Self-financing, Parental Transfer, and College Education

Appendix for Online Publication*

Jungho Lee Sunha Myong

December 13, 2021

Contents

*Jungho Lee: School of Economics, Singapore Management University, 90 Stamford Road, Singapore, 178903. Email: jungholee@smu.edu.sg. Sunha Myong: School of Economics, Singapore Management University, 90 Stamford Road, Singapore, 178903. Email: sunhamyong@smu.edu.sg.

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

$$\max_{\{C_{k1},C_{k2},n_k,m_k,d_k,J\}} u(C_{k1}) + \beta u(C_{k2}) \quad \text{subject to} \tag{A.1}$$
$$C_{k1} + m_k \leq wn_k + d_k + m_p,$$
$$C_{k2} + Rd_k \leq h,$$
$$d_k \leq m_k,$$
$$h = J \cdot \Big[\overline{h} + A\big\{m_k^\gamma + (T - \epsilon n_k)^\gamma\big\}^{\frac{\rho}{\gamma}}\Big] + (1-J) \cdot \Big[\overline{h} + \phi_0 + \phi_1 A\Big],$$
$$m_k \geq m_d, \quad n_k \geq 0, \quad T - \epsilon n_k > 0, \quad \text{if } J = 1,$$
$$m_k = m_d, \quad n_k = n_d, \quad \text{if } J = 0,$$

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.

A.1 Equilibrium without Tied-to-Investment Constraints

In this section, we analyze the case in which the tied-to-investment constraint does not bind. 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 tied-to-investment constraints. Combining the above two equations, we get $T - \epsilon n_k^* = \big(\frac{\epsilon}{w}\big)^{\frac{1}{1-\gamma}} m_k^*$. 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 tied-to-investment constraints ($\hat{n}_k = 0$).

The child chooses the corner solutions if the following condition holds:

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

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

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

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

Then, from equation (A.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

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

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 tied-to-investment 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 $G \cdot A^{\frac{1}{1-\rho}} + \frac{wT}{\epsilon} = (\phi_0 + \phi_1 A)/R - m_d + w n_d$, and let $\hat{A}(\epsilon)$ be the solution for $A(\hat{m}_k^\gamma + T^\gamma)^{\frac{\rho}{\gamma}}/R - \hat{m}_k = (\phi_0 + \phi_1 A)/R - m_d + w n_d$. 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 tied-to-investment constraint, (M_k^*, N_k^*), can be summarized as

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

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

Note the college-completion decision and the time and monetary investment do not depend on parental transfer m_p. Let H^* be the optimal human capital. Then,

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

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.

[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.

[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.

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

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

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

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

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

A.2 Equilibrium with Tied-to-Investment Constraints

In this section, we characterize the solution when the tied-to-investment constraint 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 tied-to-investment 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 tied-to-investment constraint is binding when $D_k^* > M_k^*$. Rearranging $D_k^* > M_k^*$ implies the tied-to-investment constraint is binding when parental transfer (m_p) is smaller than a threshold $\overline{m}_p = (\beta R)^{-\frac{1}{\sigma}}(H^* - RM_k^*) - wN_k^*$:

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

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

The Child's Problem

Suppose $m_p \leq \overline{m}_p$. Then, the tied-to-investment 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

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

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

The child always invests in education until the marginal return is equal to the interest rate (equation (A.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 tied-to-investment 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 tied-to-investment 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 tied-to-investment constraint. In doing so, we focus on 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 A1 describes how the tied-to-investment 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

[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 tied-to-investment constraint binds. If $\gamma < \rho$, increasing working hours reduces the marginal return to monetary investment because $\frac{\partial^2 h_1}{\partial m_k \partial n_k} < 0$.

dashed line). When the constraint is introduced, 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 tied-to-investment 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:

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

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 (A.10) should hold with equality with the binding constraint, and, hence, the child who would have chosen zero-working hours without the tied-to-investment constraint chooses to work positive hours with the binding constraint.[4]

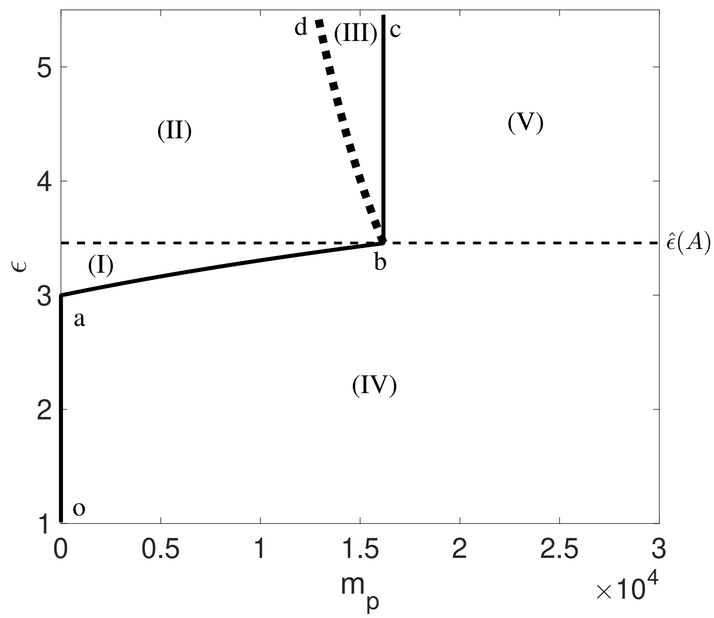
On the other hand, the value from dropping out, V_0, can be represented as follows:

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

[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 $\epsilon = \hat{\epsilon}(A)$.

The value from dropping out is determined by (A, m_p). Thus, in the space of (m_p, ϵ) in Figure A1, 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 tied-to-investment, some students will change their extensive margin decision from completion to dropping out when the tied-to-investment constraint is introduced.

Figure A1: 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 tied-to-investment constraint is introduced. Children in regions (IV) and (V) are not constrained, even in the presence of the tied-to-investment constraint.

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

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

From the children's problem (A.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 $u'\Big(\frac{x_p}{1+\beta^{\frac{1}{\sigma}}R^{\frac{1-\sigma}{\sigma}}}\Big) > \alpha\frac{\partial V_k}{\partial m_p}\Big|_{m_p=0}$, parents do not provide any transfer. Otherwise, parents choose m_p to make equation (A.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 (A.12)) does not change by α, whereas the marginal benefit of transfer (the right-hand side of equation (A.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 tied-to-investment 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 (A.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.

tied-to-investment constraint may or may not bind, depending on α.

Consider the first case. Although the tied-to-investment 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 (A.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 A1). If $\epsilon < \epsilon_0(A)$, the tied-to-investment 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 (A.7), which is illustrated in the left panel of Figure A2.

Next, consider the second case. If $\epsilon > \epsilon_0(A)$, the tied-to-investment constraint binds if $m_p < \overline{m}_p$, where $\overline{m}_p$ is defined in equation (A.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 (A.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 (A.13).

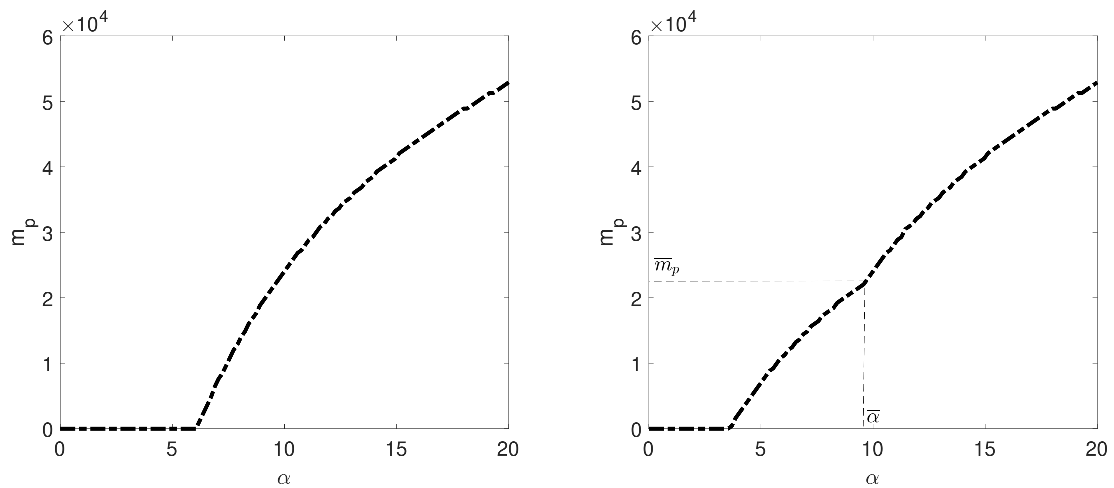
$$m_p = \begin{cases} \max\{0, \tilde{m}_p(A, x_p, \alpha, \epsilon)\}, & \text{if } \alpha < \overline{\alpha}(A, x_p, \epsilon), \\ m_p^*(A, x_p, \alpha, \epsilon), & \text{if } \alpha \geq \overline{\alpha}(A, x_p, \epsilon). \end{cases} \tag{A.13}$$

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 tied-to-investment 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 tied-to-investment is binding. Overall, the marginal value of a parental transfer increases given $(A, x_p, \alpha, \epsilon)$ when the tied-to-investment constraint is binding. The graphical representation is shown in the right panel of Figure A2.

Figure A2: 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 tied-to-investment 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.

B Identification of a Simplified Model

To focus on the identification of the distribution of the unobservable characteristics $\{F(\epsilon), F(\alpha)\}$ and production-function parameters $\{\rho, \gamma\}$, we consider a simplified version of our two-period model. The problems of the child and the parents in the simplified model are the same as in section 3 of the paper except (i) no dropout option exists ($\phi_0 \leq 0$ and $\phi_1 = 0$) and (ii) $m_d = 0$.

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

B.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 (A.12).[7] From equation (A.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 (A.5). When all the parameters in equation (A.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 B1).[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

$$\Pr\left[\epsilon \leq \hat{\epsilon}(A) \middle| A\right]. \tag{B.1}$$

[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.

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

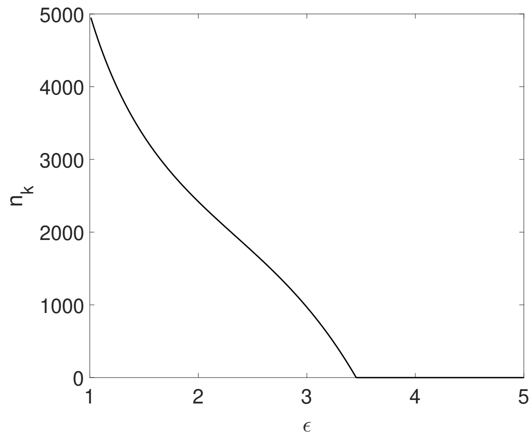
$$\mathbb{E}\left[n_k^* \middle| \epsilon \leq \hat{\epsilon}(A), A\right]. \tag{B.2}$$

The expectation in equation (B.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 B1, 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 B1: 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 B1: Identification of $(\epsilon_0, \sigma_\epsilon)$

Moment Conditions	(1) Baseline	(2) increasing ϵ_0	(3) increasing σ_ϵ
M3: $\frac{1}{n}\sum_i I(n_{ki} > 0) \cdot BA_i$	0.741	0.722	0.722
M4: $\frac{1}{n}\sum_i I(n_{ki} > 0) \cdot n_{ki} \cdot BA_i$	0.276	0.261	0.287
M5: $\frac{1}{n}\sum_i n_{ki}^2 \cdot BA_i$	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%.

B.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

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

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 A.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 (B.3). However, their impacts on the share of students with positive parental transfers,

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

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 B2, 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:

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

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 (B.5), the average parental transfers across different income quartiles can be used to identify α_1.

Table B2: Identification of $(\alpha_0, \sigma_\alpha)$

Moment Conditions		(1) Baseline	(2) increasing α_0	(3) increasing σ_α
M9:	$\frac{1}{n}\sum_i I(m_{pi} > 0) \cdot I_{F4}$	0.205	0.209	0.199
M13:	$\frac{1}{n}\sum_i I(m_{pi} > 0) \cdot m_{pi} \cdot I_{F4}$	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%.

B.3 Human Capital Parameters

Once we recover the distribution of ϵ and α, the average income in the second period (h) and the average monetary investment in the first period (m_k) can be written as a function of (γ, ρ). Therefore, the aforementioned two data moments can be informative to identify (γ, ρ).

To illustrate more clearly, we consider the following two conditional moments: the average earnings and the average monetary investment of the students who did not work during college. First, the monetary investment of the students who did not work (regardless of whether the borrowing constraint binds) during college ($\hat{m}_k$) is the solution to

$$\rho A\{m_k^\gamma + T^\gamma\}^{\frac{\rho}{\gamma}-1} m_k^{\gamma-1} = R. \tag{B.6}$$

Because the marginal return from monetary investment (the left-hand side of equation (B.6)) increases with ρ, $\hat{m}_k$ increases by ρ for a given γ. Second, the human capital of the students who did not work ($\hat{h}$) does not depend on ϵ and is a function of (ρ, γ):

$$\hat{h} = A(\hat{m}_k^\gamma + T^\gamma)^{\frac{\rho}{\gamma}}. \tag{B.7}$$

Therefore, the average earnings in the working period and the average monetary investment in the schooling period (in particular, for those who did not work in the schooling period) can be informative in identifying (γ, ρ).

C Sensitivity Analysis

Andrews et al. [2017] propose a measure called sensitivity that captures the relationship between parameter estimates and the moments of the data they depend on. The sensitivity of the parameter estimates with respect to the moment vector is a 10×19 matrix $\Lambda = -(\mathbf{D}'\mathbf{W}\mathbf{D})^{-1}\mathbf{D}'\mathbf{W}$. 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. We call these moments sensitivity moments.[10] Table C1 shows the result. The moment numbers

[10] 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.

corresponds to the ones in Table 9. We highlight a sensitivity moment if the moment is used for the identification argument in section 4.3. As we can see, the moments that we argue are important for the identification of each parameter mostly correspond to the sensitivity moments.

Table C1: 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 figures shows the sensitivity 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 sensitivity moments. The moment numbers corresponds to the ones in Table 9. We highlight a sensitivity moment if the moment is used for the identification argument in section 4.3.

D 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).

D.1 Data

We augment the main sample 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 D1 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 are 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 are 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).

Figure D1 presents the binned scatter plots of the relationship between the AFQT score and annual earnings after the college period for two-year-college students (top panel) and four-year-college dropouts (bottom panel), respectively. Although the average earnings are similar between the two-year-college students and the four-year-college dropouts, the correlation between earnings and student's ability is stronger for four-year-college dropouts.

Another key difference between two-year and four-year-college investment is the cost of attendance. Table D2 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.[11] Grants and the limits on non-need-based federal student loan aid are calculated by family income quartiles. The limit on non-need-based aid per year equals the annual net cost of attending a college, which is calculated by the difference between the sticker price and grants. As Table D2 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. The amount of non-need-based federal student loan aid available to two-year-college students is about half of that available for four-year-college students for all quartiles of the family income distribution.

D.2 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 ($J = 2$).[12]

We assume the labor supply of two-year-college students is fixed at $n_k = n_A$.[13] Also, the monetary

[11] Information on the non-need-based federal student aid is from https://studentaid.gov/complete-aid-process/how-calculated.

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

[13] 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

investment for a two-year college is fixed at $m_k = m_A$. The human capital accumulation for four-year-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. Motivated by Figure D1, 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:

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

The tied-to-investment constraint is defined as $d_k \leq (1 - s)m_k$, the same as in the main model.

Next, 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.

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.

for two-year-college students: some two-year-college students may need to work to finance the cost for 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.

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 two-year college instead of four-year college.

D.3 Estimation

The monetary investment (m_A) and the grant share (s_A) for two-year colleges are from the NPSAS 2004 (Table D2). 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 quartile, respectively, of the family income distribution. The working hours of two-year college students (n_A) is 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 7.

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 9. 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 D3.

D.4 Counterfactual Policy Experiments

In this section, we document the main findings of the counterfactual policy experiments in the extended model and discuss the robustness of our findings in the main model.

The first policy (loan policy) provides unconditional loans (not tied to investment) up to 20,000 USD in addition to the loans tied to college investment for both two-year and four-year college students.

The second policy provides an option to take up to 20,000 USD in loans not tied to investment for both two-year and four-year college students, under the condition that the student does not work more than 2,000 hours during college. The third policy (grant policy) provides 50% more grant money than the current grant level for both four-year and two-year college students. The current grant level for a four-year college is 46%, 20%, 14%, and 10% of the sticker price for the first, second, third, and fourth parental income quartile, respectively. By providing 50%-higher grants, the new grant becomes 70%, 30%, 22%, and 14% of the sticker price of a four-year college for the first, second, third, and fourth parental income quartile, respectively. The current grant level for a two-year college is 44%, 12%, 7%, and 4% of the sticker price for the first, second, third, and fourth parental income quartile, respectively. By providing 50%-higher grants, the new grant becomes 65%, 18%, 11%, and 6% of the sticker price of a two-year college for the first, second, third, and fourth parental income quartile, respectively. The fourth policy (grant + work limit) provides an option to get additional grants as specified in the third policy, under the condition that the student does not work more than 2,000 hours during college. The fifth policy (wage subsidy) provides 2 USD higher hourly wages than the current wage (8 USD) for those who work during college.

Aggregate outcomes

Table D4 summarizes the impacts of the counterfactual policies on the aggregate outcomes in the extended model. Similar to the main model, the loan policy (column (1)) has a large positive impact on the share of four-year-college graduates (15.62 percentage points), human capital (4,789 USD), and the welfare of the child (1.38%) and the parents (0.58%). Loans with and without the work restriction have similarly positive impacts on the share of four-year-college-graduates. However, the loan policy with the work restriction has greater impacts on the investment of intramarginal students than the loan policy. As a result, the average human capital increases by 5,864 USD, which is the greater than with other policies. The welfare impacts on students corresponds to a 1.28% increase in lifetime consumption, which is smaller than that for the loan policy without the work restriction, but greater than that for other policies. The welfare impact on the parents is smaller than that of the loan policy because the parental transfer decreases relatively less when the working-hours restriction exists. The grant policy (column (3)) has smaller impacts on those outcomes; it increases the share of four-year-college graduates by 2.61 percentage points, human capital by 368 USD, and the welfare of the child and the parents by 0.22% and 0.08%, respectively. Consistent with the main model, the grant with a work-restriction policy cannot increase the share of four-year-college graduates, but it can increase both the human capital (2,311 USD) and welfare of the students (0.33%) at the expense of decreasing parents' welfare (-0.04%) due to increasing parental transfers (2,646 USD). The wage-subsidy policy increases the share of four-year-college graduates by 4.42 percentage points but has a negligible impact on investment among intramarginal students and human capital. The welfare gain of the wage-subsidy policy is 0.47% for the child and 0.40% for the parents.

For all five counterfactual policy experiments, the increases in the share of four-year-college graduates are greater in the extended model than in the main model (Table 12). For instance, the loan policy increases the share of individuals who complete a four-year college by 7.80 percentage points in the main model, whereas the comparable number for the extended sample is 15.62 percentage points. The main reason for the difference is that the impact of the policy in the extended model also includes the increase in the four-year-college-completion rate among students who choose to attend a two-year college in the baseline simulation. Of the 15.62-percentage-point increase in the share of four-year-college graduates associated with the loan policy, 8.85 percentage points (57%) are from those who choose to drop out of four-year colleges, and 6.77 percentage points (43%) are from those who choose to attend two-year college in the baseline simulation. Therefore, our mechanism—that is, the negative impacts of the tied-to-investment constraint on the four-year-college-completion—applies both to students at the margin of attending a two-year college and those completing a four-year college.

The impacts of the counterfactual policies on the intensive margins of the investment among intramarginal students are similar between the main model and the extended model. Welfare implications for the child and the parents in the extended model are also similar to those of the main model.

Heterogeneous impacts by family income and ability

Panel A of Table D5 presents the distributional impact of each policy on the share of four-year-college graduates by family income and ability. Consistent with the main model, the impacts of the loan policy and the loan policy with work restriction on the share of four-year-college graduates are greater for low-ability students. For both low- and high-ability students, the impacts are greater than those in the main model, because some students change their choice from two-year-college attendance to four-year-college graduation. Consistent with the main model, the impact of the grant policy is largest for students from the bottom quartile of the family income distribution. On the other hand, the grant with a work-restriction policy slightly decreases the share of four-year-college graduates for low-ability low-income students, similar to the main model. The wage-subsidy policy increases the share of four-year-college graduates for all groups, but the impact is greater for low-ability students, which is also similar to the main model.

Panel B of Table D5 presents the distributional impacts of policies on human capital by family income and ability. For each policy, the overall patterns are similar to those in the main model. The impacts of the loan policy and the loan policy with work restriction are greater for high-ability, low-income students. The impacts of the grant policy on human capital are small for all groups. The impacts of the grant with a work-restriction policy are greater for high-ability students. The wage-subsidy program has heterogeneous impacts on human capital, increasing it for low-income students but decreasing it for high-income students.

Panel C of Table D5 presents the distributional impacts of policies on the welfare of the child by family income and ability. Similar to the findings in the main model, the welfare impacts of the loan policy and the loan policy with work restriction are greater for low-income students. The welfare impacts of the grant policy, the grant with a work restriction policy, and the wage-subsidy policy are also similar to those in the main model.

Overall, the heterogeneous impacts of the policies by family income and ability are mostly comparable between the main model and the extended model.

Table D1: 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 D2: Annual Cost for Attending 2- 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
C. Limit for non-need-based federal student loan aid			
1st income quartile	3,426	6,957	11,642
2nd income quartile	5,353	10,400	13,989
3rd income quartile	5,641	11,205	14,974
4th income quartile	5,819	11,742	16,327

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 D3: 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 D4: Policy Simulation (Including 2-Year Colleges)

Variable	(1) Loan	(2) Loan +work limit	(3) Grant	(4) Grant +work limit	(5) Wage subsidy	(6) Baseline
Share of four-year college graduates (%)	15.62	15.19	2.61	-0.05	4.42	53.09
Share of two-year college students (%)	-6.77	-6.35	-7.16	-5.35	-3.11	34.34
Working hours	-597	-1,051	-6	-676	19	3,503
Investment	3,970	4,616	1,526	3,150	-153	54,006
Human capital (annual earnings)	4,789	5,864	368	2,311	50	26,109
Parental transfer	-2,729	-1,529	83	2,646	-3,020	11,055
Welfare of students (%, lifetime consumption)	1.38	1.28	0.22	0.33	0.47	NA
Welfare of parents (%, lifetime consumption)	0.58	0.52	0.08	-0.04	0.40	NA

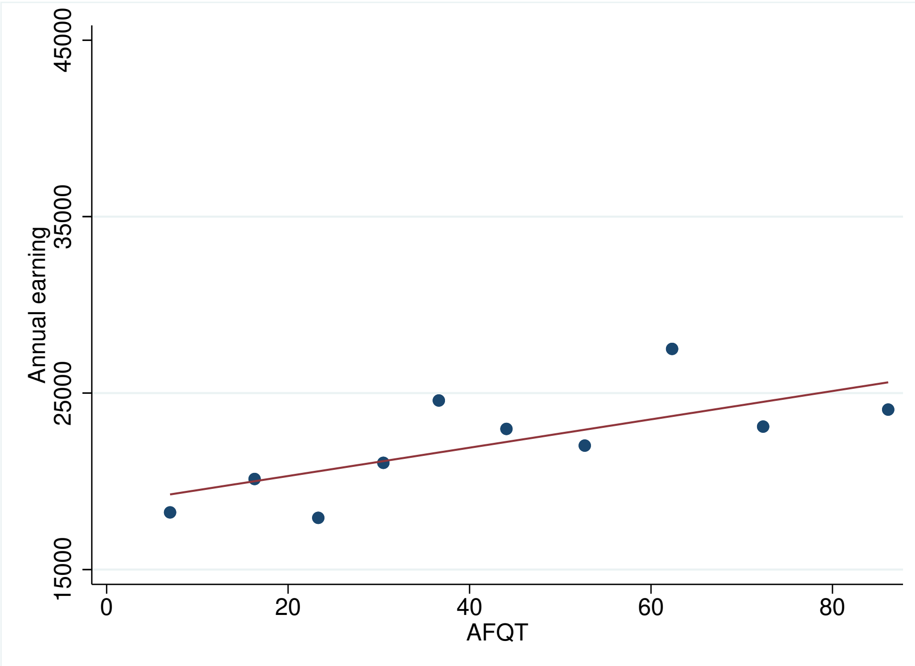
NOTE: This table shows the results from five policy simulations using the extended model. The first policy (loan policy) provides unconditional loans (loans not tied to investment) up to 20,000 USD in addition to the loans tied to college enrollment for both two-year and four-year college students. The second policy (loan + work limit) provides an option to receive loans not tied to investment up to 20,000 USD, conditional on working 2,000 hours or less during college. The take-up rate is 87.03% for the second policy. The third policy (grant policy) provides 50% additional grants from the current grant level for four-year college students. The fourth policy (grant + work limit) is the same as the second policy except that it requires the maximum working hours over the four-year-college period to be 2,000 hours for those who complete a four-year college. The take-up rate is 80.55% for the fourth policy. The fifth policy (wage subsidy) provides 2 USD higher hourly wages than the current wage (8 USD) for those who work while attending a four-year college. We report changes from the baseline (estimated) economy (column (6)) regarding (1) the share of students who complete a four-year college education (i.e., the share of four-year college graduates in the simulated economy − the share of four-year college graduates in the baseline economy), (2) the share of two-year-college students, (3) average working hours over the four-year-college period for those who complete the four-year college both in the baseline economy and in the policy simulation, (4) average monetary investments over the four-year-college period for those who complete the four-year college both in the baseline economy and in the policy simulation, (5) average parental transfer, (6) average human capital measured by annual earnings after graduation, and welfare of students (7) and parents (8) measured by consumption changes relative to the lifetime consumption in the benchmark economy.

Table D5: Policy Implications of the Share of Four-Year-College Graduates, Human Capital, and Students' Welfare (Including 2-Year Colleges)

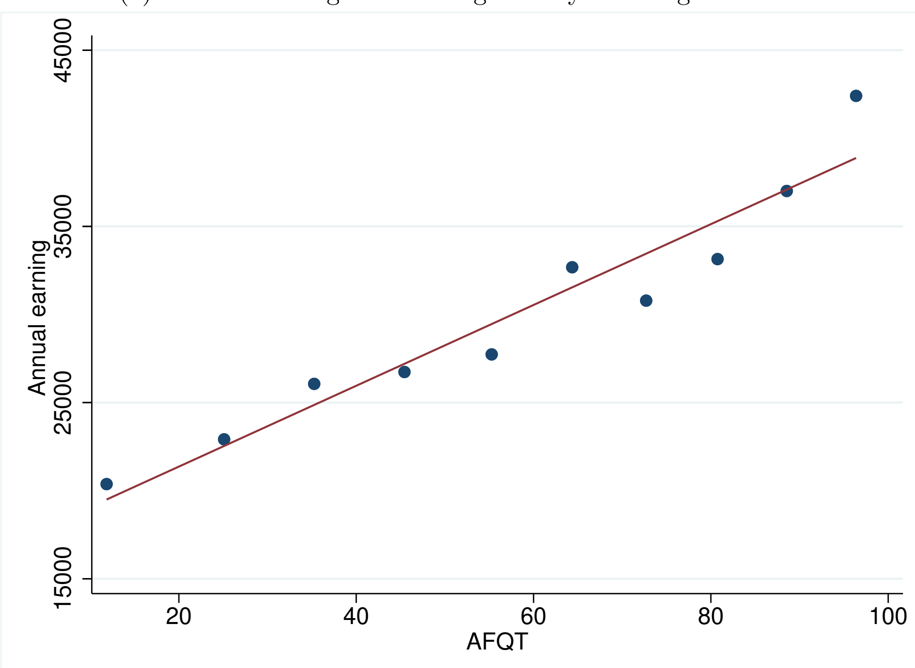
		Parental income			
		Q1	Q2	Q3	Q4
		Panel A. Share of Four-year College Graduates			
A1. Loan policy					
	Low A	22.90	21.42	19.09	10.92
	High A	13.46	12.53	9.51	4.77
A2. Loan policy + work limit					
	Low A	21.89	20.80	18.44	10.58
	High A	13.45	12.53	9.51	4.77
A3. Grants					
	Low A	6.56	2.16	1.33	1.01
	High A	3.25	1.66	1.40	0.59
A4. Grants + work limit					
	Low A	-0.28	-0.28	-0.01	0.24
	High A	-0.28	0.12	0.22	0.12
A5. Wage subsidy					
	Low A	7.00	6.06	4.55	2.24
	High A	4.85	3.70	2.88	1.18
		Panel B. Human capital			
B1. Loan policy					
	Low A	4,363	4,711	4,381	2,757
	High A	7,313	6,984	5,705	3,298
B2. Loan policy + work limit					
	Low A	4,865	5,278	5,028	3,436
	High A	8,990	8,676	7,590	5,182
B3. Grants					
	Low A	674	214	143	138
	High A	503	605	400	154
B4. Grants + work limit					
	Low A	1,254	1,428	1,539	1,499
	High A	3,265	4,023	3,905	3,278
B5. Wage subsidy					
	Low A	567	445	107	-507
	High A	689	161	-342	-1,157
		Panel C. Students' welfare			
C1. Loan policy					
	Low A	1.48	1.51	1.38	0.82
	High A	1.85	1.73	1.40	0.80
C2. Loan policy + work limit					
	Low A	1.35	1.39	1.29	0.85
	High A	1.65	1.55	1.29	0.82
C3. Grants					
	Low A	0.38	0.07	0.06	0.08
	High A	0.31	0.44	0.25	0.11
C4. Grants + work limit					
	Low A	0.27	0.19	0.24	0.30
	High A	0.27	0.59	0.47	0.39
C5. Wage subsidy					
	Low A	0.74	0.57	0.46	0.18
	High A	0.60	0.48	0.37	0.13

NOTE: This table shows the changes in the share of four-year college graduates (Panel A), average human capital (Panel B), and average students' welfare (Panel C) for each income/ability group after each policy. Q# refers 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 main sample. The cutoff values used to define the ability and family income groups are the same as in the main sample.

Figure D1: Correlation between Annual Earnings and Ability



(a) Annual earnings after college: two-year-college students



(b) Annual earnings after college: four-year-college dropouts

NOTE: The figure presents the binned scatter plots of the relationship between the AFQT score and annual earnings after college for two-year college students (top panel) and four-year-college dropouts (bottom panel), respectively. Source: NLSY97.

E 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 E1 shows estimates of the structural parameters (Panel A), model predictions (Panel B), and the impact of relaxing the tied-to-investment constraint (Panel C) for each robustness check. Column (1) of Table E1 shows the results from the main model for comparison.

E.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 D2 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 the all four-year colleges in the main model (column (2) Table D2). Panel B in Table D2 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. Panel C in Table D2 presents the annual limit on non-need-based federal student loan aid calculated by the difference between the annual sticker price and grants—that is, the annual net cost for attending a four-year colleges. The annual net cost for attending four-year private colleges are 34-67% more expensive than that for all four-year colleges in the main model, whereas the relative cost difference is greatest for students from the bottom quartile of the income distribution.

We assume the return to one additional year of college investment is the same for private and public colleges for the following reasons. The NPSAS 2004 assigns four categories of college selectivity from 1 (for the most selective) to 4 (for the college with an 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.

To account for the net cost difference between public and private colleges, we adjust the grant share for private colleges to be smaller than that for the public colleges. In particular, we assume the sticker price for private colleges is the same as in the main model, and calculate the grant ratio to match the annual net cost for private colleges by family income quartiles. For students who attend a four-year public college, the grant level is the same as in the main model, which is 46%, 20%, 14%, and 10% of the sticker price for the first, second, third, and fourth parental income quartile, respectively. For students who attend a four-year private college, the grant level is 11% of the sticker prices for students from the first quartile of the income distribution and 0% of the sticker prices for other students.[14]

Column (2) of Table E1 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 impacts of relaxing borrowing constraints 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 cost for private colleges, some of college

[14]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%.

dropouts in the main model can be explained by the expensive cost rather than the tied-to-investment constraint. Relatedly, the increase in human capital without the tied-to-investment constraint in the modified model (9,650 USD) is slightly smaller than that in the main model (11,498 USD).

E.2 Including Leisure

Second, we introduce leisure during the college period so that students divide their time between study, work, and leisure. The utility from leisure $u(l_k)$ is specified as $\zeta \frac{l_k^{1-\sigma}}{1-\sigma}$, and the human capital production function becomes $\overline{h} + A\big\{m_k^{\gamma} + (T - \epsilon n_k - l_k)^{\gamma}\big\}^{\frac{\rho}{\gamma}}$. The modified child's problem is

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

To construct a moment condition that helps us identify ζ, 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 E1 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 relaxing the tied-to-investment 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 are comparable to those in the main model, despite the smaller increase in human capital, because relaxing the tied-to-investment constraint also increases students' leisure. Overall, our results remain robust when we introduce leisure.

E.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 $\frac{1}{2}$.[15] 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 E1 shows the results. With a greater IES, the utility cost associated with limited intertemporal consumption smoothing is smaller. Other things being equal, a weaker consumption 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 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 loan, but college investment and parental transfer are close to the

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

main model (Panel B). The impacts of relaxing tied-to-investment constraints on college investment, working hours, human capital, and parental transfer are smaller than in the main model. The welfare effect of relaxing tied-to-investment 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 E1: 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
ζ	-	-	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: Relaxing Borrowing Constraints				
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 gain (child,%)	7.46	6.28	6.21	3.36
welfare gain (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 tied-to-investment constraints on outcomes. 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 $\sigma = 1.5$.

F Additional Data

F.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.[16] Focusing on college students who are enrolled in a program, we have 871 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 F1, 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

[16] 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. 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.

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 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.[17]

Table F1: Regression Estimates for Study Time

VARIABLES	(1) Study time	(2) 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

[17] 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.

F.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 and the amount received, and demographic characteristics. As summarized in Table 7 and Table D2, we use NPSAS 2004 for the annual sticker price and grant shares by family income quartiles for four-year and two-year colleges.

F.3 Beginning Postsecondary Students 2004/2009

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.

References

Isaiah Andrews, Matthew Gentzkow, and Jesse M Shapiro. Measuring the sensitivity of parameter estimates to estimation moments. *The Quarterly Journal of Economics*, 132(4):1553–1592, 2017.

Martin Browning, Lars Peter Hansen, and James J Heckman. Micro data and general equilibrium models. *Handbook of macroeconomics*, 1:543–633, 1999.

George-Levi Gayle and Andrew Shephard. Optimal taxation, marriage, home production, and family labor supply. *Econometrica*, 87(1):291–326, 2019.

Lance J Lochner and Alexander Monge-Naranjo. The nature of credit constraints and human capital. *American Economic Review*, 101(6):2487–2529, 2011.