, while accounting for the endogenous response of parental transfer. In the model, altruistic parents first make a monetary transfer to the child, who then decides whether to complete college or drop out, how much to invest in education and how much to work to finance her consumption/educational cost. We extend the Ben-Porath model to the college-financing problem, assuming human capital accumulation during college depends not only on monetary investment but also on time investment. We assume that students may face a constraint that limits the consumption smoothing between college and working period. This assumption is based on recent evidence supporting the existence of financial constraints for college students. Using Texas administrative data, Black et al. [2020] illustrates that nearly half of dependent undergraduates hit the annual borrowing limits of federal loans (Stafford loan), leading to the conclusion that millions of U.S. undergraduates encounter credit constraints. The financial constraint may be driven by other constraints, such as limited insurance against future risk (Johnson [2013]), or a preference for avoiding loans (Gopalan et al. [2021]). We focus on model predictions that are applicable regardless of the nature of the constraint.

College students choose their working hours so that the marginal benefit (associated with additional consumption) is equal to the marginal cost (associated with loss of human capital due to reduced study time). If a student does not have enough support from her parents, she is more likely to be constrained to finance the optimal level of investment and consumption during college. Working in low-skill jobs can alleviate such a constraint, which increases constrained students' incentive to work. However, as the time devoted to working increases, the time for studying decreases, and future human capital will be compromised. If the value of graduating becomes lower than the outside option value of dropping out, students decide to drop out of college.

Altruistic parents choose to transfer resources in order to equalize the marginal return from extra resources across generations. When the child can achieve the optimal level of educational investment and consumption, the parental transfer is driven by a compensating motive that equalizes the marginal return from extra consumption between the child and the parents. However, parental transfer can have a greater marginal impact on the child's utility when the child is constrained, because it can also enhance the child's human capital by reducing the child's self-financing burden.

To quantitatively evaluate the trade-off between self-financing and human capital accumulation while accounting for the endogenous response of parents, we estimate the model based on the method of simulated moments. Using the estimated model, we conduct counterfactual experiments on a wage subsidy policy. The federal work-study program in the US provides part-time jobs for students with financial needs, allowing them to earn money to help pay their education expenses. Government subsidy is essential for the work-study program because the federal government finances a large fraction of wages. To prevent students from overworking, the federal work-study program typically sets limits on the number of working hours. In line with these features, in our counterfactual wage subsidy policy, students receive a 2 USD subsidy for every working hour during college, but there is a working hour restriction in place to ensure that college graduates cannot exceed 4,000 hours of work throughout their college years.

We find that the above wage subsidy policy increases the aggregate college completion rate by 3.15 percentage points. Focusing on students who complete college in both baseline and counterfactual simulation, the wage subsidy policy decreases the working hours by 525 and increases the monetary investment by 550 USD. Consequently, the average human capital of college students (including both dropouts and graduates), as measured by annual earnings after college, increases by 1,375 USD. The parental transfer decreases by 1,841 USD because the child can earn a higher wage from working. The welfare gain of the wage subsidy policy is 0.39% and 0.30% increases in the lifetime consumption for the child and the parents, respectively. We also find substantial heterogeneity in the effects of the wage subsidy policy on students' human capital based on their family income. Specifically, we observe that the positive impact of the wage subsidy policy on students' human capital is more pronounced among low-income students. The higher earnings per unit of working hours, resulting from the wage subsidy, allow financially constrained low-income students to allocate more hours towards developing their human capital rather than using them for self-financing purposes.

To emphasize the significance of the interaction between parental transfer and the child's choices, we conduct a counterfactual analysis where we eliminate the endogenous response by parents to the wage subsidy policy. Abstracting from the endogenous responses by parents would slightly *understate* the positive impact of the wage subsidy policy on the college completion rate. This is because when endogenous responses by parents are allowed, certain parents, particularly those with children who are at risk of dropping out of college, may choose to increase their financial support to prevent their child from working excessive hours while in college.

On the other hand, without accounting for changes in parental transfer, we would *overstate* the impact of the wage subsidy policy on the human capital accumulation of the students who complete college in both baseline and counterfactual simulations. This is because the majority of parents, especially those with children who complete college, would crowd out their transfer when their child can earn higher wages during college. Accordingly, the model without endogenous parental response would overstate the increase in the average human capital and the welfare effect of the wage subsidy policy for the child, while understating the welfare effect on the parents.

This paper is related to the literature on human capital investment and intergenerational mobility.[2] Our main contribution is twofold: first, we document the prevalence of college students working in low-skill jobs and show that financial need is a significant factor driving students to work while in college; second, we develop a model that demonstrates how the option for self-financing, along with

[2]Since Becker and Tomes [1979, 1986], the question of whether and how credit constraints affect human capital investment and intergenerational mobility has been central in the literature. Earlier findings indicate credit constraints are not major determinants of college attendance (e.g., Cameron and Heckman [1998]; Keane and Wolpin [2001]; Cameron and Taber [2004]; Ionescu [2009]), whereas studies using recent data suggest credit constraints play an important role in college enrollment (e.g., Belley and Lochner [2007]; Lochner and Monge-Naranjo [2011, 2012, 2016]; Hai and Heckman [2017]; Black et al. [2020]).

the trade-off in time investment in human capital, affects the incentives of parents and the child. This provides a novel mechanism that explains heterogeneous human capital accumulation during college.

While the option to work at part-time jobs during the schooling period has been considered in previous studies (e.g., Keane and Wolpin [2001], Johnson [2013], Hai and Heckman [2017], Abbott et al. [2019], Joensen and Mattana [2021]), we extend the previous analysis by incorporating the interaction between endogenous parental transfers and students' working hours. Parents' response to the trade-off associated with their child's self-financing explains substantial variations in the means of college financing across families. Our model also enables us to quantify the welfare effects of the policy that changes the incentives of self-financing, such as wage subsidy policy, on both the child and the parents while accounting for crowd effects on parental transfer.[3]

Closely related, Brown et al. [2011] and Abbott et al. [2019] discuss how the interaction of incentives between parents and the child affects college-enrollment decisions. Our paper expands upon their analysis by incorporating not only monetary investment but also time investment, which varies substantially among students who have enrolled in college. By doing so, our model can illustrate how the characteristics of both parents and the child jointly affect children's time investment in college education. This, in turn, explains diverse college outcomes among those who have enrolled in college, including dropout rates and post-graduation labor earnings.[4]

This paper also relates to the studies that examine the impact of work-study programs on students' outcomes. While some studies find that student employment could have adverse impacts on their academic achievement ([Stinebrickner and Stinebrickner, 2003; Callender, 2008; Kalenkoski and Pabilonia, 2010]), other studies find heterogeneous impacts across students and types of jobs ([Scott-Clayton and Minaya, 2016; Darolia, 2014; Avdic and Gartell, 2015; Joensen and Mattana, 2022]). Our contribution to this body of literature is twofold. First, we present a framework that elaborates on

[3]Abbott et al. [2019] highlights the importance of endogenizing parental transfers to account for crowd-out effects in the welfare analysis due to policy changes.

[4]Garriga and Keightley [2007] also allow for reduced studying time due to working during college, but they do not explicitly account for the endogenous response of parents when their child has to work in the presence of credit constraints.

the mechanisms through which the wage during college affects the child's self-financing and human capital investment. Second, we quantify the welfare implications of a wage subsidy policy for both the child and the parents.

The paper proceeds as follows. Section 2 discusses data and motivating facts. Section 3 describes the model. Section 4 explains estimation and identification of the model. Section 5 discusses estimation results, and section 6 concludes.

2 Facts about Labor Supply by College Students

We use two main datasets for this study. First, we use the NLSY97 to document facts about students' labor supply during college. We also use it for the estimation of our structural model. Second, we use the SIPP to show the relationship between parental income and students' working hours. We now explain these two datasets in more detail.

2.1 National Longitudinal Survey of Youth 1997 (NLSY97)

The NLSY97 is a panel dataset from a nationally representative sample of youths, 12 to 17 years old, living in the United States as of December 31, 1996. The data include detailed information on how students finance the cost of postsecondary education since 1997. First, we observe the total amount of loans taken out by students. Loan data from the NLSY97 represent the answer to the following question: "Other than assistance you received from relatives and friends, how much did you borrow in government subsidized loans or other types of loans while you attended this school/institution?" As the question clearly indicates, students are asked to report all student loans, including private loans obtained to attend the school. We use the total amount of loans students take out for college education (up to three institutions at one time) in our analysis. Second, we observe the amount of transfer from parents to children (which children are not supposed to repay). We also observe lending from parents for college education separately from parental transfer. Although the amount of lending by parents is negligible, we include that lending when constructing the variable for parental transfers so as not to understate the resources allocated by parents. Given that NLSY does not provide separate data on transfers from parents and from other family members, we use the total transfer from all family members as the parental transfer. Third, the NLSY97 provides the amount of grants from either government or college.[5]

In addition to financing information, the NLSY97 reports working hours and types of jobs while enrolled in college and labor income during and after college. The data also include students' demographic characteristics, cognitive test score (the Armed Forces Qualification Test (AFQT) score), parents' income, and students' enrollment history and the highest grade completed.

We keep observations for those who ever attended a four-year college.[6] The original sample consists of 8,984 individuals born between 1980 and 1984. We first drop 1,891 individuals with missing data on AFQT scores. We drop 4,098 individuals who did not attend a four-year college. We drop an additional 943 individuals with missing data on parental transfer and student loans. We also drop 102 individuals because of missing data on their labor supply during the first two years of college. We drop 133 individuals due to missing data on labor income between ages 26 and 30, and 198 individuals due to missing data on family income during ages 16-17. Finally, we drop 455 individuals whose highest grade completed is greater than or equal to 18 to exclude students who attend a graduate program.[7] The resulting sample consists of 1,164 individuals. All monetary amounts are denominated in 1997 USD using the Consumer Price Index (CPI).

[5]The survey collected how students finance college education for each term, year, and college. Because financing information for other than the first term has too many missing observations, we impute annual data for educational financing by multiplying the financing variable for the first term by the number of terms for each academic year. For example, if the college has a trimester system, we multiply the term-one financing variables by 3 to construct the annual data.

[6]We extend our analysis to include two-year college students in Appendix A.

[7]The cost of attendance, financial aid policy, types of jobs available during study, and returns to investment are substantially different between undergraduate and graduate programs (Belasco et al. [2014]; Altonji and Zhong [2021]). To focus on the dropout and the college-graduation decision, we drop those who attended a post-college program.

Survey of Income and Program Participation (SIPP)

To supplement the NLSY97, we use the Survey of Income and Program Participation (SIPP), which is a nationally representative household-based survey of the US population. Each SIPP panel follows a large number of respondents, ranging from approximately 14,000 to 36,000, for three or four years. We use the 1996, 2001, 2004, and 2008 panels. In the SIPP, eligible household members were interviewed every four months, using questions about, for example, college-enrollment status, weekly working hours, monthly income, and demographic characteristics such as race and sex. Because the SIPP is a household-based survey, we can merge students' information with their parents' information. The SIPP also asks the main reason surveyed individuals stopped working, which we used to construct a parental-income shock we explain later. We keep observations for individuals aged 16-30 who were enrolled in their first, second, third, and fourth year of an undergraduate program at the time of the interview. All monetary amounts are denominated in 1997 USD using the CPI.

2.2 Working While in College

In Table 2, we first document the summary statistics for students' working hours after college enrollment based on the NLSY97. Four-year college students, on average, work 819 hours for the first year, 1,775 hours for the first 2 years, and 4,111 hours for the first 4 years after they start their college education. If we instead look at the median, students work 676 hours for the first year, 1,535 hours for the first 2 years, and 3,823 for the first 4 years. This finding implies more than half of the students work more than 13 hours ($\frac{676}{52}$) per week over the first year after college enrollment, and the working hours are not concentrated within a particular year after college enrollment. We also check working hours during college by using more detailed data, such as weekly working hours and monthly enrollment status, to exclude working hours during which students are not enrolled in a program. We find a similar pattern as in Table 2.[8]

[8] A similar pattern is found in other datasets as well. By using the October Supplement of the Current Population Survey (CPS), Planty et al. [2007] find that about half of full-time students and 85% of part-time college students ages

Next, we document the type of jobs a typical student works. Figure 1 shows the occupation composition of all jobs reported by college students ages 18-22 when they were enrolled in a four-year undergraduate program. Based on the 3-digit code of the 2000 Standard Occupation Classification, we calculate the share of jobs in each occupation. We exclude internships from this analysis, which account for 1.3% of jobs for college students. Across 509 occupations, 10 occupations account for 38% of jobs held by college students. The most frequently observed job is cashier, followed by retail salesperson, waiter or waitress, and nanny.

To understand the source of heterogeneity in students' working hours, we conduct a linear regression for students' working hours with respect to students' ability (the AFQT score), parental income, student loans, and the amount of grants students receive. The first column of Table 3 shows the results. A student with higher ability, more grants, or from a high-income family tends to work less. In contrast, students who take out student loans are more likely to work longer hours. In the second column of Table 3, we additionally control for parental transfers. First, the magnitude of the coefficient for parental transfer is as high as the coefficient for grants. Second, as long as we control for parental transfers, no significant association exists between parental income and students' working hours. This finding implies the negative relationship between parental income and working hours in the first column of Table 3 is mainly due to wealthy parents providing more transfers.

The relationship between parental transfer and working hours in Table 3 may be due to factors that simultaneously affect both parental transfer and students' working hours. To check whether a lack of parental transfer is indeed a reason for students' working, we use the SIPP. Every four months, the SIPP asks the main reason any surveyed individual stopped working. Possible answers include the following: (1) employer bankrupt, (2) employer sold business, and (3) slack work or business

16–24 were employed in 2005. In their analysis, full-time college students are defined as students who enroll in two- or four-year colleges and take at least 12 hours of classes per week. They also find that about 21% of full-time students work 20–34 hours per week, 9% of full-time students work 35 or more hours per week, and 47% of part-time students work more than 35 hours per week.

conditions.[9] We first construct a dummy variable (i.e., job-loss shock) that takes a value of 1 if the reason the individual stopped working is one of the three choices. Given that the SIPP does not provide parental-transfer information, we focus on the relationship between parental income and working hours. To handle the endogeneity issue, we use the father's job-loss shock (or mother's job-loss shock in the case of single-mother households) in the previous four months as an IV for parents' monthly income.[10] In the SIPP, a job loss in the current period is defined if a respondent had a job at the beginning of the reference period (4 months) and the respondent stopped working during the reference period. Therefore, the current-period income might capture monthly income before the job loss that happens later in the same reference period. For this reason, we use the job-loss shock in the previous period as an IV for parental income in the current period.[11]

Table 4 shows summary statistics for students whose parents experienced a job-loss shock, and students whose parents do not experience a job-loss shock. The average parental income before a job-loss shock is slightly lower for those whose parents experience a job-loss shock. For example, in the initial survey period, the average monthly income for parents who will experience a job-loss shock is 3,630 USD, whereas average monthly income for parents who will not experience a job-loss shock is 4,038 USD. The proportion of household heads who attended some college or above is 0.69 for both groups. Other demographic characteristics such as gender and race are also similar across the two groups.

Column (1) of Table 5 shows the results from the first-stage regression. The parental job-loss

[9] Other answers include discharged/fired, retirement or old age, childcare problems, other family/personal obligations, own illness, own injury, school/training, job was temporary and ended, quit to take another job, unsatisfactory work arrangement, and quit for some other reason.

[10] We use the father's job-loss shock for two-parent households given that paternal income is a major source of parental income in our dataset. For example, the average paternal income is almost as twice the average maternal income in the SIPP.

[11] Given that the measure for parental income during which the job loss shock incurs can be noisy, we remove the observations for the periods with the job-loss shock when we conduct the IV regression. Stevens and Schaller [2011] construct a similar job-loss shock and show that the parental job-loss shock in the previous year increases the probability that a child will repeat a grade by around 15%. They defined a parental job-loss shock as a situation in which a child's father (or mother in the case of single-mother households) experienced one of the followings: (1) discharged/fired, (2) employer bankrupt, (3) employer sold business, and (4) slack work or business conditions. We removed the first condition (discharged/fired) when we construct the job-loss shock because it could be driven by father's own misbehavior such as alcohol addiction that can have a direct effect on the child.

shock in the previous period leads to a 1,450 USD decrease in monthly parental income in the current period. Note the mean and median monthly parental income during the entire survey periods are 4,432 USD and 3,348 USD, respectively. Therefore, the magnitude of the parental job-loss shock is about 33% ($\frac{1{,}450}{4{,}432} \times 100$) of the mean monthly parental income and 43% ($\frac{1{,}450}{3{,}348} \times 100$) of the median monthly parental income.

Columns (2) and (3) of Table 5 report OLS and IV regression estimates, respectively. The magnitude of IV estimate is larger than OLS estimate, suggesting students from different income background may have a different taste for working. The coefficient for parental income from IV regression is estimated at -2.425 and statistically significant, suggesting a 1,000 USD higher parental income leads to about 2.5 fewer weekly working hours.

Note that we assume that the main channel through which the parental job-loss shock affects college students' working hours is via reduced parental income. To further confirm that a father's job loss is associated with reduced financial resources for the child, we checked whether the child took out a new loan right after their father's job loss. The result is shown in column (4) of Table 5. Controlling for an individual fixed effect, we found that students whose father experienced a job loss in the previous 4 months increased the probability of taking out a new loan by 5 percentage points. This result suggests that a father's job loss is indeed associated with a reduction in financial resources that compelled students to take up a new loan and work more.

Overall, we conclude that parental income is an important determinant for students' working decisions during college. Combining this result with the findings in Table 3, we believe parental transfer is the key mechanism behind this result; children whose fathers hit a job-loss shock will receive less transfer from their parents and will need to work more.

2.3 Discussion

We have shown that a large number of college students work a substantial number of hours in low-skill jobs, and students who have fewer resources (especially parental transfers) work more. When students have to work a substantial number of hours, the time for studying can be limited and the academic outcome can be negatively affected as described in Table 1. In Figure 2, we further depict the binned scatter plot for the highest grade completed as of age 30 with respect to first-year working hours after college enrollment. The relationship between highest grade completed and working hour is non-monotonic for those who work fewer than the median hours (676), but the highest grade completed decreases sharply for those who work more than the median hours.

The finding in Figure 2 is in line with previous studies on the relationship between labor supply during college and students' outcomes. By accounting for the dynamic selection problem associated with unobservable heterogeneity, Hotz et al. [2002] find a potentially detrimental effect (insignificant or negative effect) of working during college on the wage rate after graduation. On the other hand, Ehrenberg and Sherman [1987] find that on-campus jobs have a positive effect on academic outcomes, whereas off-campus jobs have a negative effect, which suggests heterogeneous effects of self-financing by type of job.[12] More direct evidence is found in Stinebrickner and Stinebrickner [2003], who address the endogeneity problem regarding students' labor supply by using an IV based on the mandatory work-study program at Berea College (a liberal arts college in Kentucky). They find that additional working hours during college can have a quantitatively large and statistically significant negative effect on students' academic achievement.[13]

To better understand the reasons behind students' self-financing and its potential impact on human

[12]Relatedly, by using Danish data, Joensen and Mattana [2022] find that students' work experience in a in a study-relevant job leads to a substantial increase in their post-college earnings. Light [2001] finds that students gain skills not only from in-class experience, but also from on-the-job training in the labor market. Because Light's study is based on total work experience during the schooling period, including high school and college, the impact of college-period labor supply on students' outcomes is not separately estimated.

[13]Relatedly, Stinebrickner and Stinebrickner [2008b] document a significant and positive causal effect of study time on grade performance among students at Berea College.

capital accumulation during college, we present a theory of college students' working decisions in the following section.

3 The Model

In this section, we provide a theory that can rationalize the observed pattern of students' working hours during college and its implication on college investment. Because parental transfer is important in determining students' working hours, we explicitly model the interaction between college students' labor supply, investment, and their parents' endogenous decision to transfer in the presence of financial constraints. To better illustrate the main mechanism, we focus on decisions made during four-year college. In Appendix A, we extend the model to include both two-year and four-year colleges.

3.1 Environment

A family consists of parents and a child. They live two periods: the child's college period and the child's working period. The parents are altruistic and hence receive utility from their child's utility, but the child cares only about herself. The parents first make a transfer (m_p) to the child before the college period starts, and then the child decides whether to complete college or drop out, how much money to invest in college education, how many student loans to take out, and how many hours to work during college. We abstract from the post-schooling transfer from the parents to the child. The per-period utility from consumption (c) of the parents and the child is given by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$. A child is characterized by her ability $A \in \mathbb{R}_+$ and an unobserved characteristic $\epsilon \in \mathbb{R}_+$ (which we explain below), and parents are characterized by their income $x_p \in \mathbb{R}_+$ and an altruistic preference $\alpha \in \mathbb{R}_+$.

The child's self-financing can reduce the financial burden of the child and the parents, but it may have a negative impact on the child's human capital accumulation. Human capital accumulation from a college education (h_J) is a function of four components: the child's ability, college completion ($J \in \{0,1\}$), monetary investment (m_k), and the time/effort the student puts into the college education.

If the child completes college ($J = 1$), in line with the Ben-Porath model, she needs to invest time to accumulate human capital. We further assume child ability is complementary to monetary and time investment in the following form:

$$h_1 = \overline{h} + A\{m_k^\gamma + (T - \epsilon n_k)^\gamma\}^{\frac{\rho}{\gamma}}, \quad \rho < 1. \tag{1}$$

T represents the time endowment for college education, which is the same for all individuals. n_k is the working hours during the college period. The child's time investment decreases as she works more toward self-financing.[14] The extent to which working hours affect human capital accumulation depends on ϵ, the unobservable characteristic of the child. We allow such unobserved heterogeneity in the form of ϵ, which can be interpreted as an individual's intrinsic "motivation": highly motivated students (students with a low ϵ) learn better than students who are not motivated (students with a high ϵ), given the same number of working hours. Therefore, the marginal cost of working is smaller for highly motivated students than for less motivated students, and highly motivated students tend to work more than less motivated students. We assume $\rho < 1$ to guarantee that the optimal level of human capital is finite. We also assume that $\gamma < 0$ so that the time and monetary investment is complement in the production function. $\overline{h}$ is the initial human capital stock before the college education.

If the child does not complete college ($J = 0$), the human capital depends only on the child's ability in the following form:

$$h_0 = \overline{h} + \phi_0 + \phi_1 A. \tag{2}$$

ϕ_0 captures a constant increase in human capital from attending a four-year college, and ϕ_1 captures the extent to which human capital of college dropouts varies by A. A minimum monetary investment

[14] The relationship between human capital and working during college may be nonmonotonic. Working as a cashier can be a valuable experience for students, but if too many hours are spent in such a job, a student may lose other opportunities to increase human capital. We only model this negative relationship.

(m_d) is required to enroll in a college such that $m_k \geq m_d$, and the child pays m_d if she drops out.[15] Similarly, the child works n_d hours during college ($n_k = n_d$) if she drops out.[16] To finance the college cost, the child can take out student loans (d_k), but there exists a financial constraint such that $d_k \leq \overline{d}$. Various factors can explain a student's borrowing during college. One such constraint might be the credit constraint, which sets limits on how much students can borrow. Recent evidence supporting the existence of credit constraints for college students includes Black et al. [2020]. Using Texas administrative data, Black et al. [2020] illustrates that nearly half of dependent undergraduates hit the annual borrowing limits of federal loans (Stafford loan), leading to the conclusion that millions of U.S. undergraduates encounter credit constraints. Another potential constraint is the lack of insurance against uncertainty in the future labor market outcome (Johnson [2013]). Additionally, an internal constraint, such as a behavioral bias known as debt aversion preference, can also influence students' borrowing decisions (Gopalan et al. [2021]). Our main mechanism, which we explain below, applies regardless of the underlying cause of the constraint.[17]

We first consider the child's problem. Given her parents' transfer (m_p), the child maximizes her

[15] We abstract from different lengths of the schooling period between dropping out of ($J = 0$) and completing ($J = 1$) college when we demonstrate the main mechanism in the two-period model. However, we account for differences in schooling periods and foregone earnings between dropouts and graduates in our life-cycle model and quantitative analysis.

[16] We model dropping out as an outside option for college students and assume that h_0 does not depend on time or monetary investment. Given that we assume h_0 does not depend on time investment, we fix n_d as a constant.

[17] We abstract the financial friction parents may face. In our model, although parents can borrow at the risk-free interest rate, they may not completely relax the financial constraint their child faces, because their child will never pay them back. Parental transfers in our model are driven by an altruistic motive. For low-income parents, the marginal cost of the transfer, which is the forgone marginal utility of consumption, is high; therefore, the transfer of low-income parents is, on average, smaller than that of high-income parents, even without financial constraints for parents. Therefore, incorporating a financial constraint for parents would not change our results significantly.

lifetime utility by choosing the first- and second-period consumption $\{C_{k1}, C_{k2}\}$ and $\{n_k, m_k, d_k, J\}$:

$$
\begin{aligned}
\max_{\{C_{k1},C_{k2},n_k,m_k,d_k,J\}} \quad & u(C_{k1}) + \beta u(C_{k2}) \quad \text{subject to} \\
& C_{k1} + m_k \leq w n_k + d_k + m_p, \\
& C_{k2} + R d_k \leq h, \\
& d_k \leq \overline{d}, \\
& h = J \cdot \left[\overline{h} + A\left\{m_k^{\gamma} + (T - \epsilon n_k)^{\gamma}\right\}^{\frac{\varrho}{\gamma}}\right] + (1 - J) \cdot \left[\overline{h} + \phi_0 + \phi_1 A\right], \\
& m_k \geq m_d, \quad n_k \geq 0, \quad T - \epsilon n_k > 0, \quad \text{if } J = 1, \\
& m_k = m_d, \quad n_k = n_d, \quad \text{if } J = 0.
\end{aligned}
$$

R and w are the risk-free gross interest rate and wage (for college students), respectively.

Knowing how the child behaves given parental transfer, the parents maximize their lifetime utility and their child's value by choosing the first- and second-period consumption $\{C_{p1}, C_{p2}\}$, transfer (m_p), and amount of savings (a_p):

$$
\begin{aligned}
\max_{\{C_{p1},C_{p2},m_p,a_p\}} \quad & u(C_{p1}) + \beta u(C_{p2}) + \alpha V_k(A, \epsilon, m_p) \quad \text{subject to} \\
& C_{p1} + m_p + a_p \leq x_p, \\
& C_{p2} \leq R a_p, \quad m_p \geq 0,
\end{aligned}
$$

where V_k is the value from the child's problem. α captures the extent of the parents' altruistic preference.

Let $s_k = (m_k, n_k, d_k, J, C_{k1}, C_{k2})$ be the strategy of the child and let $s_p = (m_p, a_p, C_{p1}, C_{p2})$ be the strategy of the parents. Let V_p be the value from the parents' problem. Let $s_k(s_p)$ be the best response of the child given the parents' strategy s_p. The subgame perfect Nash equilibrium is $\{s_k^*, s_p^*\}$ such that $V_k(s_k^*, s_p^*) \geq V_k(s_k, s_p^*)$ for all $s_k \neq s_k^*$ and $V_p(s_p^*, s_k^*(s_p^*)) \geq V_p(s_p, s_k^*(s_p))$ for all $s_p \neq s_p^*$.

3.2 Discussion

We impose a few assumptions to render our model tractable and parsimonious. Before characterizing the model, we discuss the limitations and justifications for such assumptions.

First, we assume parents are altruistic, but we abstract from other motives such as the exchange motive (Light and McGarry [2004]). Because most papers on inter vivos transfers mainly rely on altruism (e.g., Becker and Tomes [1986]; Restuccia and Urrutia [2004]; Brown et al. [2011]), we follow previous studies to emphasize our novel mechanism regarding self-financing and parental transfer. In addition, from the Health and Retirement Study (HRS), we find the upstream transfer made by the child is small; the median amount of transfer from the child is about 1,000 USD over two years.[18] Also, the child with a higher labor income is less likely to provide informal care for elderly parents (McGarry [1998]) due to their high opportunity cost. Thus, the exchange motive might not play a quantitatively important role in explaining parental transfer for the child's college education.[19]

Second, to endogenize parental transfers in a simpler way, we abstract from repetitive interactions between parental transfers and student actions. In the data, parental transfers are primarily concentrated in the first two years of enrollment periods. Therefore, we assume that parents first decide on the amount of transfers, and students choose their actions given parental transfers.

Finally, to better illustrate our mechanism, we abstract from leisure in our model. A key concern may be that students could reduce their leisure time instead of sacrificing their study time while working for financing. However, our empirical analysis suggests otherwise. Using the ATUS 2004 data, we found that a student's study time significantly decreases with working hours (see section III of Online Appendix for more details). To ensure the robustness of our quantitative results, we also

[18]The distribution of monetary transfer from the adult child to parents is largely skewed to the right. Although the mean is 2,555 USD, due to less than 1% of children making a transfer of more than 25,000 USD to the parents, about 27% of children give less than 500 USD to parents over two years.

[19]Brown et al. [2011] consider parental transfers both during and after schooling periods. We abstract from parents' post-schooling transfer, given that information on parents' post-schooling transfer is not available in the NLSY97. Empirically, Haider and McGarry [2012] show parental transfer made after the child's schooling period is not correlated with the transfer made during the schooling period.

incorporate leisure into our quantitative model and present the results in Appendix B.2.

3.3 Equilibrium under Optimal Investment

We first analyze a situation in which the financial constraint is not binding. In this case, the child can optimally invest and smooth consumption. Assuming an interior solution when $J = 1$, the child chooses m_k that equalizes the marginal gain in human capital to the interest rate ($\frac{\partial h}{\partial m_k} = R$). Similarly, the child chooses n_k so that the marginal cost of self-financing that reduces human capital is equalized to the marginal benefit of self-financing that increases income ($-\frac{\partial h}{\partial n_k} = wR$). The optimal monetary and time investments for an interior solution are

$$m_k^* = K_1 A^{\frac{1}{1-\rho}}, \tag{3}$$

$$T - \epsilon n_k^* = \left(\frac{\epsilon}{w}\right)^{\frac{1}{1-\gamma}} K_1 A^{\frac{1}{1-\rho}}, \tag{4}$$

where $K_1 = \left[\frac{\rho}{R}\left\{1 + \left(\frac{\epsilon}{w}\right)^{\frac{\gamma}{1-\gamma}}\right\}^{\frac{\rho}{\gamma}-1}\right]^{\frac{1}{1-\rho}}$. When students can optimally invest and smooth consumption over two periods, the college-completion decision is characterized by the lifetime income. The child chooses to complete college if the lifetime income from completing college is greater than that from dropping out.

Now consider the parents' problem. Without the binding constraint, the child can always optimally borrow to finance education and consumption and maximizes the lifetime income taking parental transfer as given. Therefore, the parental transfer does not affect the child's human capital. Altruistic parents make a transfer to equalize the marginal utility from consumption across generations, and parental transfer is driven by the compensating motive. Because the child's lifetime income increases by A and the marginal utility from transfer decreases by the child's income, parental transfer decreases by A.

3.4 Equilibrium under Suboptimal Investment

We now analyze a situation in which the financial constraint binds. If $d_k = \overline{d}$, the first-order conditions with respect to interior solutions for m_k and n_k for those who do not drop out are

$$\frac{\partial h}{\partial m_k} > R, \tag{5}$$

$$wu'(wn_k + m_p + \overline{d} - m_k) = \beta\big(-\frac{\partial h}{\partial n_k}\big)u'(h - R\overline{d}). \tag{6}$$

The marginal return from monetary investment becomes greater than the interest rate, resulting in underinvestment. Also, the marginal return from self-financing increases ($-\frac{\partial h}{\partial n_k} > wR$), and the child works more than the optimal level. Extra working hours directly reduce the effort investment and, thus, reduce human capital. Also, if $\gamma < \rho$, the marginal return from monetary investment decreases as working hours increase. Therefore, the extra working hours can further reduce human capital due to a reduction in monetary investment. Some students who could have graduated in the absence of the constraint may decide to drop out because the value from graduation becomes lower than the value from dropout.

The binding constraint also affects parental transfer. The marginal impact of the parental transfer on the child's value V_k can be represented as

$$\frac{dV_k}{dm_p} = \underbrace{\frac{\partial V_k}{\partial m_p}}_{\text{(I)}} + \underbrace{\frac{\partial V_k}{\partial h}\frac{\partial h}{\partial m_p}}_{\text{(II)}\geq 0 \text{ if } d_k = \overline{d}} \quad . \tag{7}$$

In contrast to the case without binding constraint, the second term is added. Parental transfer can increase child utility by increasing child initial endowment, and hence consumption, as described in part (I) of equation (7). When the constraint binds, the parental transfer can further increase child utility by increasing child investment and human capital, as described in part (II) of equation (7). By relaxing the constraint for the child's consumption, additional parental transfer reduces self-financing, which in turn increases time investment in human capital. If $\gamma < \rho$, the marginal return from a monetary investment increases by the student's time/effort. In this case, an additional parental transfer can also increase the child's monetary investment.

Note that parental transfers can increase with the child's ability through part (II) of equation (7). Specifically, if the elasticity of the child's human capital with respect to parental transfer is higher for high-ability students, then part (II) of equation (7) increases with respect to the child's ability. Thus, the amount of parental transfer can increase as A increases.

4 Quantitative Framework

To quantitatively evaluate the trade-off between self-financing and human capital investment while accounting for the endogenous response of parents, we extend the two-period model introduced in section 3 into a life-cycle model.

4.1 Life-Cycle Model

In our quantitative analysis, we estimate the following life-cycle model. In extending two-period model to a life-cycle model with more realistic features, we follow Lochner and Monge-Naranjo [2011]. Time is continuous. The child lives for $t \in [0, T_k]$, where $t \in [0, P_J)$ is the college period, $t \in [P_J, R_k)$ is the working period, and $t \in [R_k, T_k]$ is the retirement period. The timing when the college period ends (P_J) depends on whether the child drops out ($J = 0$) or completes college ($J = 1$). Specifically, the college period decreases by half if the child drops out: $P_0 = \frac{1}{2}P_1$.[20] The parents live for $t \in [0, T_p]$ periods, where $t \in [0, R_p)$ is parents' working period and $t \in [R_p, T_p]$ is parents' retirement period.

The parents first make a transfer (m_p) to the child at $t = 0$. The per-period utility from consumption (c) of the parents and the child is given by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$. As in the two-period model, a child is characterized by her ability $A \in \mathbb{R}_+$, unobserved characteristics $\epsilon \in \mathbb{R}_+$ that captures the individual's

[20] To simplify the quantitative exercises, we assume that the timing of labor market entrance is the same for all college graduates.

intrinsic motivation. We additionally allow different types of children regarding their debt-aversion preference, which we explain later. Parents are characterized by their lifetime income $x_p \in \mathbb{R}_+$ and an altruistic preference $\alpha \in \mathbb{R}_+$.

To make the life-cycle model tractable, we make the following assumptions. First, the human capital production function that determines labor income at the end of the college period ($t = P_J$) is defined as follows. For college graduates, $h_1 = \overline{h} + A\{m_k^\gamma + (T - \epsilon n_k)^\gamma\}^{\frac{\varrho}{\gamma}}$, where $m_k = \left\{ \int_0^{P_1} e^{-rt} m_{kt} dt \right\}$ and $n_k = \left\{ \int_0^{P_1} e^{-rt} n_{kt} dt \right\}$.[21] For college dropouts, $h_0 = \overline{h} + \phi_0 + \phi_1 A$, $m_k = m_d$, and $n_k = n_d$.

Second, to better incorporate how financial constraints affect college education in our quantitative analysis, we modify the financial constraint assumed in the two-period model in two ways. First, the borrowing limit is defined as $\overline{d} = (1 - s)m_k$ so that the present value of the total student loan borrowing, denoted as $d_k = \left\{ \int_0^{P_J} e^{-rt} d_{kt} dt \right\}$ cannot exceed the present value of monetary investment net of grant ($d_k \leq (1 - s)m_k$), where s is the share of monetary investment supported by grants.[22] Thus, the borrowing limit in the quantitative model is tied to educational investment, capturing the institutional feature of US student loans that applies to both public and private loans.

We use the above specification to capture the financial constraint in our quantitative analysis for the following reasons. First, although the tied-to-investment constraint is typically less stringent than the fixed borrowing constraints associated with federal Stafford loans,[23] if we allow students to borrow from private loans, the tied-to-investment constraint becomes a more relevant borrowing limit because private loans usually cover expenses up to the cost of attendance net of grants. Second, we find suggestive evidence from the NPSAS2004 that many students find it difficult to finance living

[21] With this specification, the model is characterized up to m_k and n_k, whereas $\{m_{kt}, n_{kt}\}$ for $t \in [0, P_J)$ are indeterminate as long as $m_k = \left\{ \int_0^{P_J} e^{-rt} m_{kt} dt \right\}$ and $n_k = \left\{ \int_0^{P_J} e^{-rt} n_{kt} dt \right\}$ are satisfied.

[22] With this specification, the child can borrow or save within the college period as long as the total borrowing during the college period does not exceed the borrowing limit $(1 - s)m_k$.

[23] Specifically, the unsubsidized Stafford loan has annual limits of 2,625, 3,500, and 5,500 USD for the first, second, and third year and beyond of college, respectively, before 2007. Considering the average cost of attendance for four-year colleges, approximately \$13,096 (denoted as m_k), the fixed annual borrowing limit would be stricter than the tied-to-investment constraint for most students, given that the share of the cost of attendance covered by grants is typically below 0.5 (Table A2).

expenses without working.[24] Hence, students might still encounter financial constraints when covering all expenses during their college years.

Third, in addition to the borrowing constraint, a behavioral bias can also affect the child's borrowing decision. Let $\tau = \{0, 1\}$ be the type of the child, which takes a value of 1 if the child is debt-averse during college. A child with a debt-aversion preference has an "internal constraint" during college ($d_k \leq 0$) in addition to the borrowing constraint ($d_k \leq m_k(1-s)$), and she borrows rationally after college. Having a debt-aversion preference is independent of other characteristics, and the proportion of students with a debt-aversion preference is q_τ.[25]

Enrolling in college requires a minimum monetary investment such that $m_k \geq m_d$. The hourly wage during the college period is fixed at w. Then, the present value of labor income during college at $t = 0$ can be written as wn_k. The labor income increase at a constant rate g over the working period $t \in [P_J, R_k)$. Define $\Phi_J = \int_{P_J}^{R_k} e^{(g-r)(t-P_J)} dt = \frac{1}{g-r}\left[e^{(g-r)(R_k-P_J)} - 1\right]$. Then, the present value of lifetime labor income at the end of the college period ($t = P_J$) is $\Phi_J h_J$.

[24] From the NPSAS 2004 data, we discover that 77.1% of enrolled Bachelor's degree students, who paid tuition and fees, indicated their reliance on work to afford school during that enrollment period. Even among students who report a net tuition and fees value of zero after accounting for all grants, 79.6% still expressed the need to work in order to afford school. Within the subgroup of students who worked during the first year and reported a net zero for tuition and fees after grants, a significant 87.7% mentioned earning spending money or covering living expenses as their primary motivation for working, while a mere 7.6% cited gaining job experience as their main reason.

[25] The literature suggests some students do not borrow even though borrowing provides an obvious monetary benefit due to debt aversion (e.g., Field [2009]; Caetano et al. [2019]; Gopalan et al. [2021]), informational friction (e.g., Hoxby and Avery [2013]; Avery et al. [2007]; Marx and Turner [2019]), or other behavioral bias (e.g., Dynarski and Scott-Clayton [2006]; Bettinger et al. [2012]; Marx and Turner [2020]). We acknowledge that some students face these other constraints that prevent them from borrowing and, thus, can also lead them to work while in college. To incorporate such constraints in a parsimonious way, we assume that some students never want to borrow during college and call them the debt-averse type.

The child's problem can be defined as follows:

$$\max_{\{C_{kt},n_k,m_k,d_k,J\}} \int_0^{T_k} e^{-\delta t} u(C_{kt})dt \quad \text{subject to}$$

$$(1-s)m_k + \int_0^{P_J} e^{-rt} C_{kt}dt \leq wn_k + d_k + m_p, \tag{8}$$

$$\int_{P_J}^{T_k} e^{-r(t-P_J)} C_{kt}dt \leq \Phi_J h - e^{rP_J} d_k, \tag{9}$$

$$d_k \leq (1-\tau)m_k(1-s), \tag{10}$$

$$h = J \cdot \Big[\overline{h} + A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}}\Big] + (1-J) \cdot \Big[\overline{h} + \phi_0 + \phi_1 A\Big], \tag{11}$$

$$n_k \geq 0, \quad T - \epsilon n_k > 0, \quad m_k \geq m_d, \quad \text{if} \quad J = 1, \tag{12}$$

$$n_k = n_d, \quad m_k = m_d, \quad \text{if} \quad J = 0, \tag{13}$$

where δ is the subjective discount rate. Equations (8) and (9) are the budget constraint during and after college, respectively. Equations (10) and (11) represent the financial constraint and the human capital production function, respectively.

The child smooths her consumption within each sub-period $t \in [0, P_J)$ and $t \in [P_J, T_k]$. Therefore, consumption grows at the constant rate $(r-\delta)/\sigma$ during and after college. If the financial constraint is binding, consumption will exhibit a discrete jump at $t = P_J$. Denote $\hat{C}_{k1} = \int_0^{P_J} e^{-rt} C_{kt}dt$, and $\hat{C}_{k2} = \int_{P_J}^{T_k} e^{-r(t-P_J)} C_{kt}dt$. Rearranging the child's problem leads to

$$\max_{\{\hat{C}_{k1},\hat{C}_{k2},m_k,n_k,d_k,J\}} \frac{\big(\hat{C}_{k1}\big)^{1-\sigma}}{1-\sigma} + \hat{\beta}\frac{\big(\hat{C}_{k2}\big)^{1-\sigma}}{1-\sigma} \quad \text{subject to}$$

$$\hat{C}_{k1} = wn_k + d_k + m_p - (1-s)m_k, \tag{14}$$

$$\hat{C}_{k2} = \Phi_J h - e^{rP_J} d_k, \tag{15}$$

equations (10), (11), (12), and (13),

where $\hat{\beta} = e^{-\delta P_J}\left(\frac{\Theta_{[P_J,T_k]}}{\Theta_{[0,P_J]}}\right)^\sigma$ and $\Theta[t_0, t_1] = \int_{t_0}^{t_1} e^{[((r-\delta)/\sigma)-r](t-t_0)}dt$.

Given that parents have access to the complete credit market, the parents' problem becomes equivalent to solve the following problem:

$$\max_{m_p} \frac{(\Theta_{[0,T_p]})^{\sigma}(x_p - m_p)^{1-\sigma}}{1-\sigma} + \alpha V_k(A, \epsilon, \tau, m_p) \quad \text{subject to} \quad m_p \geq 0,$$

where $V_k(A, \epsilon, \tau, m_p)$ is the value from the child's problem.

One limitation of our current specification is that we do not account for the heterogeneity of college types and leisure considerations. We conduct additional analyses that incorporate these components in Appendix B, and find that our main findings remain robust.

4.2 Predetermined Parameters, Specification, and Variable Construction

We first specify the predetermined parameters, which are summarized in Table 6. Focusing on college education, we normalize time so that one period represents four calendar years. In our life-cycle model, the child attends a college for $t = [0, P_J)$, where $P_0 = 0.5$ and $P_1 = 1$. The child works for $t = [P_J, R_k)$, where $R_k = 10$ and lives until $T_k = 15$. The parents retire at $R_p = 5$ and live until $T_p = 10$. We choose $\sigma = 2$, which belongs to the empirically supported range for the intertemporal elasticity of substitution (IES) (Browning et al. [1999]).[26] We set 0.07 for the growth rate of income over four years (g).[27]

A student is defined as a college dropout if she ever enrolled in a four-year college, and the highest grade completed as of age 30 is less than or equal to 14.[28] The working hours for dropouts are set at 2,000, the median working hours among dropouts for the first two years after college enrollment. As explained in section 4.3, the monetary investment is calculated by the highest grade completed minus 12, multiplied by the annual sticker price. The annual sticker price for attending a four-year college is

[26] A greater value of IES ($\frac{1}{\sigma}$) implies a weaker preference for intertemporal consumption smoothing. To examine the robustness of the findings when we assume a weaker preference for intertermporal consumption smoothing, we estimate the model with a higher value of IES ($\sigma = 1.5$) in Appendix B. The main findings remain robust.

[27] According to the experience-wage profile in Lagakos et al. [2018], the average wage for workers with 35-39 years of potential experience is 88% higher than for workers with 0-4 years of potential experience in the US, which translates into an annual growth rate of 1.7%.

[28] We choose this particular margin to define a dropout because the labor income after college presents a discrete jump when the highest grade completed changes from 14 to 15 in our sample. A similar definition of a dropout is used in the literature (e.g., Stinebrickner and Stinebrickner [2008a]).

calculated at 13,096 USD from NPSAS 2004. We specify the minimum monetary investment (m_d) as $13,096 \times 2$, assuming college dropouts enroll for two years.

Grant is calculated for each family income quartile based on the NPSAS 2004. The share of sticker price covered by grant (s) is 0.47, 0.21, 0.14, and 0.10 for the first, second, third, and fourth quartile, respectively, of the family income distribution.[29] Accordingly, the borrowing constraint is set as the borrowing limit for an additional year of college education for each income quartile, which is the average annual sticker price minus grants.

For the lower bound of the initial stock of human capital, $\overline{h}$, we use the average annual income of high school graduates, which is 16,000 USD.[30] For the wage rate of college students, w, we use the average hourly wage of college students ages 18 - 21 (8 USD), focusing on income during the first two years of the college-enrollment period. We use the same value of w for all students, because we find no systematic variation in w during the college period by students' AFQT score or parental income. The time endowment for college education T is set to be 20,000, which is hours available over four years, subtracting time spent sleeping and eating; we use the time-diary data from the ATUS 2004 to get the average time college students spend sleeping and eating. We set the annual interest rate as 0.05 based on the 10-Year Treasury Bill between 1998 and 2006.

We specify the distribution of ϵ and α as follows: $\log \epsilon \sim N(\epsilon_0, \sigma_\epsilon)$ and $\alpha = \left(\frac{x_p}{10000}\right)^{\alpha_1} + \exp(u_\alpha)$, where $u_\alpha \sim N(\alpha_0, \sigma_\alpha)$. Note that we allow for the possibility that the altruistic preference is systematically different across different income levels.

The variables used for estimation are summarized in Table 7. For parents' lifetime income x_p, we calculate parents' income over 20 years by multiplying the average family income when the child is between 16 and 17 by $4\Phi_p$, where $\Phi_p = \int_0^{R_p} e^{(g-r)t} dt = \frac{1}{g-r}\left[e^{(g-r)R_p} - 1\right]$. Working hours in the later periods in college may also include working to improve human capital (e.g., internships). For

[29] Table A2 in Appendix A shows the college cost and grant in detail.

[30] We calculate the average income of high school graduates between ages 22 and 27.

this reason, we double the working hours during the first two years of college enrollment to construct working hours for self-financing among college graduates. Following the literature (e.g., Lochner and Monge-Naranjo [2011]), the monetary investment is based on the highest grade completed. Specifically, the total monetary investment for the graduate is calculated by the highest grade completed minus 12, multiplied by the annual sticker price.[31] For the initial human capital after college, we multiply the average annual income for a student when she is between 26 and 30 by four. Finally, we use AFQT score for A.

4.3 Identification

We have the following structural components $\{F(\epsilon), F(\alpha), \rho, \gamma, \phi_0, \phi_1, q_\tau\}$ to be identified from the data. We first describe how the two unobserved type distributions $\{F(\epsilon), F(\alpha)\}$ are identified given other parameters $\{\rho, \gamma, \phi_0, \phi_1, q_\tau\}$. More detailed explanations regarding the identification of $F(\epsilon)$ and $F(\alpha)$ can be found in section II of the Online Appendix.

The distribution of ϵ can be identified by the distribution of working hours during the college period. Working hours for students from high-income families can be particularly informative. Those students are less likely to be constrained, due to a higher parental transfer. As shown in section 3.3, altruistic preference parameter α does not affect the time and monetary investments for unconstrained students. As a result, the distribution of working hours for students from high-income families is mostly influenced by the distribution of ϵ conditional on observed student ability (A). Given the parametric assumption on the distribution for ϵ, $\{\epsilon_0, \sigma_\epsilon\}$ can be identified by various moments conditions of working hours among students from high-income families. For instance, the share of working students from high-income families and their average working hours can help identify $F(\epsilon)$.

Once the distribution of ϵ is recovered, the distribution of parental transfers is solely determined by the distribution of α conditional on (A, x_p). With the parametric restriction on α, we can identify

[31] In Appendix B, we also extend our model to allow for different sticker prices and grants for public and private colleges. Our main findings are robust to this extension.

$\{\alpha_0, \alpha_1, \sigma_\alpha\}$ by using various moments of parental transfers. For example, the share of students with positive parental transfers and the average parental transfer can help identify $(\alpha_0, \sigma_\alpha)$. On the other hand, depending on α_1, the relationship between the average parental transfers across different income quartiles will change. For example, as α_1 increases, average parental transfers among the fourth income quartile relative to the first quartile will increase. Therefore, average parental transfers across different income quartiles can identify α_1.

The proportion of students with a debt-aversion preference (q_τ) directly affects the proportion of college students with no borrowing. Therefore, the proportion of college students without borrowing can identify q_τ. On the other hand, the average income after college (h) and the average monetary investment (m_k) can be written as a function of the production parameter (ρ, γ). Therefore, the aforementioned two moments can be informative in identifying (ρ, γ). $\{\phi_0, \phi_1\}$ directly changes the income and the value of dropouts. Therefore, the aggregate proportion of college dropouts and the proportion of college dropouts conditional on A can be informative in identifying $\{\phi_0, \phi_1\}$.

4.4 Estimation

We estimate the structural parameters using the method of simulated moments. To estimate 10 structural parameters, we target 19 moment conditions. The choice of moment conditions is based on the identification argument.[32] Table 8 shows how the model fits the data with respect to 19 moment conditions. To normalize units across different moment conditions, we present weighted values by using the square roots of the sample variances. The model tends to overstate the parental transfer for

[32] For identification of $F(\epsilon)$ parameters ($\{\epsilon_0, \sigma_\epsilon\}$), we target the proportion of working college students and the first and second moments of working hours for college students. Although our identification argument relies on those from high-wealth families, we target the entire population. First, defining the income threshold for high-wealth families is rather arbitrary. Second, we get similar estimates when we target the proportion of working college students and the first and second moments of working hours for college students conditional on the above median or the above 75th percentile of parental income distribution. For identification of $F(\alpha)$ parameters ($\{\alpha_0, \alpha_1, \sigma_\alpha\}$), we target the share of students with positive parental transfers and the average parental transfers conditional on each parental income quartile. We also target the second moment of parental transfer. For identification of production-function parameters ($\{\rho, \gamma\}$), we target the average income after college and the average monetary investment for college graduates. For identification of the dropout parameters ($\{\phi_0, \phi_1\}$), we target the proportion of graduates, the average income among dropouts, and the correlation between dropping out and AFQT scores. Finally, for identification of debt-aversion parameter (q_τ), we target the proportion of those who never borrowed during their enrolled period both for dropouts and graduates.

high-income families (M13) in order to match the parental transfer for low-income families (M10-12). Overall, the model fits the data reasonably well.

We do not directly target correlations between (1) parental transfer and ability and (2) working hours and ability. Thus, we can check the extent to which the model can also fit those variations in the data. As discussed in section 3.3, without the financial constraint, altruistic parents have less incentive to transfer to the high-ability child, which implies a negative correlation between parental transfer and child ability. Table 10 shows that when we incorporate the constraint that restricts consumption smoothing between college and working periods and self-financing, the model can generate a positive correlation between parental transfer and child ability, as observed in the data. Our model abstracts from other motives of parental transfer, such as a paternalistic motive (e.g., Abbott et al. [2019]), which may be why our model cannot perfectly explain the positive gradient of parental transfer with respect to child ability.

To further strengthen our identification argument, we also conduct a sensitivity analysis. Specifically, we use the measure proposed by Andrews et al. [2017] called "sensitivity," which captures the relationship between parameter estimates and the moments of the data they depend on.[33] In Table 9, we report the moments that are highly sensitive to each parameter. The moment numbers correspond to the ones in Table 8. Notably, the moments we consider important for identifying each parameter (indicated by underlining) mostly correspond to the sensitive moments.

5 Results

In this section, we present our results from the model estimation.

[33]The sensitivity of the parameter estimates with respect to the moment vector is a 10 (number of parameters) $\times$ 19 (number of moment conditions) matrix $\Lambda = -(\mathbf{D}'\mathbf{W}\mathbf{D})^{-1}\mathbf{D}'\mathbf{W}$, where $\mathbf{W}$ is the 19 $\times$ 19 weighting matrix, and $\mathbf{D} = \frac{\partial \mathbf{m}_{sim}(\psi)}{\partial \psi}|_{\psi=\hat{\psi}}$ is the 19 $\times$ 10 derivative matrix of the moment vector with respect to the model parameters evaluated at the estimates. The sensitivity of a parameter is the corresponding row of the sensitivity matrix to the parameter. Each column of the sensitivity of a parameter represents a measure of the relationship between the parameter and the corresponding moment of the data used for estimation. Following Gayle and Shephard [2019], we calculate the moment with maximum (absolute) sensitivity for each parameter and present the moments whose sensitivity is at least 50% of the maximal. As in Gayle and Shephard [2019], we multiply the mth column of the sensitivity by the standard deviation of the mth moment to make the scales of the moments comparable.

5.1 Estimates

Table 11 shows the estimates for model parameters. First, γ (-0.61) is smaller than ρ (0.83), which implies that the returns to monetary investment increase with the time investment in human capital accumulation. Second, parents' altruistic preferences show substantial heterogeneity. For instance, although the amount of parental transfer increases by family income, the altruistic preference measured by α decreases by family income ($\alpha_1 = -2.27$). Poor parents are estimated to be relatively more altruistic than rich parents, because they also contribute to financing their child's education, although the utility cost of doing so is much higher than for rich parents. Third, students' unobservable characteristic ϵ also shows substantial heterogeneity, which suggests accounting for unobserved heterogeneity is important in understanding the impact of students' working hours on the labor market outcome. Finally, the share of the debt-averse type (q_τ) is 0.32, which implies that about one-third of students in the sample would not take student loans, for reasons (e.g., behavioral biases) other than limited loan availability.[34]

5.2 Policy Experiments

In this section, we conduct counterfactual policy analyses to evaluate a wage subsidy policy. We examine the effects of such a policy while accounting for the endogenous response of parents. Subsequently, we explore how these effects are altered when assuming that parents do not adjust their transfers accordingly, in order to quantify the importance of the interaction between parental transfers and the child's self-financing when evaluating the policy implications.

5.2.1 Wage Subsidy

We are considering the following wage subsidy policy: students receive a 2 USD subsidy for every working hour during college. However, there is a working hour restriction in place to ensure that

[34]Note that the share of students who do not take student loans in the data is 0.37. Therefore, most students without student loans in the data are explained mainly by the debt-aversion preference.

students who complete college cannot exceed 4,000 hours of work throughout their college years.[35] A wage subsidy is closely related to the federal work-study program. The federal work-study program in the US provides part-time jobs for undergraduate students with financial needs that allow them to earn money to help pay education expenses. Although the program has been implemented as a "self-help" component of financial aid, government subsidies play a vital role in the program. Although the share varies by institution, a maximum of 75% of the salary the student receives can be financed by the government.[36] As a result, government spending on the work-study program is sizable: 0.96 billion USD in 2018.[37] On the other hand, the federal work-study program generally imposes a working hour restriction to prevent students from overworking. The specific details of this restriction may vary depending on the institution and program guidelines, but a typical restriction is that students cannot work more than 20 hours per week during the academic year. We choose to use a limit of 4,000 hours over four years to partially reflect this feature. Therefore, our framework can be useful for understanding the impact of the work-study program in the form of a wage subsidy.

Column (1) of Table 12 summarizes the aggregate impacts of the wage subsidy policy. The wage subsidy policy increases the aggregate college completion rate by 3.15 percentage points. Focusing on students who completed college in both baseline and counterfactual simulation, the wage subsidy policy decreases the working hours by 525 and increases the monetary investment by 550 USD. Consequently, the average human capital of college students (including both dropouts and graduates), as measured by annual earnings after college, increases by 1,375 USD. The parental transfer decreases by 1,841 USD.

Despite the decrease in parental transfer, the increased earnings from the higher wage and improved human capital result in a positive welfare gain for the child. The welfare effect of the wage subsidy

[35] Two dollars is roughly the difference between the maximum (9.32 in Washington) and the minimum (7.25 in Alabama) level of the minimum wage across states in the US in 2014.

[36] Source: fsapartners.ed.gov/knowledge-center/fsa-handbook/2020-2021/vol6/ch2-federal-work-study-program.

[37] In the 2017-2018 academic year, the total amount of federal grants (loans) awarded to students was 41.7 billion (93.9 billion) USD, the total amount of education tax benefits amounted to 17.0 billion USD, and the total amount for the federal work-study program was 0.96 billion USD. Source: Trends in Student Aid 2018.

policy for the child is a 0.39% increase in lifetime income. Similarly, the parents experience a welfare effect of a 0.30% increase in lifetime income, which can be attributed to the reduced parental transfer and the enhanced utility of the child.

To investigate the distributional impact on students' outcome and welfare, in Table 13, we report changes in the college-completion rate (Panel A1), average human capital (Panel B1), average parental transfer (Panel C1), average students' welfare (Panel D1), and average parents' welfare (Panel E1) by family income quartile and students' ability. The low-ability (high-ability) students refer to those with below-median (above-median) AFQT scores in the sample.

The college completion rates increase for all groups, but the impacts are greater for low-income students (Panel A2 of Table 13). Similarly, the impacts on human capital are positive for all groups, but the impacts are greater for low-income high-ability students. Equation (6) can be helpful for understanding the different responses of working hours across different parental income levels. When the constraint binds, the impact of a wage increase on human capital is ambiguous. First, a higher wage during the college period increases the opportunity cost of studying in terms of foregone earnings. The binding constraint further amplifies the opportunity cost of studying compared to the case without a financial constraint. This is because the consumption level of students during college is lower than the optimal level. Self-financing through wage earnings (wn_k) becomes an important means to increase consumption during the college period. As a result, a higher wage can lead to a reduction in study time and, consequently, a decrease in human capital accumulation (substitution effect).

On the other hand, a higher wage can increase students' earnings and consumption during college for each unit of working hours. As a result, this increase in consumption reduces the marginal utility of additional consumption, denoted as $u'(wn_k + m_p)$. By reducing the marginal return from extra consumption during college, a higher wage can reduce self-financing and increase human capital (income effect).

Note that the second mechanism is stronger for students with lower parental transfers m_p during the college period. For students who have limited financial support from their parents, a higher wage during college can help them maintain a reasonable consumption level without having to work extensive hours. This, in turn, can have positive effects on their college graduation and human capital. On the other hand, for students who receive substantial financial support from their parents, an increase in wages during college may have adverse effects on the accumulation of human capital. This is because the substitution effect could outweigh the income effect. Therefore, the impact of wage increases on the intensive margin of human capital would vary among students.

The parental transfer decreases for all groups, with a greater extent of decrease observed among high-income students. Although the compensation motive of altruistic parents decreases as the child can earn higher wages, parents still need to take into account the fact that if they reduce financial support for the child, the child may end up working excessive hours following the wage increase, which could have adverse effects on their human capital. Because the marginal effects of the parental transfer on a child's labor supply and human capital are generally greater for low-income students, all other factors being equal, the crowd-out effect of parental transfer would be smaller for low-income families.

The welfare effect for the child is greater for low-income students because both the intensive and extensive margins of human capital increase relatively more compared to high-income students, while the decrease in the parental transfer is smaller for low-income students. The welfare effect for the parents is also greater for low-income students because the child's welfare increases relatively more, and the increased consumption by parents following decreased parental transfer has a greater welfare effect for low-income parents.

5.3 Wage Subsidy without Endogenous Response by Parents

To quantify the significance of the interaction between parental transfer and the child's choices when assessing the impact of the wage subsidy policy, we conduct a counterfactual analysis where we eliminate the endogenous response by parents to the wage subsidy policy. In particular, when introducing the same wage subsidy policy as in the previous section, we keep the parental transfer fixed at the level obtained from the baseline simulation and only allow the child to make changes to their choices.

Column (2) of Table 12 summarizes the aggregate impacts. First, the wage subsidy policy without endogenous parental response would result in a 3.02 percentage point increase in the college completion rate, which is slightly smaller than the impact observed when we account for changes in parental transfers. To understand why we have a smaller positive impact on the college completion rate, even though the average parental transfer is greater without endogenous response by parents, it is worth noting substantial heterogeneity in the impact of the policy. While many parents would decrease transfers when the wage increases for the child, certain parents, particularly those with children who are at risk of dropping out of college, may choose to increase their financial support to prevent their child from working excessive hours while in college. For those marginal students, the endogenous response by parents, which involves increasing transfers in response to the wage increase, is important to help them to complete college. Therefore, abstracting from parents' endogenous responses could *understate* the impact of wage subsidy policy on the college completion rate.

The wage subsidy policy would have greater positive impacts on the time and monetary investment in college education if parents do not adjust their transfers and provide the same amount of transfer as in the baseline simulation. Focusing on students who completed college in both baseline and counterfactual simulation, the working hours decrease by 636, which is greater than the change observed when we account for the parental response, where the decrease is 525. Similarly, the monetary investment of those students increases by 1,494 USD, which is greater than what we observed in column (1), where the increase is 550 USD. Because most parents reduce transfer when the child can earn higher wages during college, abstracting such a crowd-out effect on parental transfers would *overstate* the impact of the wage subsidy policy on the investment of students who complete college. Overall, the increase in human capital is overestimated at 2,082 USD, which is approximately 50 percent greater than the change observed when accounting for endogenous response in column (1).

Abstracting the endogenous parental response to the wage subsidy policy would overstate the welfare effect of the policy for children. Instead of a 0.39% increase in lifetime income with the endogenous parental response, it would be overestimated as a 0.47% increase. This overestimation occurs because not only does it overstate the average parental transfer when introducing the wage subsidy policy, but it also overstates the child's human capital. Conversely, the welfare effect of the wage subsidy policy for parents would be understated when we abstract from the endogenous response by parents. The estimated effect on lifetime income is 0.17%, which is smaller than the 0.30% estimated in the analysis that accounts for the endogenous response by parents.

6 Conclusion

We document that a large number of college students work a substantial number of hours in low-skill jobs and that students who have fewer resources (especially parental transfers) tend to work more. To quantify the trade-off that working during college entails, we develop a theory that shows how—in the presence of financial constraints—the interaction between college students' labor supply for self-financing and their parents' endogenous transfer decision leads to heterogeneous human capital accumulation during college. We find that a wage subsidy policy can have positive effects on college students' human capital and the welfare of both the child and parents, particularly among low-income families. Furthermore, our results emphasize the importance of considering the endogenous response of parents to accurately evaluate the impact of the wage subsidy policy.

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Table 1: Working Hours during College and Student Outcomes

	Working hours per week			
Variables	0-15	16-30	31-45	46-70
Total credit earned	109.6	93.9	80.9	60.0
	(1.0)	(1.9)	(3.5)	(8.7)
GPA first-year	3.0	2.7	2.7	2.4
	(0.02)	(0.04)	(0.06)	(0.26)
Never meet academic advisor	0.14	0.19	0.25	0.31
	(0.01)	(0.02)	(0.04)	(0.08)
Never participate in a school club	0.47	0.62	0.75	0.78
	(0.01)	(0.02)	(0.03)	(0.06)
Stopouts	0.24	0.35	0.36	0.39
	(0.01)	(0.02)	(0.03)	(0.07)
Percentage distribution	66.9	21.3	9.8	2.0

NOTE: The table shows the academic outcomes of students who were in their first year of a four-year college for the 2003-2004 academic year by their working hours per week during the first year of the college. "Total credit earned" is the total number of normalized postsecondary credits earned within six years. "GPA first-year" is the cumulative grade point average for the 2003-2004 academic year. The maximum GPA is 4. School activity variables (meeting academic advisor and participating in a school club) collect information on how frequently the student engaged in the activity for the first academic year, with three categories: 0:never, 1: sometimes, 2: often. "Never meet academic advisor" is the share of students who never met their academic advisor. "Never participate in a school club" is the share of students who never participated in a school club. Stopouts is the share of students who withdraw from college temporarily (longer than 4 months) during the 2003-2004 academic year. Standard deviations in parentheses. Source: Beginning Postsecondary Students 2004 and 2009.

Table 2: Working Hours during College

	Working hours during		
	First year	First 2 years	First 4 years
Mean	819	1,775	4,111
Std.	695	1,268	2,561
10th percentile	0	315	1,168
50th percentile	676	1,535	3,823
90th percentile	1,825	3,540	7,380
Number of observations	1,164	1,164	1,164

NOTE: This table shows the summary statistics for individuals' working hours after college enrollment. Source: NLSY97.

Table 3: Regression Estimates for Working Hours

VARIABLES	(1) Working hours	(2) Working hours
AFQT	-2.539*	-1.572
	(1.494)	(1.501)
Grants/1000	-5.851***	-5.520***
	(1.446)	(1.438)
Student Loan/1000	6.603***	7.061***
	(2.128)	(2.115)
Annual parental income/1000	-1.586**	-0.817
	(0.693)	(0.711)
Parental Transfer/1000		-6.211***
		(1.469)
Constant	2,062***	2,020***
	(108.0)	(107.7)
Observations	1,164	1,164
R-squared	0.026	0.041

NOTE: This table shows the regression estimates for working hours for the first 2 years after enrollment with respect to observable variables. The amounts of grants, student loans, and parental transfers are aggregated over the enrollment period. Annual parental income refers to the average family income when a student's age is between 16 and 17. Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: NLSY97.

Table 4: Summary Statistics (SIPP)

	(1) Head never displaced	(2) Head displaced after 1st survey period
Monthly parental income in 1st survey period		
Mean	4,130	3,753
Std.	(4,568)	(4,045)
25th percentile	1,250	1,198
50th percentile	3,087	2,900
75th percentile	5,709	5,108
Head education (some college or above)	0.65	0.64
	(0.47)	(0.48)
Head age	49	49
	(7)	(6)
Grants	0.32	0.37
	(0.47)	(0.48)
Male	0.48	0.47
	(0.49)	(0.50)
White	0.77	0.75
	(0.42)	(0.44)
Black	0.14	0.16
	(0.35)	(0.37)
Number of students	23,947	228

NOTE: This table shows the summary statistics for students whose parents do not experience a job-loss shock (column (1)) and for students whose parents experienced a job-loss shock after the first survey period (column (2)). The parental job-loss shock is a dummy variable taking a value of 1 if a student's father (or mother in the case of single-mother households) lost his/her job in the previous 4 months due to (1) employer bankrupt, (2) employer sold business, or (3) slack work or business conditions. The observation is each student level. We report the information in the first survey period. The average and standard deviation (in parentheses) of each variable are reported, otherwise indicated. The head of a household is defined as the male in two-parent households and the female in single-mother households. Head education is a dummy variable taking the value of 1 if the household head has attended some college or above institutions. Grants is a dummy variable for students who received a grant during the survey period (4 months). Source: SIPP.

Table 5: Regression Estimates for Working Hours (SIPP)

VARIABLES	First Stage (1) Parental Income (Monthly)	OLS (2) Working Hours (Weekly)	2SLS (3) Working Hours (Weekly)	(4) New Loan
Previous job-loss shock	-1.450***			0.0462**
	(0.208)			(0.0199)
Parental Income/1000		-0.0299*	-2.425***	
(Monthly)		(0.0165)	(0.826)	
Year FE	Y	Y	Y	Y
Race/Sex/Grant Dummies	Y	Y	Y	
IV for Parental Income			Y	
Individual FE				Y
Observations	77,025	77,025	77,025	71,428

NOTE: This table shows regression estimates for the weekly working hours with respect to observable variables from the SIPP. The observation is at each student-period (4 months) level. We use the parental job-loss shock, a dummy variable taking a value of 1 if a student's father (or mother in the case of single-mother households) lost his/her job in the previous 4 months due to (1) employer bankrupt, (2) employer sold business, or (3) slack work or business conditions as an instrumental variable for monthly parental income. Grants is a dummy variable indicating whether the student received a grant during the period, while New Loan is a dummy variable for students who took a new loan during the period. Standard errors in parentheses. Standard errors are clustered at each student level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Source: SIPP.

Table 6: Predetermined Parameters

Parameter	Value	Description	Data source
P_0	0.5	Start of working period for dropouts	
P_1	1	Start of working period for graduates	
R_k	10	Start of retirement period for the child	
T_k	15	End of lifetime for the child	
R_p	5	Start of retirement period for parents	
T_p	10	End of lifetime for parents	
σ	2	IES=0.5	Browning et al. [1999]
g	0.07	Growth rate of earnings over 4 years	Lagakos et al. [2018]
n_d	$2,000$	Median working hours among dropouts for the first two years of college	NLSY97
m_d	$13,096 \times 2$	Mean annual sticker price×2	NPSAS 2004
s	0.47	Share of grant, first income quartile	NPSAS 2004
	0.21	Share of grant, second income quartile	NPSAS 2004
	0.14	Share of grant, third income quartile	NPSAS 2004
	0.10	Share of grant, fourth income quartile	NPSAS 2004
$\bar{h}$	16,000×4	Mean annual earnings for high school graduates×4	NLSY97
w	8	Mean hourly wage of college students	NLSY97
T	20,000	Time endowment over college period	ATUS 2004
$r = \delta$	$(1.05)^4 - 1$	5% is the annual interest rate	US 10 Year T-Bill 1998-2006

NOTE: This table summarizes the predetermined parameters for estimation. One unit of period is normalized as 4 years.

Table 7: Variable Construction for Estimation

Variable	Data
x_p	Family income over 20 years imputed by mean annual family income between ages 16 and 17
m_p	Total parental transfers over college period
d_k	Total student loans over college period
n_k	2 × First 2-year working hours
m_k	Annual sticker price × (highest grade completed − 12)
h	4 × Mean annual earnings after college between ages 26 and 30
A	AFQT score

NOTE: This table summarizes how the variables are constructed for estimation. Source: NLSY97.

Table 8: Moment Conditions and Model Fit

#	Moments	Data	Simulation
M1	$\frac{1}{n}\sum_{i=1}^{n} h_i \cdot BA_i$	1.1053	1.1228
M2	$\frac{1}{n}\sum_{i=1}^{n} m_{ki} \cdot BA_i$	1.7934	1.7787
M3	$\frac{1}{n}\sum_{i=1}^{n} I(n_{ki} > 0) \cdot BA_i$	1.7360	1.7142
M4	$\frac{1}{n}\sum_{i=1}^{n} I(n_{ki} > 0) \cdot n_{ki} \cdot BA_i$	1.0492	1.1208
M5	$\frac{1}{n}\sum_{i=1}^{n} n_{ki}^2 \cdot BA_i$	0.6485	0.6600
M6	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot I_{F1i}$	0.3772	0.4948
M7	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot I_{F2i}$	0.4486	0.3865
M8	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot I_{F3i}$	0.4773	0.4340
M9	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot I_{F4i}$	0.5350	0.4920
M10	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F1i}$	0.1827	0.1709
M11	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F2i}$	0.1836	0.1670
M12	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F3i}$	0.2612	0.2720
M13	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F4i}$	0.2901	0.4350
M14	$\frac{1}{n}\sum_{i=1}^{n} m_{pi}^2$	0.1398	0.1223
M15	$\frac{1}{n}\sum_{i=1}^{n} BA_i$	1.8833	1.8775
M16	$\frac{1}{n}\sum_{i=1}^{n} h_i \cdot (1 - BA_i)$	0.4325	0.3259
M17	$\frac{1}{n}\sum_{i=1}^{n} A_i \cdot (1 - BA_i)$	0.4670	0.4541
M18	$\frac{1}{n}\sum_{i=1}^{n} I(d_{ki} \leq 0) \cdot (1 - BA_i)$	0.3066	0.4930
M19	$\frac{1}{n}\sum_{i=1}^{n} I(d_{ki} \leq 0) \cdot BA_i$	0.5787	0.3944

NOTE: This table compares actual and simulated moments. The variable definition for $\{h, m_k, n_k, m_p, d_k, A\}$ is shown in Table 7. BA is a dummy variable for the college graduates. $I_{F\#}$ refers to a dummy variable for #th family income (x_p) quartile. i refers to each observation, while n represents the total number of observations.

Table 9: Sensitivity Analysis

Variable	Sensitivity Moments
γ	**M1, M2**
ρ	**M2**
ϵ_0	**M3, M4, M5**, M6, M10
σ_ϵ	**M3, M4, M5**, M10
α_0	**M7, M9, M13**
α_1	**M7, M8**, M19
σ_α	**M9, M12**
ϕ_0	M10, **M15, M17**, M19
ϕ_1	M12, **M15, M17**, M18, M19
τ	**M18, M19**

NOTE: This table shows the sensitive moments for each parameter. We calculate the moment with maximum (absolute) sensitivity for each parameter and present the moments whose sensitivity is at least 50% of the maximal. We call these moments sensitive moments. The moment numbers correspond to the ones in Table 8. We highlight a sensitive moment if the moment is used for the identification argument in section 4.3.

Table 10: Out-of-Sample Fit

		Ability Quartiles			
		First	Second	Third	Fourth
m_p	Data	6,816	10,389	15,148	20,087
	Model	10,786	15,310	18,251	19,375
n_k	Data	3,358	3,462	3,436	3,028
	Model	4,322	3,526	3,342	3,317

NOTE: This table compares actual and simulated moments, which are not directly targeted for estimation. We present the average parental transfers (m_p) for all students and the average working hours (n_k) for college graduates conditional on each ability quartile.

Table 11: Parameter Estimates

Variable	Estimate	Standard Error
γ	-0.61	0.03
ρ	0.83	0.01
ϵ_0	1.50	0.03
σ_ϵ	0.45	0.03
α_0	-5.02	0.15
α_1	-2.27	0.03
σ_α	1.15	0.12
ϕ_0	-4.52	0.59
ϕ_1	0.11	0.06
q_τ	0.32	0.01

NOTE: This table shows parameter estimates for the quantitative model. We report the value for ϕ_0 and ϕ_1 after dividing by 1,000.

Table 12: Policy Simulation

	(1) Wage subsidy	(2) Wage subsidy without endogenous parental transfer	(3) Baseline
College completion rate (percentage point)	3.15	3.02	77.35
Working hours	-525	-636	3,573
Investment	550	1,494	54,218
Human capital (annual earnings)	1,375	2,082	30,959
Parental transfer	-1,841	0	15,930
Welfare of students (%, lifetime consumption)	0.39	0.47	NA
Welfare of parents (%, lifetime consumption)	0.30	0.17	NA

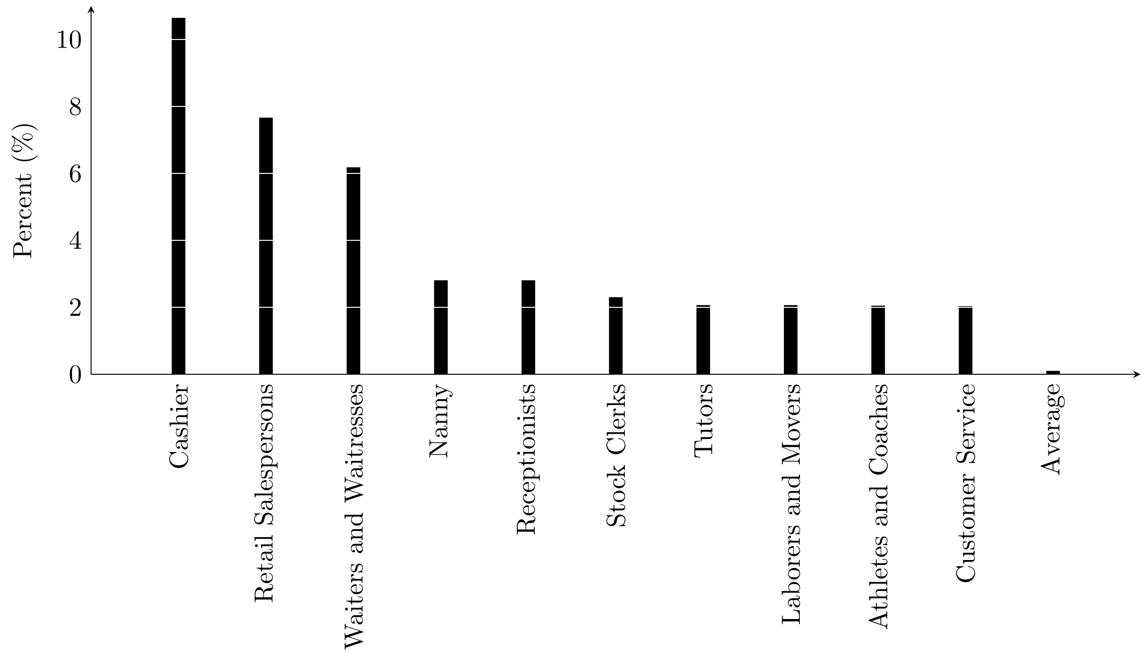
NOTE: This table presents the results from simulations of the wage subsidy policy (columns (1)-(2)) alongside the baseline model simulation (column (3)). Under the wage subsidy policy, hourly wages are increased by 2 USD compared to the current wage of 8 USD for students who work during college. Additionally, a working hour restriction is implemented to ensure that students who complete college do not exceed 4,000 hours of work during college. Column (1) represents the results when accounting for the endogenous response by parents to the policy change. In column (2), the results are documented assuming that parents do not respond to the policy change and maintain the same transfer as in the baseline simulation. We report changes from the baseline (estimated) economy regarding (1) the college-completion rate (i.e., college-graduation rate in the simulated economy − college-graduation rate in the baseline economy), (2) average working hours over the college period for those who complete college both in the baseline economy and in the policy simulation, (3) average monetary investments over the college period for those who complete the college both in the benchmark economy and in the policy simulation, (4) average parental transfer during the college period, (5) average human capital measured by annual earnings after college, and average welfare of students (6) and parents (7) measured by consumption changes relative to the lifetime consumption in the baseline economy.

Table 13: Heterogeneous Impacts of Policy Simulation

		Parental income			
		Q1	Q2	Q3	Q4
		Panel A. College-completion rate			
A1. Wage subsidy					
	Low A	6.05	4.45	3.80	1.22
	High A	3.10	2.93	2.19	0.87
A2. Wage subsidy, fixed parental transfer					
	Low A	5.73	4.73	3.83	1.48
	High A	2.78	2.45	1.72	0.88
		Panel B. Human capital			
B1. Wage subsidy					
	Low A	1,582	1,584	1,181	243
	High A	2,483	2,359	1,614	193
B2. Wage subsidy, fixed parental transfer					
	Low A	1,788	1,951	1,703	1,007
	High A	3,216	3,173	2,645	1,420
		Panel C. Parental transfer			
C1. Wage subsidy					
	Low A	-935	-819	-1,572	-2,789
	High A	-1,742	-1,581	-2,281	-3,112
C2. Wage subsidy, fixed parental transfer					
	Low A	0	0	0	0
	High A	0	0	0	0
		Panel D. Students' welfare			
D1. Wage subsidy					
	Low A	0.54	0.58	0.45	0.18
	High A	0.45	0.46	0.35	0.13
D2. Wage subsidy, fixed parental transfer					
	Low A	0.61	0.49	0.44	0.33
	High A	0.61	0.51	0.46	0.33
		Panel E. Parents' welfare			
E1. Wage subsidy					
	Low A	0.91	0.21	0.12	0.06
	High A	0.86	0.24	0.13	0.06
E2. Wage subsidy, fixed parental transfer					
	Low A	0.61	0.06	0.01	0.00
	High A	0.65	0.10	0.04	0.02

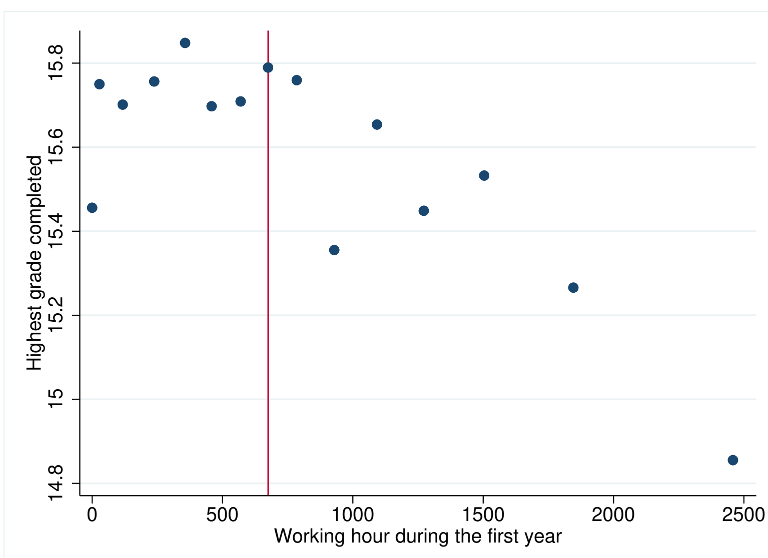
NOTE: This table shows the changes in the college-completion rate (Panel A), average human capital (Panel B), average parental transfer (Panel C), average students' welfare (Panel D), and average parents' welfare (Panel E) for each income/ability group after each policy. Q# refers to the #th quartile of the parental income distribution. The low-ability (high-ability) students refer to those with below-median (above-median) AFQT scores in the sample.

Figure 1: Jobs Held by College Students



NOTE: The figure shows the most frequently chosen occupations by four-year college students during ages 18-22. Source: NLSY97.

Figure 2: Working Hours and Highest Grade Completed



NOTE: The figure shows binned scatter plots for the highest grade completed with respect to first-year working hours. The vertical line presents the median working hours. Source: NLSY97.

Appendix

A Incorporating Two-Year College

The main model focuses on students who ever attended a four-year college. In this section, we extend the main model to incorporate the option to attend a two-year college in the college-investment decision. For the clarity of exposition, we call the model (sample) in the main paper the main model (sample). We call the model (sample) that includes two-year-college investment the extended model (sample).

A.1 Data

We augment the main sample for the estimation, constructed from the NLSY97, by adding individuals who attend a two-year college. An additional 531 two-year-college students who have information on the AFQT score, family income, highest grade completed, student loan, working hours, parental transfer, and grants are added to the main sample of 1,164 four-year college students, which leads to 1,695 individuals in the extended sample. Note that students who transfer from two-year college to four-year college are included in the main sample and are treated as four-year college students.

Table A1 documents summary statistics of students who attend only a two-year college (column (1)), who drop out of a four-year college (column (2)), and who complete a four-year college (column (3)). All monetary values are in 1997 USD. The AFQT score is lower for two-year college students than for four-year college dropouts or four-year college graduates. Family income is similar between two-year college students and four-year college dropouts but is about 40% higher for four-year college graduates. Whereas the average family income between two-year-college students and four-year-college dropouts is similar, the parental transfer is substantially greater for four-year-college dropouts (4,592 USD) than two-year-college students (2,033 USD). On the other hand, the parental transfers for four-year college graduates (15,511 USD) are three times greater than for four-year college dropouts. The amount of student loans taken by four-year-college graduates (14,406 USD) is three times greater than that of two-year-college students (4,895 USD), and 70% higher than that of four-year-college dropouts (8,435 USD). The number of working hours during the first two years in college is greater for two-year-college students (2,499 hours) than for four-year-college dropouts (2,205 hours) or four-year-college graduates (1,654 hours). The annual income after the college period is similar between two-year-college students and four-year-college dropouts (22,153 and 21,901 USD, respectively), and 60% higher for four-year-college graduates (34,553 USD).

Another key difference between two-year and four-year college investment is the cost of attendance. Table A2 summarizes the annual sticker price (including tuition, fees, books and supplies, and cost of living posted by the colleges), grants, and limits on non-need-based federal student loan aid, which are calculated from the 2004 NPSAS in 1997 USD value. As Table A2 shows, the annual sticker price for attending a two-year college (6,075 USD) is about 46% of that for a four-year college (13,096 USD). The shares of the sticker price supported by grants are similar across two-year and four-year college students for those from the bottom quartile of the family income distribution, whereas the grant shares are higher for four-year college students for other income groups.

A.2 The Model

To incorporate the option to attend a two-year college, we modify our main model in the following ways. The extensive margins of college investment are characterized by four-year-college dropout ($J = 0$), four-year-college completion ($J = 1$), and two-year-college attendance ($J = 2$).[38]

We assume the labor supply of two-year college students is fixed at $n_k = n_A$.[39] Also, the monetary investment for a two-year college is fixed at $m_k = m_A$. The human capital accumulation for four-year-

[38] We do not differentiate two-year-college dropout from two-year-college graduation.

[39] We find from the data that earnings of two-year college students after college do not systematically vary by their labor supply during the college period. This finding might be driven by the mixed motives for working while in college for two-year college students: some two-year college students may need to work to finance the cost of college, and their work experience during the college period is not related to their career development. On the other hand, given that two-year college programs focus more on vocational education, some two-year college students may choose to work to accumulate career-related human capital during the college period.

college graduates and four-year-college dropouts is the same as in equations (1) and (2) in the paper. The human capital accumulation for two-year-college students is specified as $\overline{h} + \pi_0 + \pi_1 A$, similar to that for four-year-college dropouts. The intercept and the slope of the linear projection of earnings on the AFQT score differ between two-year college attendees and four-year college dropouts. Then, the human capital accumulation function for each extensive margin of college investment is specified as follows:

$$h = \begin{cases} \overline{h} + \phi_0 + \phi_1 A, & \text{if } J = 0, \\ \overline{h} + A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}}, & \text{if } J = 1, \\ \overline{h} + \pi_0 + \pi_1 A, & \text{if } J = 2. \end{cases}$$

As in the main model, $\tau = \{0, 1\}$ indicates the type of child, which takes a value of 1 if the child has a debt aversion during the college period. τ follows a uniform distribution with a probability of $\tau = 1$ being equal to q_τ. As in the main model, the borrowing constraint in the quantitative analysis is defined as $d_k \leq (1 - s)m_k$. Thus, students who do not have debt-averse preferences can borrow up to the sticker price net of grants for an additional year of college.

Time is continuous. The child lives for $t \in [0, T_k]$, where $t \in [0, P_J)$ is the college period; $t \in [P_J, R_k)$ is the working period; and $t \in [R_k, T_k]$ is the retirement period. The end of the college period (P_J) depends on whether the child does not complete a four-year college education ($J = 0$), graduates from a four-year college ($J = 1$), or attends a two-year college ($J = 2$). The college period for attending a two-year college or dropping out of a four-year college is half that of attending a four-year college: $P_0 = P_2 = \frac{1}{2}P_1$. The parents live for $t \in [0, T_p]$ periods, where $t \in [0, R_p)$ is parents' working period and $t \in [R_p, T_p]$ is parents' retirement period.

Let V_k^J be the value of choosing $J \in \{0, 1, 2\}$. The child chooses J that maximizes her utility. The parents' problem is the same as in the main model, except the child can also choose to attend a two-year college instead of a four-year college.

A.3 Estimation

The monetary investment (m_A) and the grant share (s_A) for two-year colleges are from the NPSAS 2004 (Table A2). m_A is set to $6,075 \times 2$ USD, where $6,075$ USD is the average annual sticker price for attending two-year colleges. s_A is 0.44, 0.12, 0.07, and 0.04, for the first, second, third, and fourth quartiles, respectively, of the family income distribution. The working hours of two-year college students (n_A) are set to 2,500, the average working hours of two-year college students observed in the extended sample. Predetermined parameters other than m_A, n_A, and s_A are the same as in Table 6.

In the estimation, we have two additional parameters, π_0 and π_1, that determine the human capital accumulation from a two-year-college education. To estimate the model, we include three moments in addition to the 19 moments used in the main estimation shown in Table 8. Those moments conditions are (1) the share of students who attend two-year college ($M20 = \frac{1}{n}\Sigma_i I(TwoYear_i)$, where $TwoYear_i$ indicates the dummy variable that takes a value of 1 if the student attends only a two-year college), (2) the average human capital (annual earnings after the college period) of two-year students ($M21 = \frac{1}{n}\Sigma_i h_i \cdot TwoYear_i$), and (3) the correlation between the child's ability and two-year-college attendance ($M22 = \frac{1}{n}\Sigma_i A \cdot TwoYear_i$). The estimates for the extended model is shown in Table A3.

A.4 Counterfactual Policy Experiments

In this section, we conduct counterfactual policy analyses to evaluate the wage subsidy policy. Under the wage subsidy policy, hourly wages are increased by 2 USD compared to the current wage of 8 USD for students who work during college. Additionally, a working hour restriction is implemented to ensure that students who complete a four-year college do not exceed 4,000 hours of work during college. Consistent with the analysis of the main model, we first present the findings from the wage subsidy policy, then discuss how these findings would change when we abstract from the endogenous response by parents to the policy change.

Table A4 summarizes the impacts of the counterfactual policies on the aggregate outcomes in the extended model. The wage subsidy policy (column (1)) increases the share of four-year college graduates by 1.68 percentage points. Focusing on students who complete four-year colleges in both the baseline simulation and the counterfactual simulation, the wage subsidy policy decreases working hours by 467 and increases monetary investment by 504. Overall, the average human capital, measured by annual earnings after college, increases by 835 USD. Many parents crowd out transfer when the child can earn a higher wage during college, leading to an average parental transfer decrease of 2,159 USD. The welfare gain of the wage subsidy policy is 0.38% for the child and 0.32% for the parents.

In column (2), we report the results when we abstract from the endogenous response by parents to the policy change and fix the parental transfer at the same level as in the baseline simulation. The findings are comparable to the main analysis. First, abstracting from endogenous responses by parents results in a smaller positive impact on the college completion rate but a greater positive impact on the intensive margin of investment among those who complete a four-year college. Overall, the average impact on human capital would be overstated if changes in parental transfer are not accounted for, as the majority of parents would crowd out their transfer when the child can earn a higher wage during college. Second, abstracting endogenous response by parents would overstate the welfare effect of the wage subsidy policy for the child (estimated as a 0.56% increase in lifetime consumption), whereas it would understate the welfare effect of the policy for the parents (estimated as a 0.26% increase in lifetime consumption).

Overall, the findings from the counterfactual policy evaluation of the extended model is similar to those in the main model.

Table A1: Summary Statistics for the Extended Sample

Variable	(1) 2-year	(2) 4-year dropout	(3) 4-year complete
AFQT	43.07	52.82	66.01
	(24.29)	(25.29)	(24.42)
Family income	48,934	49,041	69,655
	(44,962)	(46,300)	(55,812)
Highest grade completed	13.66	13.43	16.16
	(1.21)	(0.71)	(0.63)
Parental transfer	2,033	4,592	15,511
	(7,506)	(11,394)	(28,681)
Student loan	4,895	8,435	14,406
	(22,976)	(14,713)	(18,643)
Working hours	2,499	2,205	1,654
(first two years of college)	(1,462)	(1,529)	(1,157)
Annual income	22,153	21,901	34,553
(after college)	(14,924)	(13,804)	(22,367)
No. observations	531	256	908

NOTE: The table presents summary statistics of samples of students who attend only two-year colleges (column (1)), who drop out from four-year colleges (column (2)), and who graduate from four-year colleges (column (3)). The standard deviations are in parentheses. Source: NLSY97.

Table A2: Annual Cost for Attending 2-Year and 4-Year Colleges

Variable	2-year (1)	4-year (public+private) (2)	4-year (private) (3)
A. Annual price			
Tuition and fees	1,526	6,137	12,051
Non-tuition expenses	4,549	6,960	7,182
Sticker price	6,075	13,096	19,233
B. Share of sticker price supported by grant			
1st income quartile	0.44	0.47	0.39
2nd income quartile	0.12	0.21	0.27
3rd income quartile	0.07	0.14	0.22
4th income quartile	0.04	0.10	0.15

NOTE: The table presents the annual cost for attending 2-year colleges, 4-year colleges including public and private colleges, and 4-year private colleges. Data are from the NPSAS 2004. Monetary value is in 1997 USD.

Table A3: Estimates for the Main and the Extended Models

Parameters	(1) Main Model	(2) Extended Model
γ	-0.61	-0.62
ρ	0.83	0.83
ϵ_0	1.50	1.65
σ_ϵ	0.45	0.50
α_0	-5.02	-5.41
α_1	-2.27	-2.22
σ_α	1.15	1.21
q_τ	0.32	0.38
ϕ_0	-4.52	-4.46
ϕ_1	0.11	0.15
π_0	-	-0.09
π_1	-	0.05

NOTE. The table shows the parameter estimates for the main and the extended models. ϕ_0, ϕ_1, π_0, and π_1 are divided by 1,000.

Table A4: Policy Simulation (Including 2-Year Colleges)

Variable	(1) Wage subsidy	(2) Wage subsidy without endogenous parental response	(3) Baseline
Share of four-year college graduates (%)	1.68	-0.75	53.09
Share of two-year college students (%)	-0.37	1.00	34.34
Working hours	-467	-474	3,503
Investment	504	1,726	54,006
Human capital (annual earnings)	835	896	26,109
Parental transfer	-2,159	0	11,055
Welfare of students (%, lifetime consumption)	0.38	0.56	NA
Welfare of parents (%, lifetime consumption)	0.32	0.26	NA

NOTE: This table presents the results from simulations of the wage subsidy policy (columns (1)-(2)) alongside the baseline model simulation (column (3)) using the extended model with the option to attend a two-year college. Under the wage subsidy policy, hourly wages are increased by 2 USD compared to the current wage of 8 USD for students who work during college. Additionally, a working hour restriction is implemented to ensure that students who complete a four-year college do not exceed 4,000 hours of work during college. Column (1) represents the results when accounting for the endogenous response by parents to the policy change. In column (2), the results are documented assuming that parents do not respond to the policy change and maintain the same transfer as in the baseline simulation. We report changes from the baseline (estimated) economy regarding (1) the share of four-year college graduates, (2) the share of two-year college students, (3) the average number of working hours over the college period for those who complete college both in the baseline economy and in the policy simulation, (4) the average monetary investments over the college period for those who complete the college both in the benchmark economy and in the policy simulation, (5) the average parental transfer during the college period, (6) the average human capital measured by annual earnings after college, and the average welfare of students (7) and parents (8) measured by consumption changes relative to the lifetime consumption in the baseline economy.

B Robustness Check

To examine the robustness of our main findings, we modify the main model in three ways and re-estimate each model, and then compare how the main findings change according to different model specifications. Table B1 shows estimates of the structural parameters (Panel A), model predictions (Panel B), and the impact of the financial constraint compared with the optimal case (Panel C) for each robustness check. Column (1) of Table B1 shows the results from the main model for comparison.

B.1 Private vs. Public College

First, we incorporate heterogeneity in college type by allowing the annual net cost for attending private and public four-year colleges to be different. Columns (2) and (3) of Panel A in Table A2 document the annual sticker price, which is the sum of tuition, fees, books and supplies, and cost-of-living, posted by all four-year colleges and by four-year private colleges only. The annual sticker price for attending a private college is 19,233 USD, which is 47% higher than that for all four-year colleges in the main model (column (2) Table A2). Panel B in Table A2 presents the share of the sticker price supported by grants by family income quartiles. The grant share for high-income students is relatively greater from private colleges than public colleges.

We assume that the monetary investment for an additional year of college, represented as m_k, is equal for both public and private colleges. Based on this assumption, we calculate the grant ratio to match the annual net cost for private colleges across different family income quartiles. In other words, we set the grant shares for private colleges to be lower than those documented in Table A2, ensuring that the net cost of attending a private college, as calculated using the formula $m_k \times (1 - s)$ in the quantitative analysis, corresponds to the observed data. By keeping the same monetary investment for one year of college education (m_k), we are making the assumption that the return to one additional year of college investment is equal for both private and public colleges. Furthermore, this assumption implies that attending a more expensive college does not necessarily result in higher human capital.

The motivation behind this assumption stems from the lack of a clear positive correlation between the quality of private colleges and their tuition, as observed in the NPSAS 2004 data.[40] The above assumption implies that the adjusted grant share (s) for private college is 0.11 for the first quartile of the income distribution and 0 for other students.[41]

Column (2) of Table B1 summarizes the results. Most parameter estimates and model predictions are comparable to those of the main model. The average parental transfer is slightly higher in the modified model (17,654 USD) than in the main model (15,930 USD) (Panel B). This difference can be explained by increased parental transfer for children attending private colleges, because parents of those children have a stronger compensating motive given that the increased college cost reduces the child's consumption. As shown in panel C, the impact of the financial constraint on the college completion rate is slightly smaller in the modified model (-6.50) than in the main model (-8.35). The reason is that in the modified model with increased costs for private colleges, some of college dropouts in the main model can be explained by the expensive cost rather than the financial constraint. Relatedly, the decrease in human capital explained by the constraint in the modified model (-9,650 USD) is slightly smaller than that in the main model (-11,498 USD).

B.2 Including Leisure

Second, we introduce leisure during the college period so that students divide their time between study, work, and leisure. We add leisure in child's utility during college in an additive separable form such as $u(C_{k1}) + \beta u(C_{k2}) + u(l_k)$, where $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ and $u(l) = \kappa \frac{l_k^{1-\sigma}}{1-\sigma}$. The human capital production function becomes $\overline{h} + A\{m_k^\gamma + (T - \epsilon n_k - l_k)^\gamma\}^{\frac{\rho}{\gamma}}$.

[40] In particular, the NPSAS 2004 assigns four categories of college selectivity from 1 (for the most selective) to 4 (for the college with open admission). On average, the selectivity measures from the NPSAS 2004 are similar between public four-year colleges and non-for-profit private four-year colleges (2.1 vs. 2.0). The share of the most selective colleges is higher for private four-year colleges (30%) than for public four-year colleges (19%). However, the share of moderately selective colleges is higher for public colleges (60%) than for private colleges (44%), and the share of least selective colleges is higher for private colleges (26%) than for public colleges (22%). Therefore, on average, the cost difference may not necessarily reflect the quality difference between public and private colleges.

[41] If the annual net cost of attending private colleges is greater than the annual sticker price in the main model, we set the grant share to 0%.

To construct a moment condition that helps us identify κ, we calculate the average leisure hours for college students who are enrolled in a college from the ATUS 2004. Of 17 major categories of activities in the time-use data in ATUS 2004, we add time spent on leisure and sports, which is about 240 minutes per day and 5,800 hours for the four years of the college period.

Column (3) in Table B1 shows the results. When a portion of non-working hours is spent on leisure, all else being equal, the predicted labor earnings will be lower than the labor earnings in the data. To counteract such an effect, the new estimates have different parameter values for the human capital production function (e.g., γ, ρ, ϕ_0, ϕ_1). The model's predictions on choice variables are similar to the main model. The impacts of the financial constraint on the college completion rate, working hours, and human capital are smaller than those in the main model because the impact of working while in college on human capital accumulation decreases. The welfare effect of the students and parents is comparable to those in the main model, despite the smaller increase in human capital, because the financial constraint also decreases students' leisure. Overall, our results remain robust when we introduce leisure.

B.3 Different Intertemporal Elasticity of Substitution

The consumption intertemporal elasticity of substitution (IES) is $\frac{1}{\sigma}$ when the utility function is $u(\cdot) = \frac{c^{1-\sigma}}{1-\sigma}$. A lower value of IES (a higher value of σ) implies a stronger preference for intertemporal consumption smoothing. In our main model, we choose $\sigma = 2$ following Lochner and Monge-Naranjo [2011], which implies IES is $\frac{1}{2}$.[42] We estimate the model with a lower value of $\sigma = 1.5$ (a higher value of IES) to examine how the model implication changes when the preference for intertemporal consumption smoothing is weaker.

Column (4) of Table B1 shows the results. With a greater IES, the utility cost associated with limited intertemporal consumption smoothing is smaller. Other things being equal, a weaker consump-

[42] IES of 0.5 is an intermediate value in the estimates reported in Browning et al. [1999].

tion smoothing motive would result in a higher college completion rate, higher monetary investment, and lower working hours. To match the data on college investment, ρ decreases from 0.83 to 0.79, and π_0 decreases from -4.52 to -5.66. To match the data on labor supply, ϵ_0 decreases from 1.50 to 1.47. On the other hand, as the utility cost that incurs to the child due to limited consumption smoothing decreases, the parental transfer would decrease without changes in the distribution of α. To match the parental transfer in the data, α_0 changes from -5.02 to -4.24. With a lower σ (higher IES), the model implies a lower value for student loans, but college investment and parental transfer are close to the main model (Panel B). The impacts of the financial constraint on college investment, working hours, human capital, and parental transfer are smaller than in the main model. The welfare effect of relaxing the borrowing constraints decreases for both the child and parents when σ has a smaller value. Although the magnitudes are different, the main findings remain robust.

Table B1: Robustness Checks

	(1) Baseline	(2) Private	(3) Leisure	(4) $\sigma = 1.5$
Panel A: Estimates				
γ	-0.61	-0.62	-0.44	-0.59
ρ	0.83	0.83	0.85	0.79
ϵ_0	1.50	1.48	1.41	1.47
σ_ϵ	0.45	0.47	0.65	0.52
α_0	-5.02	-5.05	-5.27	-4.23
α_1	-2.27	-2.14	-2.25	-1.83
σ_α	1.15	1.06	0.97	0.70
q_τ	0.32	0.33	0.31	0.36
ϕ_0	-4.52	-4.87	-3.63	-5.38
ϕ_1	0.11	0.11	0.14	0.16
κ	-	-	0.04	-
Panel B: Model Prediction				
average BA	0.77	0.79	0.81	0.81
average m_p	15,930	17,654	16,551	15,633
average m_k	47,871	47,204	48,295	47,874
average n_k	3,216	3,284	3,050	3,055
average d_k	28,910	29,672	29,349	27,379
average h	30,959	30,426	27,595	29,190
$corr(m_p, A)$	0.16	0.18	0.18	0.24
$corr(n_k, A)$	-0.06	-0.07	-0.11	-0.17
$corr(m_p, n_k)$	-0.54	-0.54	-0.57	-0.55
$corr(m_p, m_k)$	0.05	0.05	0.07	0.02
Panel C: Impacts of the Constraint				
ΔBA	-8.35	-6.50	-5.86	-4.98
Δm_p	7,536	8,053	8,438	7,005
Δn_k	2,091	2,049	1,901	1,652
Δm_k	-6,827	-6,705	-4,197	-4,743
Δh	-11,498	-9,650	-6,250	-4,683
welfare loss (child,%)	-7.46	-6.28	-6.21	-3.36
welfare loss (parents,%)	-2.06	-1.86	-2.03	-1.69

NOTE. The table summarizes results for each robustness-check analysis. Panel A presents the parameter estimates. Panel B presents the model predictions. Panel C presents the impacts of the financial constraint on outcomes compared with the optimal case. Column (1) presents the results for the main model. Column (2) presents the results for the model that allows different costs for public and private colleges. Column (3) presents the results for the model when we incorporate leisure as an additional choice variable for the child. Column (4) presents the results for the model with $\sigma = 1.5$.

Self-financing, Parental Transfer, and College Education

Appendix for Online Publication*

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September 26, 2023

Contents

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I Characterization of the Two-Period Model

In this section, we discuss the details of the characterization of the two-period model. We use the same notation defined in section 3. The main purpose of characterization is to provide a clear identification of the quantitative model. For this reason, we made one change to the two-period model in section 3 by replacing $\overline{d}$ with m_k to be consistent with the tied-to-investment constraint specification for quantitative model in section 5. The borrowing constraint can then be written as $d \leq m_k$, indicating that students can borrow up to the amount of their educational investment (m_k), while they are restricted from borrowing beyond this limit. Note that the characterization of the optimal investment and consumption would not be affected by this change. While the characterization of the model with binding constraint would change slightly when we assume $d \leq m_k$ instead of $d \leq \overline{d}$, the qualitative implications remain the same.

Given the parents' transfer (m_p), the child maximizes lifetime utility by choosing the first- and second-period consumption $\{C_{k1}, C_{k2}\}$ and $\{n_k, m_k, d_k, J\}$:

$$\max_{\{C_{k1},C_{k2},n_k,m_k,d_k,J\}} u(C_{k1}) + \beta u(C_{k2}) \quad \text{subject to} \tag{I.1}$$

$$C_{k1} + m_k \leq w n_k + d_k + m_p,$$

$$C_{k2} + R d_k \leq h,$$

$$d_k \leq m_k,$$

$$h = J \cdot \Big[\overline{h} + A\big\{m_k^{\gamma} + (T - \epsilon n_k)^{\gamma}\big\}^{\frac{\rho}{\gamma}}\Big] + (1 - J) \cdot \Big[\overline{h} + \phi_0 + \phi_1 A\Big],$$

$$m_k \geq m_d, \quad n_k \geq 0, \quad T - \epsilon n_k > 0, \quad \text{if } J = 1,$$

$$m_k = m_d, \quad n_k = n_d, \quad \text{if } J = 0,$$

where R and w are the risk-free gross interest rate and wage, respectively.

Knowing how the child behaves given parental transfer, the parents maximize their lifetime utility and their child's value by choosing the first- and second-period consumption $\{C_{p1}, C_{p2}\}$, transfer (m_p), and amount of savings (a_p):

$$\max_{\{C_{p1},C_{p2},m_p,a_p\}} u(C_{p1}) + \beta u(C_{p2}) + \alpha V_k(A, \epsilon, m_p) \quad \text{subject to}$$

$$C_{p1} + m_p + a_p \leq x_p,$$

$$C_{p2} \leq Ra_p, \quad m_p \geq 0,$$

where $V_k(A, \epsilon, m_p)$ is the value function of the child, and α captures the extent of the parents' altruistic preference.

I.1 Equilibrium under Optimal Investment

In this section, we analyze the case in which the child can optimally invest and smooth consumption. We solve the child's problem for a given parental transfer m_p, and then solve for m_p to fully characterize the model. For $J = 1$, we characterize the solution when $T - \epsilon n_k > 0$ and $m_k > m_d$ hold. Note that the human capital production function for $J = 1$ is $h_1 = \overline{h} + A\{m_k^\gamma + (T - \epsilon n_k)^\gamma\}^{\frac{\rho}{\gamma}}$.

For an interior solution ($m_k > m_d$, $n_k > 0$), the optimality conditions imply

$$\frac{\partial h}{\partial m_k} = \rho A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}-1} m_k^{\gamma-1} = R$$
$$-\frac{\partial h}{\partial n_k} = \epsilon\rho A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}-1} (T - \epsilon n_k)^{\gamma-1} = Rw.$$

Without the constraint, the child chooses m_k that equalizes the marginal gain in human capital to the interest rate. Similarly, the child chooses n_k so that the marginal cost of self-financing that reduces human capital is equalized to the marginal benefit of self-financing that increases income by Rw. Denote $\{m_k^*, n_k^*\}$ to be the interior solution without the constraints. Combining the above two equations, we get $T - \epsilon n_k^* = \left(\frac{\epsilon}{w}\right)^{\frac{1}{1-\gamma}} m_k^*$. Therefore, the child's monetary investment decreases as the labor supply during college increases.

The optimal monetary and time investments for an interior solution are

$$m_k^* = K_1 A^{\frac{1}{1-\rho}},$$

$$T - \epsilon n_k^* = \Big(\frac{\epsilon}{w}\Big)^{\frac{1}{1-\gamma}} K_1 A^{\frac{1}{1-\rho}},$$

where $K_1 = \Big[\frac{\rho}{R}\Big\{1+\big(\frac{\epsilon}{w}\big)^{\frac{\gamma}{1-\gamma}}\Big\}^{\frac{\rho}{\gamma}-1}\Big]^{\frac{1}{1-\rho}}$. Note that the optimal monetary and time investments increase as ability increases.

Denote $\{\hat{m}_k, \hat{n}_k\}$ to be the corner solutions without the constraints ($\hat{n}_k = 0$). The child chooses the corner solutions if the following condition holds:

$$\rho A\big\{\hat{m}_k^\gamma + T^\gamma\big\}^{\frac{\rho}{\gamma}-1}\hat{m}_k^{\gamma-1} = R, \tag{I.2}$$

$$\epsilon\rho A\big\{\hat{m}_k^\gamma + T^\gamma\big\}^{\frac{\rho}{\gamma}-1}T^{\gamma-1} > Rw. \tag{I.3}$$

For a given A, let $\hat{m}_k(A)$ be the unique solution that satisfies equation (I.2), and let $\hat{\epsilon}(A)$ be the solution for the following equation:

$$\hat{\epsilon}(A) \equiv \frac{Rw}{\rho A}\big\{\hat{m}_k(A)^\gamma + T^\gamma\big\}^{1-\frac{\rho}{\gamma}}T^{1-\gamma}.$$

Then, from equation (I.3), $n_k = 0$ if and only if $\epsilon > \hat{\epsilon}(A)$.

If the child chooses to drop out of a college ($J = 0$), human capital is determined as $h_0 = \overline{h} + \phi_0 + \phi_1 A$, and the child's m_k and n_k are m_d and n_d, respectively.

The lifetime income of the child W_J ($J \in \{0,1\}$) can be written as

$$W_J = \begin{cases} \overline{h}/R + G \cdot A^{\frac{1}{1-\rho}} + \frac{wT}{\epsilon} + m_p, & \text{if } J = 1 \text{ and } \epsilon \leq \hat{\epsilon}(A), \\ \overline{h}/R + A(\hat{m}_k^{\gamma} + T^{\gamma})^{\frac{\rho}{\gamma}}/R - \hat{m}_k + m_p, & \text{if } J = 1 \text{ and } \epsilon > \hat{\epsilon}(A), \\ \overline{h}/R + (\phi_0 + \phi_1 A)/R - m_d + wn_d + m_p, & \text{if } J = 0, \end{cases}$$

where $G = \left(\frac{\rho}{R}\right)^{\frac{1}{1-\rho}}\left(\frac{1}{\rho} - 1\right)\left[1 + \left(\frac{\epsilon}{w}\right)^{\frac{\gamma}{1-\gamma}}\right]^{\frac{\rho(1-\gamma)}{\gamma(1-\rho)}} > 0$. Let J^* be the college-completion decision without the constraint. Without the borrowing constraint, the optimal college-completion decision (J^*) is characterized by the lifetime income such that $J^* = 1$ if and only if $W_1 \geq W_0$. Let $A^*(\epsilon)$ be the solution for $G \cdot A^{\frac{1}{1-\rho}} + \frac{wT}{\epsilon} = (\phi_0 + \phi_1 A)/R - m_d + wn_d$, and let $\hat{A}(\epsilon)$ be the solution for $A(\hat{m}_k^{\gamma} + T^{\gamma})^{\frac{\rho}{\gamma}}/R - \hat{m}_k = (\phi_0 + \phi_1 A)/R - m_d + wn_d$. Then, the optimal choice for J^* can be characterized such that $J^* = 1$ if and only if $A \geq A^*(\epsilon)$ for $\epsilon < \hat{\epsilon}(A)$, and $J^* = 1$ if and only if $A \geq \hat{A}(\epsilon)$ for $\epsilon \geq \hat{\epsilon}(A)$.[1]

The child's choice without the constraint, (M_k^*, N_k^*), can be summarized as

$$M_k^* = \begin{cases} m_k^* = K_1 A^{\frac{1}{1-\rho}}, & \text{if } \epsilon < \hat{\epsilon}(A) \text{ and } A \geq A^*(\epsilon), \\ \hat{m}_k, & \text{if } \epsilon \geq \hat{\epsilon}(A) \text{ and } A \geq \hat{A}(\epsilon), \\ m_d, & \text{otherwise.} \end{cases} \tag{I.4}$$

$$N_k^* = \begin{cases} n_k^* = T/\epsilon - \epsilon^{\frac{\gamma}{1-\gamma}} w^{\frac{-1}{1-\gamma}} K_1 A^{\frac{1}{1-\rho}}, & \text{if } \epsilon < \hat{\epsilon}(A) \text{ and } A \geq A^*(\epsilon), \\ \hat{n}_k = 0, & \text{if } \epsilon \geq \hat{\epsilon}(A) \text{ and } A \geq \hat{A}(\epsilon), \\ n_d, & \text{otherwise.} \end{cases} \tag{I.5}$$

Note the college-completion decision and the time and monetary investment do not depend on

[1] To simplify the characterization with $n_k = 0$, we assume that $\phi_1 < T^{\rho}$. Under this condition, which is the case in our baseline simulation, the college-completion rate among those who do not work ($n_k = 0$) weekly increases by A.

parental transfer m_p. Let H^* be the optimal human capital. Then,

$$H^* = \begin{cases} h_1^* = \overline{h} + K_2 A^{\frac{1}{1-\rho}}, & \text{if } \epsilon < \hat{\epsilon}(A) \text{ and } A \geq A^*(\epsilon), \\ \hat{h}_1^* = \overline{h} + A(\hat{m}_k^\gamma + T^\gamma)^{\frac{\rho}{\gamma}}, & \text{if } \epsilon \geq \hat{\epsilon}(A) \text{ and } A \geq \hat{A}(\epsilon), \\ h_0^* = \overline{h} + \phi_0 + \phi_1 A, & \text{otherwise}, \end{cases} \tag{I.6}$$

where $K_2 = K_1^\rho \{1 + (\frac{\epsilon}{w})^{\frac{\gamma}{1-\gamma}}\}^{\frac{\rho}{\gamma}}$. Let $W^* = W_1 J^* + W_0(1 - J^*)$ be the child's lifetime income without credit constraint. The child's lifetime income increases by A.[2] Denote $\overline{W}^* = W^* - m_p$ to be the child's lifetime income net of parental transfer.

Now consider the parents' problem. Note that without borrowing constraints, the child can always optimally borrow to finance education and consumption. Therefore, without borrowing constraints, parental transfer does not affect the child's human capital and is driven by the compensating motive. Altruistic parents make a transfer to equalize the marginal utility from consumption across generations:

$$u'\Big(\frac{x_p - m_p}{1 + \beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\Big) = \alpha u'\Big(\frac{\overline{W}^* + m_p}{1 + \beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\Big).$$

Note that $m_p \leq 0$ holds. If parental income x_p is low enough or parents' altruism α is small enough, parents choose $m_p = 0$ because

$$u'\Big(\frac{x_p}{1 + \beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\Big) > \alpha u'\Big(\frac{\overline{W}^*}{1 + \beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\Big).$$

[2] Consider two individuals, A and B, who are identical except for their ability. Suppose B's ability is higher than A's. Denote $\{m_k^A, n_k^A\}$ to be the optimal choices of individual A, at which A is maximizing her lifetime utility. Note that without borrowing constraints, maximizing lifetime utility implies maximizing lifetime income. Suppose B's choice is the same as $\{m_k^A, n_k^A\}$, which is feasible for B without borrowing constraints. Even in this case, the lifetime income for B is greater than A because w is homogeneous and B's human capital is greater than A's with identical inputs. Because (m_k^B, n_k^B) maximizes B's lifetime income, whereas (m_k^A, n_k^A) is in the feasible set for B, (m_k^B, n_k^B) is weakly better than (m_k^A, n_k^A). Therefore, B's lifetime income is greater than A's lifetime income without borrowing constraints.

To sum, the optimal parental transfer (m_p^*) without constraints can be characterized as follows:

$$m_p^* = \begin{cases} \frac{x_p}{1+\alpha^{-\frac{1}{\sigma}}} - \frac{\alpha^{-\frac{1}{\sigma}}\overline{W}^*}{1+\alpha^{-\frac{1}{\sigma}}}, & \text{if } x_p > \alpha^{-\frac{1}{\sigma}}\overline{W}^*, \\ 0, & \text{otherwise.} \end{cases} \tag{I.7}$$

Because the child's income increases by A, the marginal utility from the parental transfer, and, hence m_p, decreases by A without borrowing constraints.

I.2 Equilibrium under Suboptimal Investment

In this section, we characterize the solution when the financial constraint in the form of $d \leq m_k$ exists. First, when parental transfers are lower than a certain threshold (which depends on children's characteristics A and ϵ), children's time and monetary investment are constrained by the constraint. To show this point, we first specify the optimal borrowing:

$$D_k^* = \frac{(\beta R)^{-\frac{1}{\sigma}} H^* + (M_k^* - wN_k^* - m_p)}{1 + (\beta R)^{-\frac{1}{\sigma}} R}.$$

The constraint is binding when $D_k^* > M_k^*$. Rearranging $D_k^* > M_k^*$ implies the constraint is binding when parental transfer (m_p) is smaller than a threshold $\overline{m}_p = (\beta R)^{-\frac{1}{\sigma}}(H^* - RM_k^*) - wN_k^*$:

$$\overline{m}_p = \begin{cases} (\beta R)^{-\frac{1}{\sigma}}(h_1^* - Rm_k^*) - wn_k^*, & \text{if } \epsilon < \hat{\epsilon}(A) \text{ and } A \geq A^*(\epsilon), \\ (\beta R)^{-\frac{1}{\sigma}}(\hat{h}_1^* - R\hat{m}_k), & \text{if } \epsilon \geq \hat{\epsilon}(A) \text{ and } A \geq \hat{A}(\epsilon), \\ (\beta R)^{-\frac{1}{\sigma}}(h_0^* - Rm_d) - wn_d, & \text{otherwise,} \end{cases} \tag{I.8}$$

where h_1^*, $\hat{h}_1^*$, and h_0^* are defined in equation (I.6).

The Child's Problem

Suppose $m_p \leq \overline{m}_p$. Then, the constraint binds and the child's problem becomes

$$\max_{\{n_k, m_k\}} u(wn_k + m_p) + \beta u(h - Rm_k) \quad \text{subject to}$$

$$h = J \cdot \Big[\overline{h} + A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}}\Big] + (1 - J) \cdot \Big[\overline{h} + \phi_0 + \phi_1 A\Big],$$

$$m_k \geq m_d, \quad n_k \geq 0, \quad T - \epsilon n_k > 0, \quad \text{if } J = 1,$$

$$m_k = m_d, \quad n_k = n_d, \quad \text{if } J = 0.$$

The first-order conditions with respect to m_k and n_k for students who complete college are

$$\frac{\partial h}{\partial m_k} = R \tag{I.9}$$

$$wu'(wn_k + m_p) \geq \beta\big(-\frac{\partial h}{\partial n_k}\big)u'(h - Rm_k). \tag{I.10}$$

The child always invests in education until the marginal return is equal to the interest rate (equation (I.9)). However, if the child cannot finance consumption from borrowing, the marginal return from self-financing increases ($-\frac{\partial h}{\partial n_k} > wR$), and the child would work more than the optimal level to finance consumption. Note that if $\gamma < \rho$, the marginal gain in human capital with respect to m_k decreases as working hours increase.[3] Therefore, the extra working hours can further reduce human capital due to the reduction in monetary investment when $\gamma < \rho$. As a result, the level of human capital decreases.

When the constraint $d \leq m_k$ is introduced, parental transfer (m_p) affects the child's investment decision in addition to the child's characteristics (A, ϵ). To demonstrate how the constraint changes the child's investment decision, in what follows, we present a graphical characterization of the choices of the child who would decide to complete college without the constraint. In doing so, we focus on

[3]For the interior solution ($m_k > m_d$), $\frac{\partial h_1}{\partial m_k} = \rho A\big\{1 + \big(\frac{T-\epsilon n_k}{m_k}\big)^\gamma\big\}^{\frac{\rho}{\gamma}-1} m_k^{\rho-1} = R$ always hold regardless of whether the constraint binds. If $\gamma < \rho$, increasing working hours reduces the marginal return to monetary investment because $\frac{\partial^2 h_1}{\partial m_k \partial n_k} < 0$.

characterizing the changes in the choice variables with respect to (ϵ, m_p) given A, which will be useful when we discuss the identification of ϵ and α.

Figure I1 describes how the constraint affects child's labor supply. The horizontal dashed line represents $\epsilon = \hat{\epsilon}(A)$. The solid line $(\overline{0abc})$ represents $\max\{0, \overline{m}_p\}$. The vertical line $\overline{bc}$ represents $\overline{m}_p = (\beta R)^{-\frac{1}{\sigma}}(\hat{h}_1^* - R\hat{m}_k)$ when $n_k = \hat{n}_k = 0$, and the line $\overline{ab}$ represents $\overline{m}_p = (\beta R)^{-\frac{1}{\sigma}}(h_1^* - Rm_k^*) - wn_k^*$ when $n_k = n_k^* > 0$.

If the constraint does not bind, child's labor supply depends only on ϵ. In particular, $n_k = \hat{n}_k = 0$ if $\epsilon > \hat{\epsilon}(A)$ (above the horizontal dashed line), and $n_k = n_k^* > 0$, otherwise (below the horizontal dashed line). When the constraint is introduced, the child's labor supply depends not only on ϵ but also on m_p. Students with $m_p > \max\{0, \overline{m}_p\}$ are not constrained (in regions (IV) and (V)), and, therefore, they will not change their decisions. The constraint affects the choices of students who are in regions (I), (II), and (III).

First, for students in region (I) who work positive hours even without the constraint, the constraint increases their labor supply because the marginal utility of labor increases due to the value from consumption smoothing. Second, consider students in regions (II) and (III). Those students would not work without the constraint $(n_k = \hat{n}_k = 0)$ because of the high opportunity cost of working on human capital. Whether the constraint increases their working hours depends on the parental transfer because the marginal benefit of self-financing decreases by parental transfer with the binding constraint. The dotted line $\overline{bd}$ represents the solution $(\hat{m}_p)$ in the following equation:

$$\beta\epsilon\rho A\{\hat{m}_k^\gamma + T^\gamma\}^{\frac{\rho}{\gamma}-1}T^{\gamma-1}(\hat{h} - R\hat{m}_k)^{-\sigma} = w(\hat{m}_p)^{-\sigma}. \tag{I.11}$$

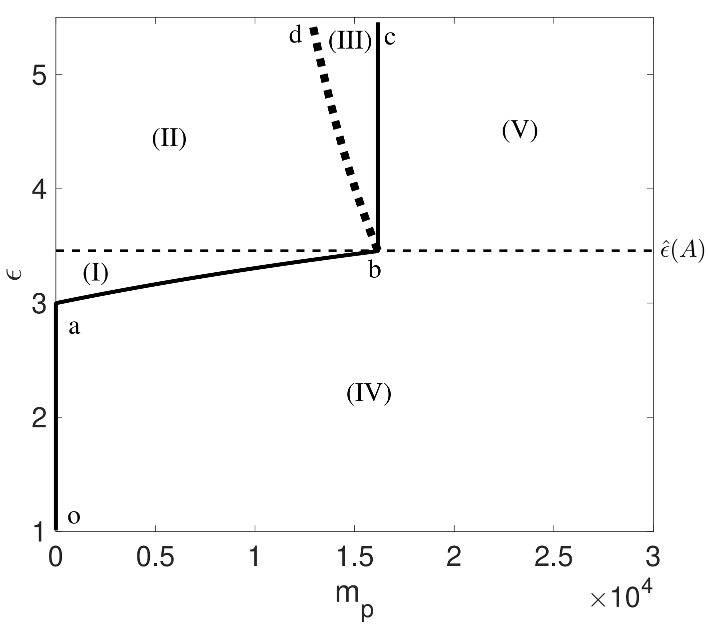
If $m_p \geq \hat{m}_p$ (region (III)), the child does not work, although the borrowing constraint binds, because the marginal cost of working at $n_k = 0$ is still higher than the marginal benefit of self-financing. If $m_p < \hat{m}_p$ (region (II)), equation (I.10) should hold with equality with the binding constraint, and, hence, the child who would have chosen zero-working hours without the constraint chooses to work positive hours with the binding constraint.[4]

On the other hand, the value from dropping out, V_0, can be represented as follows:

$$\begin{cases} \dfrac{(wn_d + m_p)^{1-\sigma}}{1-\sigma} + \beta\dfrac{(h_0 - Rm_d)^{1-\sigma}}{1-\sigma}, & \text{if } m_p < \overline{m}_p, \\ \dfrac{\left(1+\beta^{\frac{1}{\sigma}}R^{\frac{1-\sigma}{\sigma}}\right)^{\sigma}}{1-\sigma}\Big(h_0/R - m_d + wn_d + m_p\Big)^{1-\sigma}, & \text{otherwise.} \end{cases}$$

The value from dropping out is determined by (A, m_p). Thus, in the space of (m_p, ϵ) in Figure I1, for each m_p, there exists a unique value for dropping out that does not vary by ϵ. If the value from completing college decreases substantially due to the constraint, some students will change their extensive margin decision from completion to dropping out when the constraint is introduced.

Figure I1: Policy Function of the Child



NOTE: This figure shows the policy function of the child over (ϵ, m_p). The dashed line represents $\hat{\epsilon}(A)$. The solid line $(\overline{oabc})$ represents $\overline{m}_p$. The dotted line $(\overline{bd})$ refers to $\hat{m}_p$. Children in regions (I), (II), and (III) are constrained when the constraint is introduced. Children in regions (IV) and (V) are not constrained, even in the presence of the constraint.

[4] Note that $\hat{m}_p$ is decreasing in ϵ and $\overline{m}_p$ is increasing in ϵ up to $\epsilon = \hat{\epsilon}(A)$. Moreover, $\overline{m}_p = \hat{m}_p$ when $\epsilon = \hat{\epsilon}(A)$.

Parents' Problem

With the children's value function in hand, we now discuss the parents' problem:

$$\max_{m_p} \frac{\left(1+\beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}\right)^{\sigma}\left(x_p-m_p\right)^{1-\sigma}}{1-\sigma}+\alpha V_k(A, \epsilon, m_p) \quad \text{subject to} \quad m_p \geq 0.$$

The first-order condition implies that

$$u'\left(\frac{x_p-m_p}{1+\beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\right) \geq \alpha \frac{\partial V_k}{\partial m_p}. \tag{I.12}$$

From the children's problem (I.1), parental transfers expand children's budget set (regardless of whether or not the child constrained), and, therefore, V_k is an increasing function of m_p. If $u'\left(\frac{x_p}{1+\beta^{\frac{1}{\sigma}} R^{\frac{1-\sigma}{\sigma}}}\right) > \alpha \frac{\partial V_k}{\partial m_p}\Big|_{m_p=0}$, parents do not provide any transfer. Otherwise, parents choose m_p to make equation (I.12) hold as equality. Such a solution exists given that $\frac{\partial V_k}{\partial m_p}$ converges to zero as m_p goes to infinity.[5] Given that the marginal cost of transfer (the left-hand side of equation (I.12)) does not change by α, whereas the marginal benefit of transfer (the right-hand side of equation (I.12)) increases by α, parental transfers (m_p) are an increasing function of α given (ϵ, A, x_p).[6]

In what follows, we focus on characterizing m_p with respect to unobservable characteristics of the child and parents (α, ϵ), given the observable characteristics (A, x_p). This characterization will be useful when we discuss the identification of α. To provide a clear exposition, we focus on students who graduate college both with and without the constraint.

To illustrate how parents' policy function changes depending on the child's unobservable characteristic ϵ, we discuss the characterization of m_p for a given (A, x_p) for two cases. First, if ϵ is smaller than a threshold, the child can always choose the optimal investment even without a parental transfer. In this case, m_p can be characterized by equation (I.7). Second, if ϵ is greater than the threshold, the

[5] This is because $\frac{\partial V_k}{\partial m_p} = \tilde{c}(H^*/R + wN_k^* - M_k^* + m_p)^{-\sigma}$ when $m_p \geq \overline{m}_p$, where $\tilde{c}$ is a constant.

[6] $\frac{\partial m_p}{\partial \alpha}$ is bounded above because the marginal increase in m_p is smaller than x_p in equilibrium.

constraint may or may not bind, depending on α.

Consider the first case. Although the constraint exists, when the child's cost of working (ϵ) is small, she can achieve the optimal level of human capital even without parental transfers. In this case, the parental transfer is driven solely by compensating motives. To be more specific, from equation (I.8), we define $\Omega = (\beta R)^{-\frac{1}{\sigma}}(h_1^* - Rm_k^*) - wn_k^*$. For a given A, (1) Ω is an increasing function of ϵ when $\gamma < \rho$, (2) $\lim_{\epsilon \to 0} \Omega = -\infty$, and (3) $\Omega > 0$ at $\epsilon = \hat{\epsilon}(A)$. Therefore, for a given A, a unique $\epsilon_0(A) < \hat{\epsilon}(A)$ exists so that $\Omega = 0$ at $e = \epsilon_0(A)$ (point **a** in Figure I1). If $\epsilon < \epsilon_0(A)$, the constraint is not binding for all $m_p \geq 0$ (because $\overline{m}_p$ is negative if $\epsilon < \epsilon_0(A)$). Therefore, m_p is characterized by equation (I.7), which is illustrated in the left panel of Figure I2.

Next, consider the second case. If $\epsilon > \epsilon_0(A)$, the constraint binds if $m_p < \overline{m}_p$, where $\overline{m}_p$ is defined in equation (I.8). Given that m_p is an increasing function of α for any (A, x_p, ϵ), define $\overline{\alpha}(A, x_p, \epsilon)$ to be the α at which $m_p^*(A, x_p, \alpha, \epsilon) = \overline{m}_p$. Let $\tilde{m}_p(A, x_p, \alpha, \epsilon)$ be the parental transfer satisfying equation (I.12) as equality when the child is constrained. Then, for a given $(A, x_p, \alpha, \epsilon)$, parental transfers by those who have a child with $\epsilon > \epsilon_0(A)$ can be represented by equation (I.13).

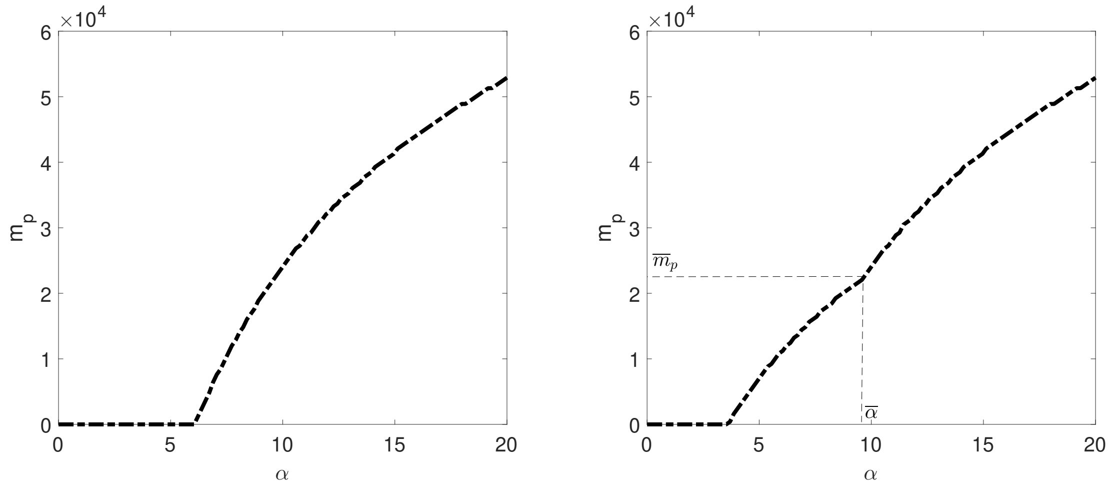
$$m_p = \begin{cases} \max\{0, \tilde{m}_p(A, x_p, \alpha, \epsilon)\}, & \text{if } \alpha < \overline{\alpha}(A, x_p, \epsilon), \\ m_p^*(A, x_p, \alpha, \epsilon), & \text{if } \alpha \geq \overline{\alpha}(A, x_p, \epsilon). \end{cases} \tag{I.13}$$

For a $\alpha < \overline{\alpha}(A, x_p, \epsilon)$ so that the child is constrained, $\tilde{m}_p(A, x_p, \alpha, \epsilon)$ is greater than or equal to $m_p^*(A, x_p, \alpha, \epsilon)$. To show this point, consider the derivative of value function for college graduates with respect to m_p:

$$\frac{dV_k}{dm_p} = \underbrace{\frac{\partial V_k}{\partial m_p}}_{\text{(I)}} + \underbrace{\frac{\partial V_k}{\partial h}\frac{\partial h}{\partial m_p}}_{\text{(II)} \geq 0 \text{ if } d_k = m_k} .$$

First of all, when the constraint is binding, parental transfers can increase the child's human capital by reducing n_k and increasing m_k (Part II). Moreover, parental transfers can reduce the utility cost associated with the limited intertemporal consumption smoothing by providing liquidity during college (Part I). As a consequence, the marginal impact of a parental transfer on the child's value function is higher when the is binding. Overall, the marginal value of a parental transfer increases given $(A, x_p, \alpha, \epsilon)$ when the constraint is binding. The graphical representation is shown in the right panel of Figure I2.

Figure I2: Parental Transfers



NOTE: The figure illustrates the policy function of the parent with respect to α for a given (A,x_p, ϵ). The left panel plots the parental transfer for the child with a small enough ϵ ($\epsilon < \epsilon_0(A)$) who can always choose the optimal level of investment even without a parental transfer. The right panel plots the parental transfer for the child who may face a binding constraint depending on m_p ($\epsilon > \epsilon_0(A)$). $\overline{\alpha}$ in the right panel is a cutoff value of α, below which the child faces the binding borrowing constraint.

II Identification of $F(\epsilon)$ and $F(\alpha)$

Based on the characterization of children's time and monetary investment and parental transfer regarding ϵ and α (as shown in section I.1 and I.2), we discuss how the distribution of ϵ and α can be recovered from the observed data distribution.

II.1 Distribution of ϵ

To show the moments that can identify the distribution of ϵ, we exploit the following intuition: the time and monetary investments for students from a high-income family are less likely to be constrained. In our model, as the parents' income increases, the parental transfer increases from equation (I.12).[7] From equation (I.8), students with a higher parental transfer are less likely to be constrained.

Consider an unconstrained student from a high-income family. The optimal working hours are characterized by equation (I.5). When all the parameters in equation (I.5) are known and A is given, the working hours of the unconstrained student are solely determined by ϵ. Note the working hours of the unconstrained student is a decreasing function of ϵ as long as $\rho > \gamma$ (as illustrated by Figure II1).[8] Therefore, the distribution of working hours among students from high-income families can be informative to recover the distribution of ϵ.

We additionally impose a parametric assumption on ϵ (a log-normal distribution). As a result, we need to identify only the mean (ϵ_0) and standard deviation (σ_ϵ) for the log-normal distribution by using various moments of working hours among students from high-income families. For example, conditional on A, the proportion of working students from high-income families can be approximated by

$$\Pr\big[\epsilon \leq \hat{\epsilon}(A)\big|A\big]. \tag{II.1}$$

Similarly, conditional on A, the average working hours of working students from high-income families can be approximated by

$$\mathbb{E}\big[n_k^*\big|\epsilon \leq \hat{\epsilon}(A), A\big]. \tag{II.2}$$

[7]This prediction is supported by data. In the main sample, the median and mean of the parental transfer for the lowest quartile of family income distribution are 0 and 5,878, respectively. On the other hand, the median and mean of parental transfer for the highest family income quartile are 11,811 and 23,380, respectively.

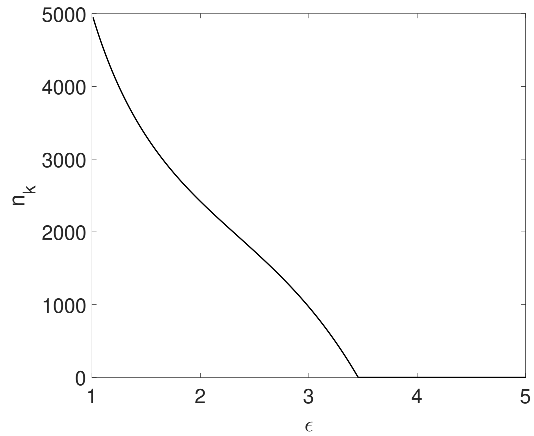
[8]In our main model, γ is estimated negative, so such condition is satisfied.

The expectation in equation (II.2) is over ϵ. Because the mean of ϵ increases by both ϵ_0 and σ_ϵ, increasing either ϵ_0 or σ_ϵ decreases the share of working students from high-income families. However, increasing ϵ_0 and increasing σ_ϵ can have opposite impacts on the average working hours. The reason is that the skewness of the distribution of ϵ depends only on σ_ϵ, and the measure around zero increases as the skewness increases. On the other hand, the measure around zero decreases as ϵ_0 increases. Because working hours increase as ϵ decreases, conditional on the same share of working students, increasing σ_ϵ generates higher average working hours than increasing ϵ_0 does.

To illustrate this point, in Table II1, we simulate the model and report how increasing ϵ_0 and increasing σ_ϵ affect the share of working students, the average working hours for working students, and the second moment of working hours for students who complete college.[9] In particular, if we increase ϵ_0 by 2.2% or increase σ_ϵ by 20%, the share of working students among college graduates decreases by a similar magnitude (M3). However, such a change can have opposite impacts on the average working hours for working students (M4) and the second moment of the working hours among college graduates (M5). Therefore, the share of working students, especially from high-income families, and their average working hours are informative in identifying ϵ_0 and σ_ϵ.

[9] We simulate these moment conditions because they are used for estimation. The same pattern is observed when we simulate the corresponding moments conditional on high-income families.

Figure II1: Labor Supply of the Unconstrained Child by ϵ



NOTE: This figure shows how the working hours (n_k) of the unconstrained child changes with respect to ϵ.

Table II1: Identification of $(\epsilon_0, \sigma_\epsilon)$

Moment Conditions	(1) Baseline	(2) increasing ϵ_0	(3) increasing σ_ϵ
M3: $\frac{1}{n}\sum_{i=1}^{n} I(n_{ki} > 0) \cdot BA_i$	0.741	0.722	0.722
M4: $\frac{1}{n}\sum_{i=1}^{n} I(n_{ki} > 0) \cdot n_{ki} \cdot BA_i$	0.276	0.261	0.287
M5: $\frac{1}{n}\sum_{i=1}^{n} n_{ki}^2 \cdot BA_i$	0.129	0.120	0.149

NOTE.This table shows the impacts of changes in $(\epsilon_0, \sigma_\epsilon)$ on three moment conditions (M3, M4, and M5), without adjusting the weights used in the estimation (The moment numbers correspond to the ones in Table 9.) M4 and M5 are divided by 10^4 and 10^8, respectively. Column (1) presents the moments in the baseline simulation. Column (2) presents the moments when ϵ_0 increases by 2.2%, and column (3) presents the moments when σ_ϵ increases by 20%.

II.2 Distribution of α

Given that the distribution of ϵ is known, the distribution of parental transfer is determined by the distribution of α conditional on (A, x_p). Given the parametric assumption on $\alpha = \left(\frac{x_p}{10000}\right)^{\alpha_1} + \exp(u_\alpha)$, where $u_\alpha \sim N(\alpha_0, \sigma_\alpha)$, we need to identify only $\{\alpha_0, \alpha_1, \sigma_\alpha\}$ by using various moments of parental transfers.

Let $g(\epsilon)$ be the pdf of ϵ. Given that ϵ and α are independent, the average parental transfer conditional on (A, x_p) can be expressed as

$$\mathbb{E}[\mathbf{m}_p(A, x_p, \alpha)|A, x_p], \tag{II.3}$$

where $\mathbf{m}_p(A, x_p, \alpha) = \int_\epsilon m_p(A, x_p, \epsilon, \alpha) g(\epsilon)\, d\epsilon$ and the expectation is over α. Because $\frac{\partial m_p(A,x_p,\epsilon,\alpha)}{\partial \alpha}$ is positive and bounded above for all (A, x_p, ϵ) (as discussed in section I.2), $\mathbf{m}_p(A, x_p, \alpha)$ is increasing in α for any given distribution of ϵ by the monotone convergence theorem.

Note that increasing either α_0 or σ_α increases equation (II.3). However, their impacts on the share of students with positive parental transfers,

$$\Pr\big[\mathbf{m}_p(A, x_p, \alpha) > 0|A, x_p\big], \tag{II.4}$$

can be different. This is also related to the fact that the skewness of the distribution of α depends only on σ_α, and the measure of α around zero increases as the skewness increases. On the other hand, the measure of α around zero decreases as α_0 increases. Because parental transfer increases by α, conditional on the same average parental transfer, increasing σ_α leads to the share of students with positive parental transfers smaller than the share from increasing α_0. Thus, the share of students with positive parental transfers and the average parental transfers can help to identify $(\alpha_0, \sigma_\alpha)$.

To illustrate this point, in Table II2, we simulate the model and report how increasing α_0 and increasing σ_α affect the share of positive parental transfers and the average parental transfer among those from the top quartile of the income distribution. In particular, increasing α_0 by 2.3% or increasing σ_α by 30% increases the average parental transfer from the top quartile of the family income distribution by a similar magnitude (M13). However, such a change can have opposite impacts on the share of students from the top quartile of the family income distribution with positive parental transfers (M9). Therefore, the share of students with positive parental transfers and their average parental transfer can help to identify α_0 and σ_α.

Depending on α_1, the relationship between the average parental transfers across different income quartiles will change. For example, consider the following moment:

$$\frac{\mathbb{E}[\mathbf{m}_p(A, x_p, \alpha)|A, x_p^{75th}]}{\mathbb{E}[\mathbf{m}_p(A, x_p, \alpha)|A, x_p^{25th}]}, \tag{II.5}$$

where x_p^{75th} and x_p^{25th} are 75th and 25th percentiles of parental income distribution, respectively. As α_1 increases, the average parental transfers at the 75th income percentile relative to 25th income percentile will increase. As illustrated in equation (II.5), the average parental transfers across different income quartiles can be used to identify α_1.

Table II2: Identification of $(\alpha_0, \sigma_\alpha)$

Moment Conditions		(1) Baseline	(2) increasing α_0	(3) increasing σ_α
M9:	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot I_{F4i}$	0.205	0.209	0.199
M13:	$\frac{1}{n}\sum_{i=1}^{n} I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F4i}$	0.877	0.930	0.930

NOTE. This table shows the impacts of changes in $(\alpha_0, \sigma_\alpha)$ on two moment conditions (M7 and M13), without adjusting the weights used in the estimation. M13 is divided by 10,000. (The moment numbers corresponds to the ones in Table 9.) Column (1) presents the moment in the baseline simulation. Column (2) presents the moments when α_0 increases by 2.3%, and column (3) presents the moments when σ_α increases by 30%.

III Additional Data

III.1 American Time Use Survey

To generate the child's time endowment for higher education (T in the human capital function), we use the time-diary data set of the American Time Use Survey (ATUS) 2004. We get the average time spent sleeping and eating by enrollment status and educational attainment. Time use is classified into 17 major categories.[10] Focusing on college students who are enrolled in a program, we have 871

[10]The 17 categories of activities are as follows: 1. Personal care, 2. Household Activities, 3. Caring for and Helping Household Members, 4. Caring for and Helping Non-household Members, 5. Work and Work-Related Activities, 6.

observations in the sample.

For the time endowment of students, we subtract time for sleeping and eating as fixed time costs for living. For sleeping, we use time for sleeping (t010101). For college students who are enrolled in a program, the average (median) sleeping time is 519 (510) minutes per day. We also subtract time for eating and drinking (t110101), which is, on average (median), 62 (55) minutes per day. College students spend in total about 580 minutes sleeping and eating; thus, for each day, they have 14.33 hours not spent sleeping or eating, which results in about 20,000 hours over 4 years.

The correlation between time spent on education and working is -0.35 without controlling for any other components. In Table III1, we run linear regressions for study time on working and leisure hours. If increased working hours perfectly substitute for leisure hours and do not affect study time, working hours would not be correlated with study time. We find that the coefficients of working hours are significantly negative in columns (1) and (2). Therefore, the data support the idea of a trade-off between study time and working hours.

On the other hand, to document the trend in study time over time (footnote 1 in the paper), we use the recent ATUS 2012 data. We combine ATUS-CPS with ATUS Activity summary file to document the study time for full-time college students. To calculate weekly time taking classes and studying, we first sum the time allocated to the following activities: t060101 (taking class for degree, certification, or licensure), t060102 (taking class for personal interest), t060103 (waiting associated with taking classes), t060104 (security procedures related to taking classes), t060199 (taking classes), t060301 (research/homework for class for degree, certification, or licensure), t060302 (research/homework for class for personal interest), and t060399 (research/homework n.e.c.). We then multiply the average study time per day by 7.

Because the ATUS-CPS data does not provide information on whether the individual attends a

Education, 7. Consumer Purchases, 8. Professional and Personal Care Service, 9. Household Services, 10. Government Services and Civic Obligations, 11. Eating and Drinking, 12. Socializing, Relaxing, and Leisure, 13. Sports, Exercise, and Recreation, 14. Religious and Spiritual Activities, 15. Volunteer Activities, 16. Telephone Calls, 17. Traveling.

four-year college or a two-year college, we report study time for two groups. First, we report the study time for students who are full-time college students. Second, we report the study time for students who are full-time students and who have completed at least two years of college education. The average weekly study time of full-time college students in 2012 is 14.84 hours, and that for the full-time college students who have completed at least two years of college is 14.96 hours.[11]

Table III1: Regression Estimates for Study Time

	(1)	(2)
VARIABLES	Study time	Study time
Working hours	-0.0798***	-0.136***
	(0.0134)	(0.0132)
Leisure hours		-0.418***
		(0.0335)
Age	0.295	-0.858
	(0.689)	(0.642)
Female	-21.94*	-37.68***
	(12.57)	(11.64)
Constant	154.3***	329.6***
	(28.20)	(29.54)
Observations	871	871
R-squared	0.042	0.188

NOTE: This table shows the estimates for linear regressions for study time on working and leisure hours. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

III.2 National Postsecondary Student Aid Study

The 2003-2004 National Postsecondary Student Aid Study (NPSAS 2004) is a nationally representative cross-sectional study of undergraduate and graduate students enrolled in postsecondary education in the US. We use the sample of undergraduate students, consisting of about 80,000 students who were enrolled at any time between July 1, 2003 and June 30, 2004 in about 1,400 postsecondary institutions. The sample collects data on the enrollment status, the cost of higher education, types of financial aid

[11] If we additionally account for time spent on extracurricular school activities except sports (t060201-t060299) and all other education-related activities (t069999), the weekly time spent on education is 15.03 hours for the full-time college students and 15.15 hours for the full-time college students who completed at least two-years of college education.

and the amount received, and demographic characteristics. As summarized in Table B2 in the paper, we use NPSAS 2004 for the annual sticker price and grant shares by family income quartiles for four-year and two-year colleges.

III.3 Beginning Postsecondary Students

The Beginning Postsecondary Students Longitudinal Study (BPS) is a representative sample of US college students, consisting of students who are enrolled in their first year of postsecondary education. The sample consists of around 16,700 students who were first-time, beginning students in 2003-2004 academic year. The respondents were interviewed in their first, third, and sixth year since entering college. The survey collects data on college enrollment, completion, employment, financial aid, and demographic characteristics. We use the BPS 2004 cohort to document the trade-off between working while in college and students' outcomes in Table 1 in the paper.