

The Return to College: Selection Bias and Dropout Risk*

Lutz Hendricks[†] Oksana Leukhina[‡]

November 7, 2011

Preliminary.

Abstract

We study two long-standing questions: (i) What part of the measured return to education is due to selection? (ii) The ex post return to schooling appears higher than the return to most financial assets. How large are the contributions of various frictions to the “high” return to schooling? We focus in particular on the roles of college dropout risk, borrowing constraints, and learning about ability.

We develop and calibrate a model of school choice. Key model features are: (i) ability heterogeneity, (ii) students learn about their abilities while in college, (iii) borrowing constraints, (iv) dropping out of college is a choice.

Preliminary results indicate that the probability of graduating from college increases strongly with ability. Most college dropouts are students of intermediate abilities who try college in part to learn about their abilities and in part because of the option value of receiving a large earnings gain upon graduation. Ability selection accounts for about 70% of the measured lifetime earnings gap between college graduates and high school graduates.

JEL: E24, J24 (human capital), I21 (analysis of education).

Key words: Education. College dropout risk.

*For helpful comments we thank seminar participants at Indiana University, University of Washington, the 2011 Midwest Macro Meetings, the 2011 SED Meetings, and the 2011 Cologne Macro Workshop. The usual disclaimer applies.

[†]University of North Carolina, Chapel Hill; lutz@lhendricks.org

[‡]University of Washington; oml@u.washington.edu

1 Introduction

The question:

1. Part of the college wage premium is an ability premium. How large is this part?
2. The ex post return to college is high relative to the returns earned by financial assets (Heckman, Lochner, and Todd, 2008). What is the contribution of college completion risk, ability selection, and borrowing constraints towards sustaining the high rate of return? How large is the ex ante rate of return for persons of various abilities?

The approach: We develop a model of school choice with the following features:

1. Individuals differ in their abilities. Abilities affect adult earnings and the likelihood of graduating from college.
2. Individuals are uncertain about their abilities when choosing whether or not to attend college.
3. College students are borrowing constrained.
4. College has a consumption value.
5. In contrast to much of the literature, our model does not feature a “psychic cost” of schooling.

We include these model features for the following reasons:

1. Ability heterogeneity: it is the basis for selection bias.
2. Uncertain abilities: one-third of students attempting 4 year colleges drop out without earning a bachelor’s degree. One possible reason is that students learn about their abilities or graduation prospects as they move through college (Manski, 1989).
3. Borrowing constraints: A large literature discusses their importance. Even if most students have access to sufficient borrowing so they can finance college expenditures, borrowing constraints affect selection into college by ability (Belley and Lochner, 2007).

4. Consumption value of college: In the data, some students attend college even though their probability of graduating, conditional on observable characteristics, is low. In our model, such students try college mainly for its consumption value.
5. No psychic cost: Many existing models of school choice attribute a large share of individual variation to a “psychic cost.” Examples include Cunha, Heckman, and Navarro (2005) and Navarro (2008). We agree with Heckman, Lochner, and Todd (2006) that “explanations based on psychic costs are intrinsically unsatisfactory” (p. 436).

We calibrate the model for men in the 1960 birth cohort. Our main data source is the NLSY79, which provides us with schooling, cognitive test scores, and partial earnings histories. We complete the earnings histories using CPS data.

Results. Preliminary results are as follows:

1. About 70% of the measured lifetime earnings gap between college graduates and high school graduates is due to ability selection.
2. Uncertainty about individual abilities and thus college completion prospects accounts for a large share of college dropouts. This is consistent with the argument proposed by Manski (1989).
3. College graduation prospects vary strongly with ability. Students in the lowest ability decile have a less than 3% chance of graduating from college, while student in the top decile have a 90% chance of graduating.

1.1 Related Literature

Our main contribution, relative to the large literature that studies college choice, is to model college completion risk jointly with ability selection.

A large number of previous studies developed Roy models where college completion is not risky. Students commit to dropping out of college at the time of high school graduation. Prominent examples of such models include Heckman, Lochner, and Taber (1998), Cunha, Heckman, and Navarro (2005), and Navarro (2008), among many others.

Models with college completion risk have, for the most part, abstracted from heterogeneity in abilities that affect earnings. Examples include Akyol and Athreya (2005), Garriga and Keightley (2007), Chatterjee and Ionescu (2010), and Stange (2011)¹. These models cannot address the question how ability selection affects measured college wage premiums.

Trachter (2011) presents a model of risky college completion with ability heterogeneity. Since his model features only 2 ability types, it is of limited value for studying ability selection. We also calibrate our model using a richer set of empirical observations, in particular regarding the relationship between measured abilities, college choices and earnings.

2 The Model

2.1 Model Outline

We study a partial equilibrium model of school choice. We follow a single cohort, starting at the date of high school graduation, through college (if chosen), work, and retirement.

Figure 1 summarizes the agent's life-cycle. At the start of age $t = 1$, all agents graduate from high school. They are endowed with assets k_1 , ability a , a signal about ability m , and a net price of attending college q_1 . Ability is not observed until the agent starts working. Agents choose whether to start working right away as high school graduates or to attempt college. Agents are not allowed to return to school after they start working.

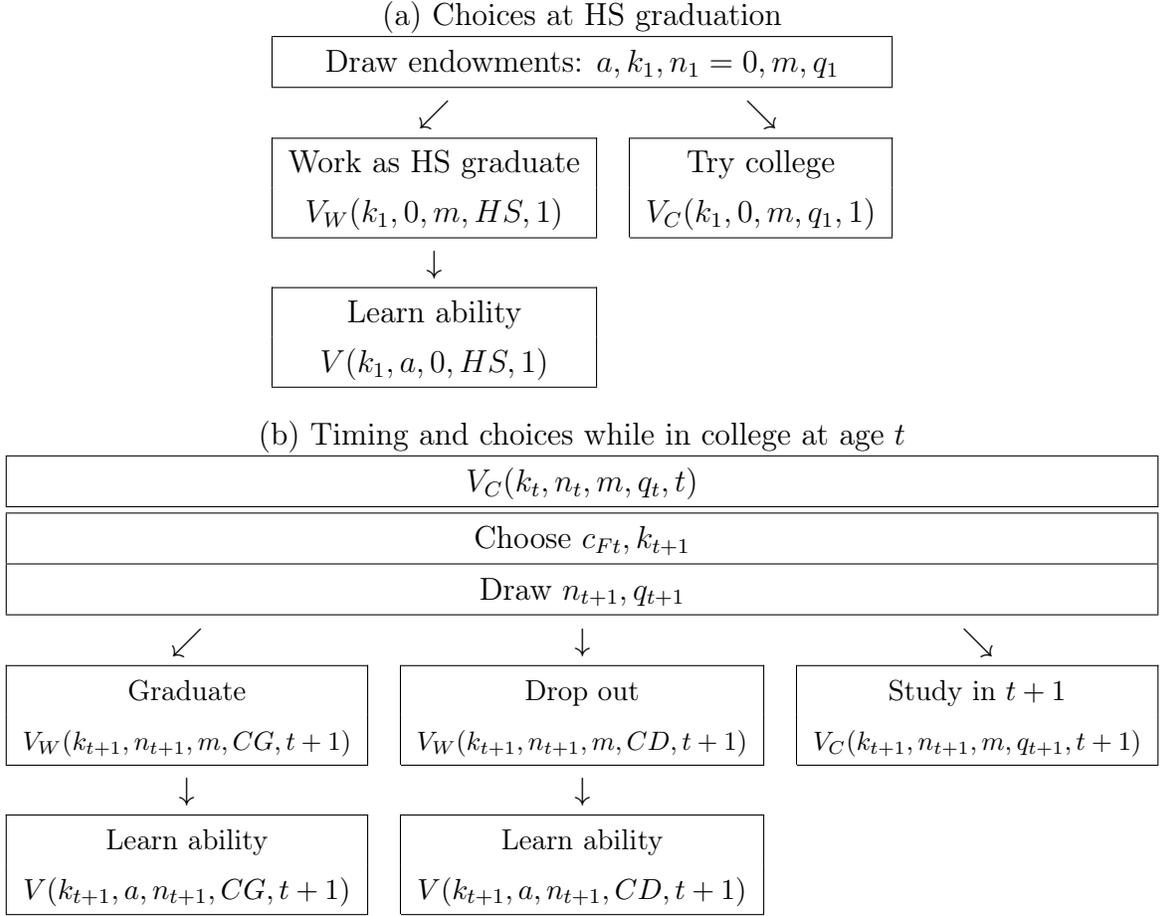
Working agents choose a consumption path to maximize lifetime utility subject to a lifetime budget constraint that equates the present value of income to the present value of consumption spending.

While in college, students accumulate college credits n . Once a student reaches n_{grad} credits he graduates and works as a college graduate. The accumulation of credits is stochastic. More able students accumulate credits faster.

In each period, students pay a tuition cost q_t , they pay for consumption c_{Ft} , they attempt n_c credits and succeed in a random subset. They update their beliefs about their abilities and how long it will take to graduate. They decide whether to continue studying next period or drop out and work as a college dropout. A student who fails to achieve enough

¹It is possible to interpret some of the psychic costs in Stange's model as variation in returns to college. However, his model cannot quantify the contribution of ability selection to measured wage premiums.

Figure 1: Model Timing



credits by the end of year T_c must drop out of college and start working. The cost of college q_t evolves randomly.

The details are described next. We motivate our assumptions in Section 2.8.

2.2 Endowments

At age 1 each person draws the following endowments:

1. An ability a that is not observed to the agent until he starts working.
2. A noisy signal m of the individual's true ability level a .
3. A net price of attending college q_1 . We think of this as capturing tuition, scholarships, grants, parental transfers that are conditional on attending college, and other costs

or payoffs associated with attending college.

4. Initial assets k_1 . We think of these as capturing financial assets and parental transfers that are received regardless of whether the person attends college.
5. $n_1 = 0$ completed college credits.

For computational reasons we assume that each endowment takes on discrete values. For example, ability takes on the values \hat{a}_i for $i = 1, \dots, N_a$. The notation for the other endowments is analogous.

The endowments may be correlated. However, in order to limit the agent's state space, we assume that, conditional on m , a is not correlated with q_1 and k_1 . Hence, only m is useful for forming beliefs about the agent's true ability.

2.3 Preferences

Agents enter the model at age 1 and live until age T . They consume two goods: a market good c_F and a non-market good c_L . Expected utility is given by

$$E_0 \sum_{t=1}^T \beta^t u(c_t) \tag{1}$$

where $c_t = C(c_{Ft}, c_{Lt})$ is a consumption aggregator.

2.4 Choices at High School Graduation

At the beginning of life, the agent chooses whether to attempt college or work as a high school graduate. We summarize the value of working by the value function $V_W(k_\tau, n_\tau, m, s, \tau)$ where τ is the age at which work starts, k_τ denotes the level of assets, n_τ is the number of completed college credits, s is the level of completed schooling. s takes on the values HS for high school graduates, CD for college dropouts and CG for college graduates. Working as a high school graduate yields value $V_W(k_1, 0, m, HS, 1)$. Section 2.5 describes how V_W is determined.

We summarize the value of starting year t of college by $V_C(k_t, n_t, m, q_t, t)$. Section 2.6 describes how V_C is determined. An agent chooses to start college if $V_C(k_1, 0, m, q_1, 1) > V_W(k_1, 0, m, HS, 1)$.

2.5 Work

Upon completing schooling, the worker learns her ability. At this point all uncertainty has been resolved and the ability signal m no longer matters. The worker's value after learning a , $V(k_\tau, a, n_\tau, s, \tau)$, is determined as follows.

Let $Y(s, \tau)$ denote the lifetime earnings received by a worker with ability $a = 0$ and no completed college credits. It depends on completed schooling s and the age at which work begins. Starting work later reduces lifetime earnings mainly because the worker foregoes earnings during the periods prior to τ . We assume that each completed college credit increases lifetime earnings by a constant factor $e^{\mu s}$. This may reflect human capital accumulation. The effect of ability on lifetime earnings is independent of schooling. The present value of lifetime earnings of a person who starts working in state (a, n_τ, s, τ) is then given by $e^{a+\mu n_\tau} Y(s, \tau)$. All high school graduates share $\tau = 1$ and $n_\tau = 0$. However, there is variation in both τ and n_τ among college dropouts and college graduates.

The worker chooses market consumption at all ages past τ to solve

$$V(k_\tau, a, n_\tau, s, \tau) = \max_{\{c_{Ft}\}} \sum_{t=\tau}^T \beta^{t-\tau} u(C[c_{Ft}, \hat{c}_L]) \quad (2)$$

subject to a budget constraint that equates the present value of consumption to lifetime earnings plus the value of assets owned at age τ :

$$e^{a+\mu n_\tau} Y(s, \tau) + Rk_\tau = \sum_{t=\tau}^T c_{Ft} R^{t-\tau} \quad (3)$$

R is the gross interest rate. The worker buys market goods c_F at price 1. He receives a fixed amount of the non-market good, \hat{c}_L , for free. We discuss the role of the non-market good in Section 2.8.

Before ability is revealed, the value of working is given by

$$V_W(k_\tau, n_\tau, m, s, \tau) = E_a \{V(k_\tau, a, n_\tau, s, \tau) | n_\tau, m, \tau\} \quad (4)$$

$$= \sum_{i=1}^{N_a} V(k_\tau, \hat{a}_i, n_\tau, s, \tau) Pr(\hat{a}_i | n_\tau, m, \tau) \quad (5)$$

where $Pr(\hat{a}_i | n_\tau, m, \tau)$ is the agent's belief about her ability, which we derive in Section 2.7.

2.6 College

The value of being in college at age t , $V_C(k_t, n_t, m, q, t)$, is determined as follows. A student enters the period with assets k_t and earns capital income Rk_t . Assets may be negative. He then pays tuition q_t and chooses consumption c_{Ft} so that next period's assets are determined by the budget constraint

$$k_{t+1} = Rk_t - c_{Ft} - q_t \quad (6)$$

Borrowing is constrained by $k_{t+1} \geq k_{min,t+1}$. The student receives a fixed amount of non-market consumption, \bar{c}_L , for free and enjoys period utility $u(C[c_{Ft}, \bar{c}_L])$.

After choosing consumption, the student attempts n_c courses and completes each with probability $\Pr_c(a)$. More able students are more likely to pass a course: $\Pr'_c(a) > 0$. Based on the number of credits completed, n_{t+1} , the student updates her beliefs about a . He then decides whether to work or study in period $t + 1$. The option of studying next period is not available if

1. $n_{t+1} \geq n_{grad}$: the student graduates from college and works as a college graduate with continuation value $V_W(k_{t+1}, n_{t+1}, m, CG, t + 1)$.
2. $n_{t+1} < n_{grad}$ and $t = T_c$: the student fails to earn enough credits in the last year of college. He must work as a college dropout with continuation value $V_W(k_{t+1}, n_{t+1}, m, CD, t + 1)$.
3. k_{t+1} is too low to pay for tuition next period: $Rk_{t+1} < q + k_{min,t+2}$. The student must work as a college dropout next period. For such states, we set $V_C(k_{t+1}, n_{t+1}, m, q, t + 1) = -\infty$.

If neither of these conditions is satisfied, the student chooses to remain in college if the continuation value in college is greater than that of working as a college dropout: $V_W(k_{t+1}, n_{t+1}, m, CD, t + 1) > V_C(k_{t+1}, n_{t+1}, m, q_{t+1}, t + 1)$. The Bellman equation is therefore given by

$$V_C(k_t, n_t, m, q_t, t) = \max_{k_{t+1} \geq k_{min,t+1}} u(C[Rk_t - k_{t+1} - q, \bar{c}_L]) + \beta \sum_{n_{t+1}} \Pr(n_{t+1} | n_t, m, t) V_{EC}(k_{t+1}, n_{t+1}, m, q, t + 1) \quad (7)$$

where $V_{EC}(k, n, m, q, t) = V_W(k, n, m, CG, t)$ if the student graduates from college, $V_{EC}(k, n, m, q, t) = V_W(k, n, m, CD, t)$ if the student is forced to drop out of college, and $V_{EC}(k, n, m, q, t) = \max\{V_C(k, n, m, q, t), V_W(k, n, m, CD, t)\}$ if the student can choose whether to work or study next period.

2.7 Probabilities

We now derive the probabilities governing how students accumulate credits and form beliefs about their abilities. The probability of passing a course, $\Pr_c(a)$, is an exogenous, increasing function of ability. All other probabilities and beliefs are found using Bayes' Rule.

The probability of passing j courses in one year, $\Pr_n(j|a)$, is given by the standard Binomial formula. Then

$$\Pr(n_{t+1}|n_t, m, t) = \sum_{i=1}^{N_a} \Pr_n(n_{t+1} - n_t|\hat{a}_i) \Pr(\hat{a}_i|n_t, m, t) \quad (8)$$

The agent's beliefs about his ability follow from Bayes' Rule:

$$\Pr(\hat{a}_i|n_t, \hat{m}_j, t) = \frac{\Pr(\hat{a}_i) \Pr(\hat{m}_j|\hat{a}_i) \Pr(n_t|\hat{a}_i, t)}{\Pr(n_t, \hat{m}_j|t)} \quad (9)$$

where $\Pr(\hat{a}_i)$ is the unconditional probability of drawing ability level \hat{a}_i , $\Pr(\hat{m}_j|\hat{a}_i)$ is the probability of drawing signal \hat{m}_j conditional on ability \hat{a}_i ; both are model primitives. $\Pr(n_t|\hat{a}_i, t)$ is the Binomial formula for n_t successes out of $(t-1)n_c$ draws. Also from Bayes' Rule, we have $\Pr(n_t, \hat{m}_j|t) = \sum_i \Pr(\hat{a}_i) \Pr(n_t, \hat{m}_j|\hat{a}_i, t)$ and $\Pr(n_t, \hat{m}_j|\hat{a}_i, t) = \Pr(\hat{m}_j|\hat{a}_i) \Pr(n_t|\hat{a}_i, t)$.

2.8 Discussion of Model Assumptions

Our model assumptions attempt to capture key features that may be important for the main issues we wish to investigate: ability selection and the risk of dropping out of college.

We model *dropping out* of college as a *choice*. Similar to Garriga and Keightley (2007), students drop out if they receive poor "grades," which imply that graduating from college would take longer than previously expected. Relative to the simpler alternative where dropping out is a shock (as in Akyol and Athreya 2005) our approach has the benefit that

we can use data on the characteristics and the timing of dropouts in the calibration. Relative to the literature that treats dropping out as an ex ante decision, we capture how the risk of failure affects the ex ante rate of return of college for students of various characteristics. Manski (1989) argues that *learning about ability* may explain why many students drop out of college. We wish to investigate the quantitative importance of this explanation. We therefore allow for the possibility that students observe only a noisy signal of their abilities. The sensitivity analysis examines how the findings change when we assume that abilities are perfectly known at the time of high school graduation.

We incorporate *heterogeneity in financial assets* and in the net cost of attending college to capture the role of borrowing constraints for college selection. Whether borrowing constraints are important remains controversial in the literature (see Cameron and Taber 2004, Belley and Lochner 2007, among others). In our model, the vast majority of students have access to sufficient funds to pay for college tuition. However, some are subject to soft borrowing constraints which limit the amount of consumption they can afford in college.

We assume that college has a *consumption value*, \bar{c}_L , in order to address two empirical observations. First, data on the financial resources available to college students, summarized in Section 3, suggest that students spend less on consumption than do working individuals at similar ages. Further, many students do not take advantage of available loans to smooth consumption between college and work periods (see Bowen, Chingos, and McPherson 2009, ch. 8). In our model, non-market consumption c_L reduces the marginal utility of market consumption among college students. Even if individuals smooth the marginal utility of market consumption over time, consumption *spending* jumps upon graduation.

The second observation is that students with low measured abilities attempt college, even though their ex ante probability of graduating is low. We document this fact in Section 3. In our model, the consumption value of college is an important reason why low ability students attempt college.

Our concept of non-market consumption may remind the reader of the *psychic costs* commonly found in models of school choice (e.g., Cunha, Heckman, and Navarro (2005) and Navarro (2008)). However, the two concepts play very different roles. The psychic cost is an idiosyncratic utility or disutility of attending college. Its role is to account for the observed imperfect correlation between school choices and background variables, such as cognitive test scores and family income. Its standard deviation is typically large (e.g., it

is \$82,000 in Stange 2011) and a large fraction of school choices is determined by psychic costs.

In our model, the consumption value of college is the same for everyone. Its role is to generate reasonable levels of consumption and borrowing among college students. There is no psychic cost that leads otherwise identical students to make different school choices. Even without a psychic cost, our model accounts for a wide range of observations that we document below. Since we agree with Heckman, Lochner, and Todd (2006) that “explanations [of school choice] based on psychic costs are intrinsically unsatisfactory” (p. 436), we view this as an important contribution.

2.9 Computational Issues

We compute the model by iterating over guesses of the calibrated parameter values. For each guess, we solve the household problem by backward induction. We then simulate life histories for 100,000 persons and compute statistics that exactly correspond to the calibration targets. We search for parameter values that minimize a weighted sum of squared deviations between data and model moments.

All state variables are restricted to discrete grids when we solve the household problem. This is necessary because the expected marginal value of k_{t+1} while in college is not continuous in k_t . The reason is that the decision whether to drop out for a given number of credits n_{t+1} depends on k_{t+1} .

3 Calibration

We calibrate the model parameters to match moments for men born around 1960. Our main data sources are NLSY79 and High School & Beyond (HS&B).

NLSY79 is a representative, ongoing sample of persons born between 1957 and 1964 (Bureau of Labor Statistics; US Department of Labor, 2002). We collect education, earnings and cognitive test scores for all men. We include members of the supplemental samples, but use weights to offset the oversampling of minorities. Appendix B provides additional detail.

HS&B is published by the National Center for Educational Statistics (NCES). It covers 1980 high school sophomores. Participants were interviewed bi-annually until 1986. In

1992 postsecondary transcripts from all institutions attended since high school graduation were collected. We retain all men who report sufficient information to determine when they attended college and whether a degree was earned. HS&B also contains information on college tuition, financial resources, parental transfers, and student debt. Appendix C provides additional detail.

3.1 Mapping of Model and Data Objects

We discuss how we conceptually map model objects into data objects. Variables without observable counterparts include abilities, ability signals, consumption, and completed college credits.

We count a student as attending college if he attempts at least 9 non-vocational credits in a given year.

We use cognitive test scores as noisy measures of individual *ability signals*. Specifically, we use the 1989 Armed Forces Qualification Test (AFQT) percentile rank. The AFQT aggregates a battery of aptitude test scores into a scalar measure. The tests cover numerical operations, word knowledge, paragraph comprehension, and arithmetic reasoning (see NLS User Services 1992 for details). We remove age effects by regressing AFQT scores on the age at which the test was administered (in 1980). We transform the residual so that it has a standard Normal distribution. In mapping AFQT scores to the model, we assume that AFQT scores are noisy measures of the agent’s ability signal: $AFQT = m + \varepsilon_{AFQT}$ where $\varepsilon_{AFQT} \sim N(0, \sigma_{AFQT})$ is a measurement error term.

Since HS&B lacks AFQT scores, we treat GPA quartiles as equivalent to AFQT quartiles. Borghans, Golsteyn, Heckman, and Humphries (2011) show that high school GPAs and AFQT scores are highly correlated.

Financial variables. Our interpretation of assets k_1 and college costs q deserves a more detailed discussion. A college student’s budget constraint is given by $k_{t+1} = Rk_t - c_{Ft} - q_t$. Consumption of college students, c_{Ft} , is not observed.

k_1 collects financial resources the student receives *regardless* of college attendance. This includes the student’s financial assets and any transfers he receives from his parents that are not conditional on attending college, x_t . Since NLSY79 data suggest that student assets

are mostly small, we set them to zero. In the model we assume that x_t is paid out as a lump sum at high school graduation.² For persons who do not attempt college we measure k_1 as the sum of all parental transfers observed during the first T_c years after college graduation. Our data only contain transfers for the first 2 years after graduation. We therefore assign each person initial assets of $k_1 = T_c(x_1 + x_2)/2$.

q_t collects all payments that are *conditional* on attending college in year t . These consist of tuition net of scholarships, grants, and labor earnings while in college. We label this sum \bar{q}_t . Room and board are contained in c_{Ft} and therefore excluded from \bar{q}_t . HS&B data allow us to measure \bar{q}_t for the first 2 years in college. In addition, the student receives parental transfers that are conditional on attending college, x_{ct} . The model's net cost of college corresponds to $q_t = \bar{q}_t - x_{ct}$.

Unfortunately, the data do not allow us to distinguish conditional from unconditional transfers. We only observe total parental transfers, $x_t + x_{ct}$, while a student attends college. To solve this problem we proceed as follows. We assume that each model agent is endowed with k_1 and q_1 . We choose the distributions of these endowments such that the distribution of $2k_1/T_c$ among high school graduates matches the observed distribution of parental transfers $x_1 + x_2$, and such that the distribution of $q_t - k_1/T_c$ matches the observed distribution of $\bar{q}_t - (x_t - x_{ct})$ among college students in the data.

As students move through college, they may choose to consume more than their total financial resources. In that case k_t falls below zero, which we interpret as student debt.

3.2 Distributional Assumptions

The distribution of endowments approximates a joint Normal distribution. For computational reasons all endowments are rounded to discrete grid points. In addition, we impose that, conditional on m , a is orthogonal to q_1 and k_1 , so that the latter are not useful for forming beliefs about ability. We implement this restriction as follows.

1. We draw abilities from $N(0, \sigma_a)$ and round them to a 9 point grid.
2. We draw signals from $N(a, \sigma_m)$ and round them to a 13 point grid.

²If x is paid out over time, the household problem gains a state variable, which is computationally costly.

3. We draw net costs of college and initial assets according to

$$\tilde{q}_1 = \alpha_{qm}m + \alpha_{qk}\varepsilon_k + \varepsilon_q \quad (10)$$

$$\tilde{k}_1 = \alpha_{km}m + \alpha_{kq}\varepsilon_q + \varepsilon_k \quad (11)$$

where $\varepsilon_k, \varepsilon_q$ are standard Normal random variables. q_1 is given by $\mu_q + \sigma_q\tilde{q}_1/\sigma_{\tilde{q}_1}$, rounded to the nearest point on a grid of size 5. k_1 is given by $\mu_k + \sigma_k\tilde{k}_1/\sigma_{\tilde{k}_1}$, rounded to the nearest point on a grid of size 40.

Aside from rounding to discrete grid points, our approach implies that all endowments are jointly Normally distributed. Varying the α parameters we can adjust the correlations between m, q_1, k_1 . We normalize $\alpha_{kq} = 0$.

3.3 Fixed Parameters

We adopt the following normalizations:

1. The period is one year.
2. We use the Consumer Price Index (all wage earners, all items, U.S. city average) reported by the Bureau of Labor Statistics to convert dollar figures into year 2000 prices.
3. The non-market good is only consumed while in college: $\hat{c}_L = 0$.

We set the following parameters based on outside evidence:

1. Preferences: Utility is logarithmic in the composite consumption good. The consumption aggregator is of the form $C(c_{Ft}, c_{Lt}) = [c_{Ft}^\alpha + c_{Lt}^\alpha]^{1/\alpha}$. The elasticity of substitution between the two consumption goods is set to 2 ($\alpha = 0.5$). While we lack evidence on this parameter, our results vary little with its value. The discount factor is $\beta = 0.98$.
2. Prices: The gross interest rate is $R = 1.03$.

Table 1: Fixed parameters

Parameter	Description	Value
Preferences		
β	Discount factor	0.98
α	Elasticity of substitution	0.50
College		
T_C	Maximum duration of college	6
n_{grad}	Number of credits to graduate	8
n_c	Number of credits attempted	3
$k_{min,t}$	Borrowing limit	$\max(\$19,750, \$5,093t)$
Other		
R	Gross interest rate	1.03

- College: In our HS&B sample, 95% of college graduates finish college by their 6th year (Bowen, Chingos, and McPherson 2009 report a similar finding). We therefore set the maximum duration of college to $T_C = 6$. The number of credits needed to graduate is set to $n_{grad} = 8$. In each year, students attempt $n_c = 3$ credits. This number is set so that graduating in 3 years is possible, but not common, which accords with the data. In reality, students typically complete around 130 credits by the time of college graduation. Increasing the number of model credits would increase the number of ability signals a student receives in each period, which may affect the rate of learning. It is, however, computationally costly.
- Borrowing constraints: For the NLSY79 birth cohorts, most loans taken out during college are Stafford loans (see Johnson 2010). Until 1986, students could borrow \$2,500 in each year of college up to a total of \$12,500. We ignore the restriction that loan amounts cannot exceed college related expenditures. We set $k_{min,t} = -\max(\$12,500, \$2,500t)$ and convert dollar values into year 2000 prices.

Table 1 summarizes these parameter values.

3.4 Calibrated Parameters

The following parameters are calibrated jointly:

1. The distribution of endowments is governed by the parameters $\sigma_a, \sigma_m, \mu_q, \sigma_q, \mu_k, \sigma_k, \alpha_{mq}, \alpha_{mk}, \alpha_{qk}$.
2. σ_{AFQT} : The standard deviation of noise in AFQT scores.
3. $Y(s, \tau)$: The lifetime earnings functions. For each s , we calibrate $Y(s, 4)$ and assume that postponing the start of work by one year reduces lifetime earnings by factor $1/R$. Thus, $Y(s, \tau) = Y(s, 4)R^{4-\tau}$.

We assume that college dropouts receive the same earnings as high school graduates: $Y(CD, \tau) = Y(HS, \tau)$. Of course, college dropouts increase their earnings by accumulating college credits, while high school graduates do not have this option.

4. γ_1, γ_2 : The probability of passing a credit is given by $[1 + \gamma_1 e^{-\gamma_2 a}]^{-1}$.
5. μ : The effect of completing credits on lifetime earnings.
6. \bar{c}_L : The consumption value of college.

We calibrate the model parameters to match moments that we estimate from two data sources. From the NLSY79 sample, we estimate average *lifetime earnings* within each school group and AFQT decile. From HS&B we estimate:

1. The fraction of persons *attempting college* and the fraction of persons earning a *bachelor's degree* within each high school GPA quartile.
2. The fraction of students in each high school GPA quartile who *drop out* of college at the end of each year.
3. The mean and standard deviation of cumulative tuition and fees net of scholarships, grants, earnings, and parental transfers in the first 2 years of college. As explained in Section 3.1, this corresponds to $2(q - k_1/T_c)$ in the model.
4. The mean and standard deviation of the parental transfers high school graduates receive during the first 2 years after graduation. As explained in Section 3.1, this corresponds to $2k_1/T_c$ in the model.
5. The fraction of students with student loans and the mean size of student loans for students enrolled in years 1 through 4 of college.

Table 2: Calibrated parameters

Parameter	Description	Value
Endowments		
σ_a	Standard deviation of ability	0.27
σ_m	Standard deviation of signal	0.22
σ_{AFQT}	Standard deviation of AFQT	0.21
μ_{k_1}	Distribution of k_1	0.93
μ_{q_1}	Mean of q_1	-3.11
σ_{q_1}	Standard deviation of q_1	3.90
α_{MK}	Correlation m, k_1	-0.55
α_{MQ}	Correlation m, q_1	-1.03
α_{KQ}	Correlation k_1, q_1	-0.42
Other parameters		
\bar{c}_L	Consumption in college	0.060
$Y(HS, 4)$	Lifetime earnings, $\tau = 4$	74.5
$Y(CG, 4)$		87.1
μ	Earnings gain for each completed credit	0.017
γ_1, γ_2	Govern probability of passing a course	2.53, 2.41

The Appendix describes our data construction in detail. We show the data moments in Section 3.5 where we compare our model with the calibration targets.

Table 2 shows the values of the calibrated parameters. We highlight parameters that are important for our findings.

The dispersion of abilities, σ_a , is considerably larger than the one estimated by Hendricks and Schoellman (2011). A one standard deviation increase in ability raises lifetime earnings by 0.27. As we will show below, larger values of σ_a are associated with a larger contribution of ability selection to the measured college premium. We explore the implications of lower values in the sensitivity analysis.

The mean of q_1 is negative. The majority of students incurs no financial cost when attending college. This is consistent with our empirical finding that the mean of tuition net of scholarships, grants and earnings (\bar{q}) is negative among college students. q_1 subtracts parental transfers that are conditional on attending college from \bar{q} and is therefore negative

Table 3: Correlation of Endowments

	a	m	k_1	q_1
a	1.00			
m	0.76	1.00		
k_1	-0.30	-0.40	1.00	
q_1	-0.52	-0.69	0.07	1.00

as well.

Figure 2 shows the distribution of agents’ beliefs over their abilities for selected values of the signal m . Agents face considerable uncertainty about their abilities. This allows the model to generate large numbers of college dropouts.

Table 3 shows the correlation coefficients of the individual endowments. The high negative correlation of m and q_1 implies strong school sorting by m . Students who believe they can graduate from college typically face low college costs.

The chances of graduating from college depend strongly on ability. Figure 3 shows the probability of achieving at least n_{grad} credits in T_c years. Low ability students have essentially no chance of graduating. High ability students are virtually guaranteed to graduate.

3.5 Model Fit

We compare how closely the model attains each set of calibration targets. Overall, the model matches the non-financial targets quite well. While it matches the financial moments less well, their measurement is also more difficult.

Schooling and lifetime earnings. Table 4 shows that the model closely fits the observed fraction of persons attaining each school level and their mean log lifetime earnings. Two key features of the data are: (i) 46% of those attempting college fail to attain a bachelor’s degree; (ii) college graduates earn 54% more than high school graduates over their lifetimes.

Figure 4 shows average lifetime earnings by school group and AFQT decile. Each panel displays one school group. Given that sample sizes are small, we fit weighted linear least squares lines to the data for each school group. These are labeled “Targets” and represent

Figure 2: Probability $a|m$

Figure 3: Probability of graduating from college $|a$

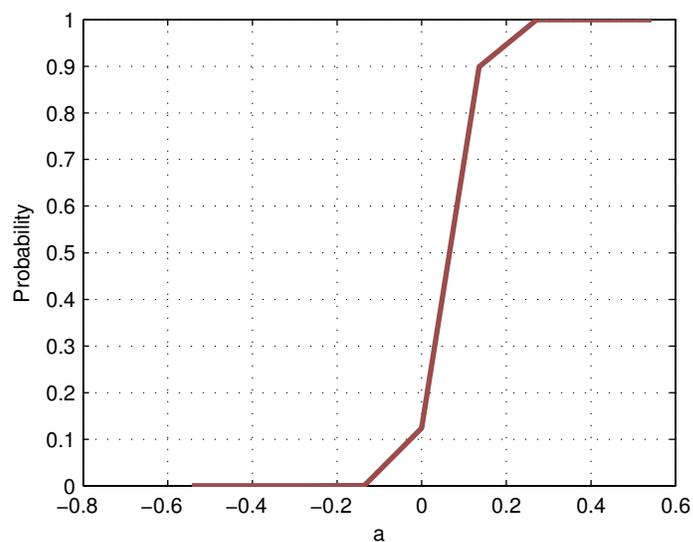


Table 4: School Outcomes and Lifetime Earnings

	School group		
	HS	CD	CG
Fraction			
Data	46.9	24.3	28.8
Model	47.7	24.4	27.8
Gap (pct)	1.7	0.7	-3.4
Lifetime earnings			
Data	676	787	1156
Model	696	756	1145
Gap (pct)	2.9	-4.0	-1.0

Note: The table shows the fraction of person that chooses each school level and the exponential of their mean log lifetime earnings, discounted to age 1. “Gap” denotes the percentage gap between model and data values.

the calibration targets for the model. Small cells are dropped from the data moments. These include high school graduates in the top AFQT quintile and college graduates in the bottom 40% of the AFQT distribution. The model closely fits the data.

College graduates and dropouts. Figure 5 shows the fraction of persons attempting and graduating from college in each AFQT quartile. For comparison, we also show statistics derived from High School & Beyond data (see Appendix C for details). The model replicates the patterns observed in the data.

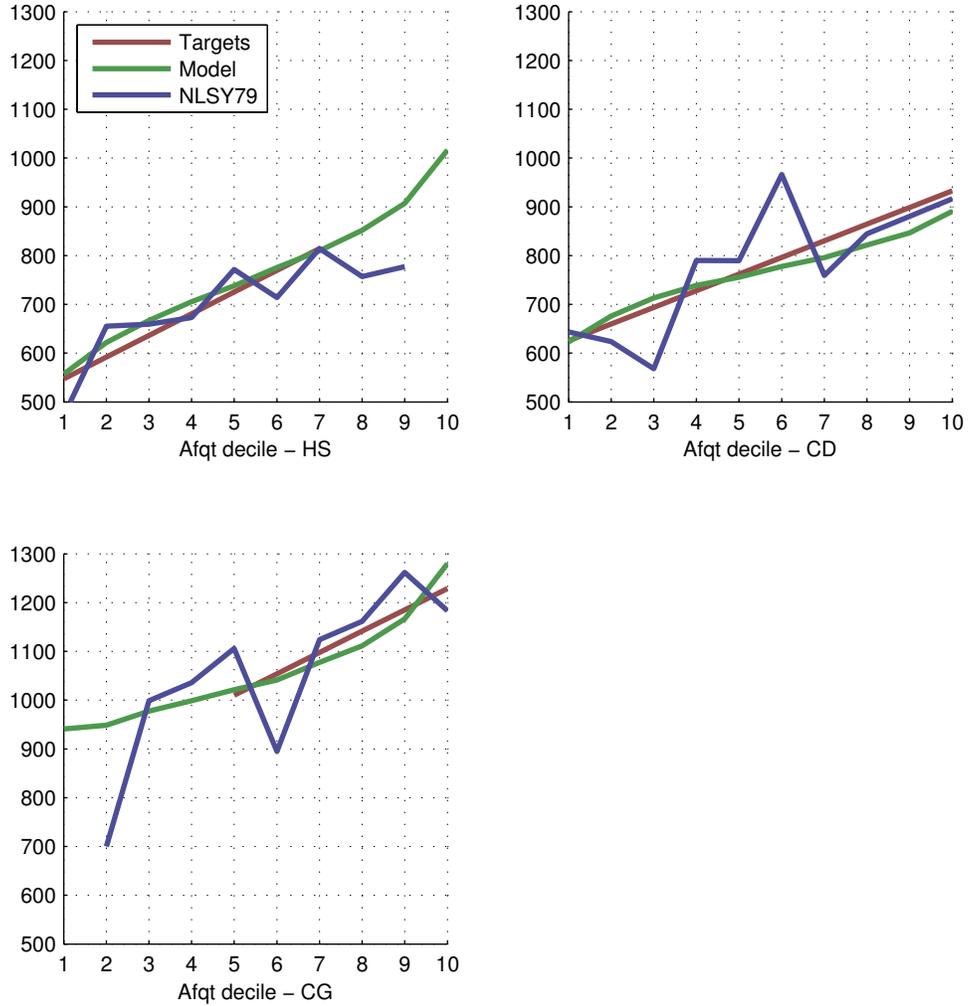
The behavior of low ability persons poses a challenge. Around one quarter of persons in the lowest AFQT quartile attempt college, while fewer than 5% achieve college degrees. Previous models invoked random psychic costs to account for the college entry decisions of these students. In our model, low AFQT students view college mainly as a consumption good.

Figure 6 compares dropout rates between the model and High School & Beyond data. Dropout rates decline strongly with AFQT and with time spent in college. The model is broadly consistent with the variation of dropout rates across ages and AFQT quartiles.

Financial resources. The final set of calibration targets consists of financial variables. Figure 7 shows points on the CDFs of q among college students and of k_1 among high school graduates. Recall that q and k_1 are not observable for all school groups. The model captures the distribution of q reasonably well. The model does less well in capturing the distribution of k_1 . At the same time, measuring k_1 in the data requires strong assumptions. We are therefore not overly concerned about the model's failure to match its distribution.

Table 5 shows student debt levels at the end of the first 4 years in college. The model overstates debt levels by a factor of about 2. Model households aim to smooth marginal utility between college and work periods. The non-market consumption good received in college reduces the marginal utility of the market good and thus lowers demand for it. However, this effect is not strong enough to prevent almost all students from borrowing.

Figure 4: Lifetime earnings by AFQT / school



Notes: Lifetime earnings are discounted to age 1 and expressed in thousands of year 2000 dollars. “NLSY79” shows raw data, including cells with few observations. “Targets” shows a weighted linear regression, dropping small cells.

Figure 5: College Choice and AFQT

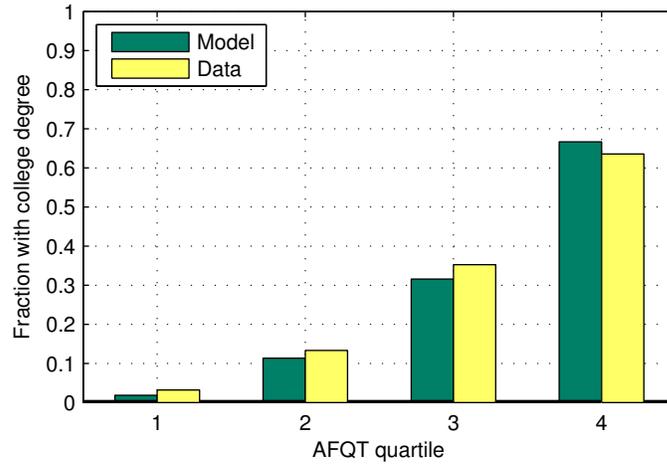
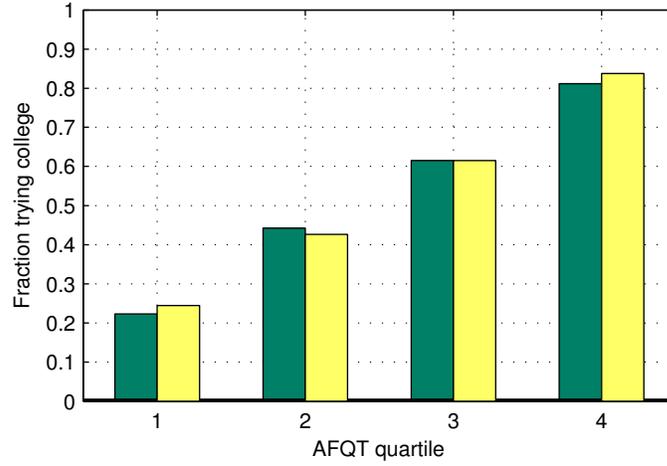
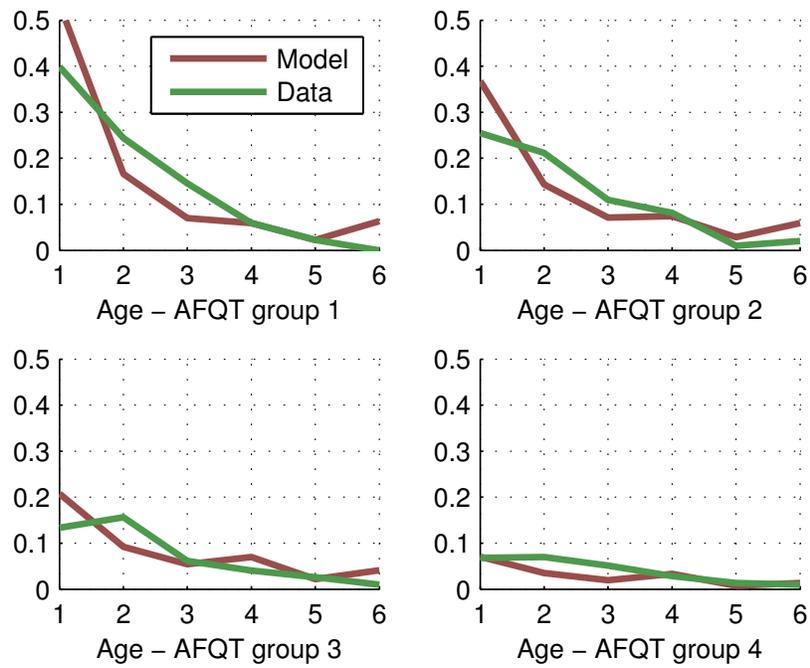


Table 5: Student Debt

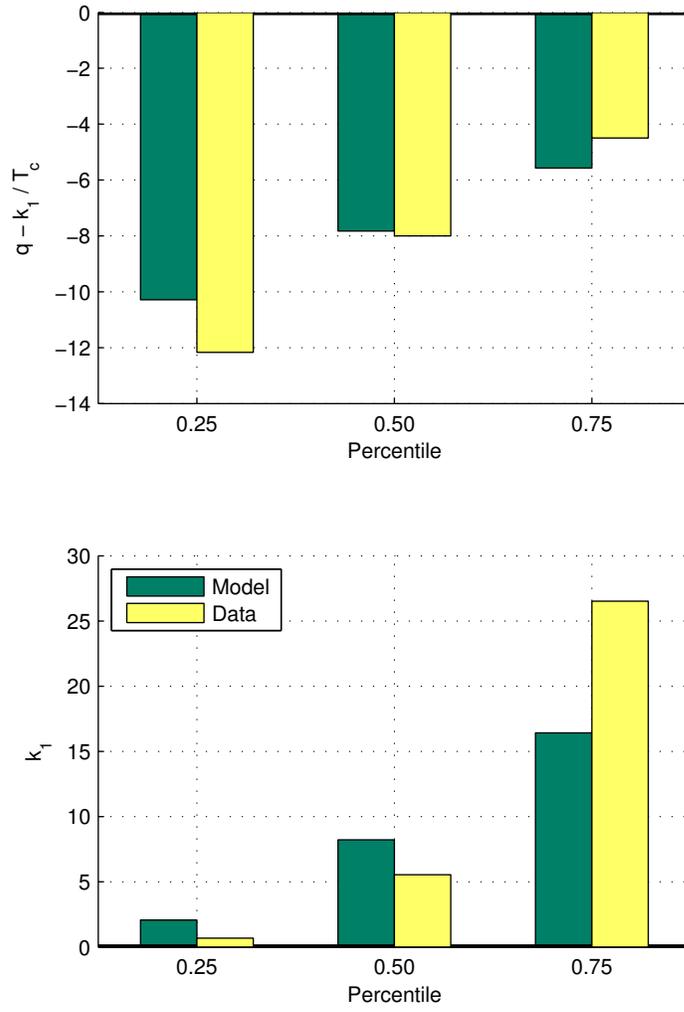
Year	Mean debt		Fraction with debt	
	Model	Data	Model	Data
1	3,454	3,549	64.0	27.7
2	7,197	6,060	89.7	36.0
3	12,610	8,045	97.0	42.5
4	16,611	9,740	99.0	48.0

Figure 6: Dropout rates by AFQT / year in college



Notes: The figure shows the fraction of persons initially enrolled in college who drop out at the end of each year in college.

Figure 7: Financial Resources



Note: The figure shows points on the CDF of q and k_1 .

Table 6: Ability Selection

	School group			
	HS	CD	CG	CG-HS
Mean log ability	-0.16	-0.03	0.30	0.45
Mean log lifetime earnings	4.24	4.39	4.85	0.61
Mean lifetime earnings, $a = 0.00$	814	871	951	138

4 Results

4.1 Ability Selection

Our main question is: What fraction of the college earnings premium represents selection by ability as opposed to returns to schooling?

In the model, the mean log lifetime earnings of school group s , discounted to the start of work, is given by $\mathbb{E}[a + \mu n_\tau + \log(Y(s, \tau))|s]$. The lifetime earnings gap between college graduates and high school graduates may be decomposed into a term reflecting selection, $\mathbb{E}[a|CG] - \mathbb{E}[a|HS]$, and a term reflecting the wage gains from completing college, $\mathbb{E}[\mu n_\tau + \log Y(s, \tau)|CG] - \mathbb{E}[\mu n_\tau + \log Y(s, \tau)|HS]$.

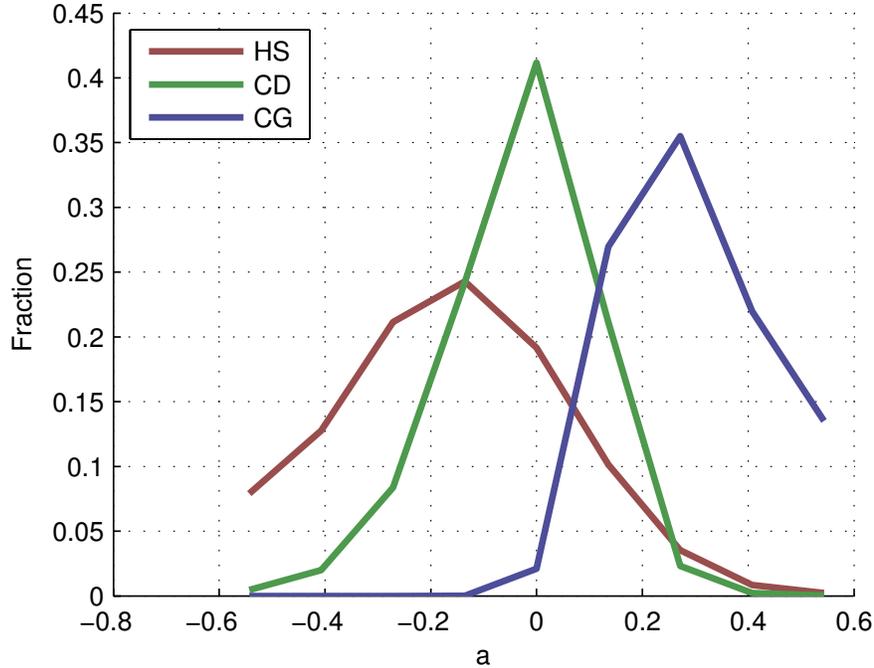
Table 6 shows the decomposition implied by the model. It attributes 74% of the 0.61 log point lifetime earnings gap between college graduates and high school graduates to ability selection. For a person of median ability, completing college increases lifetime earnings by \$138,000 or about 17%.

Ability selection accounts for a large part of the measured college earnings premium for two reasons: (i) Ability dispersion is “large” and (ii) school sorting by ability is strong, so that the ability distributions of college graduates and high school graduates show little overlap.

Figure 8 illustrates ability sorting. It shows the distribution of abilities in each school group. There are virtually no college graduates with abilities below the median. At the same time, around 80% of high school graduates are endowed with abilities at or below the median. College dropouts are overwhelmingly drawn from ability levels near the median.

One reason why ability sorting is strong is that it occurs at two levels: at college entry and at the dropout / college completion stage. Figure 9 illustrates both levels of selection.

Figure 8: School Sorting By Ability



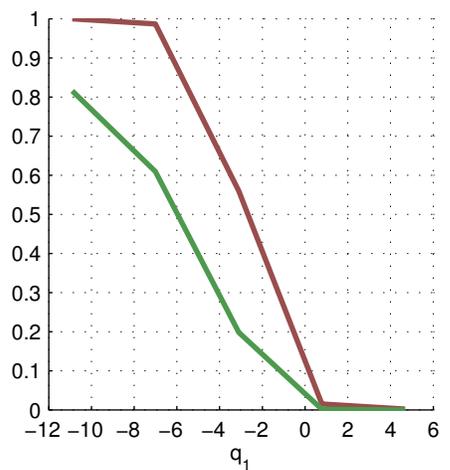
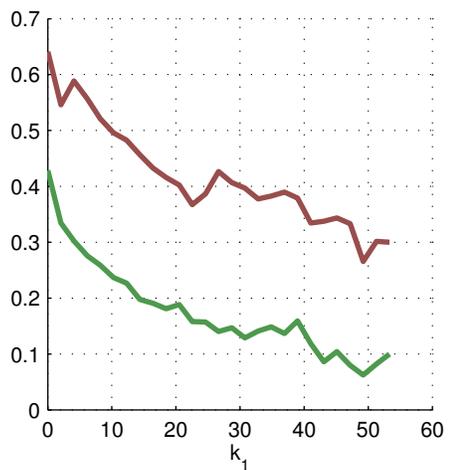
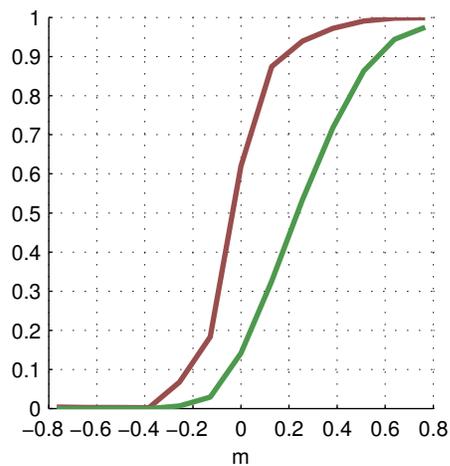
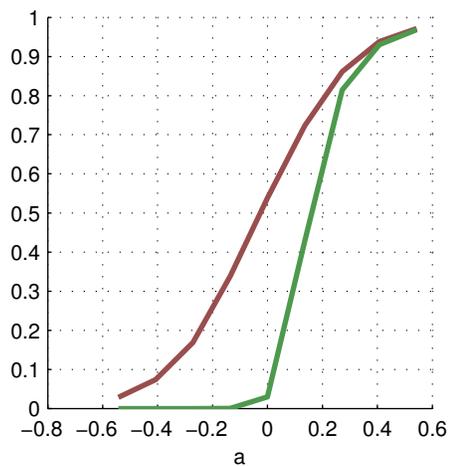
Consider the first panel. For each ability level, it shows the fraction of persons who attempt college and who attain a college degree. This is based on the simulated histories of 50,000 individuals whose endowments are drawn as described in the Calibration Section. The second panel shows the same for each ability signal.

It is evident that selection into college attendance is mainly governed by ability signals. For all signal values either fewer than 20% or more than 80% of students attempt college. Since abilities and signals are strongly correlated, this implies that college attendance and abilities are also strongly related. Very few high ability students receive such poor signals that they refrain from attempting college.

The second level of selection, college graduation, is dominated by individual abilities. Even though 55% of median ability persons attempt college, almost none manage to attain a degree. Taken together the two levels of selection imply that the ability distributions for high school graduates and college graduates are strongly separated.

College attendance is also strongly related to college costs, q , because they are highly correlated with ability signals. Initial assets, k_1 , do not play a major role.

Figure 9: Schooling and Individual Endowments



4.2 Understanding College Entry

Figure 10 summarizes the incentives for students of various ability signals to enter college. The top panel shows the fraction of persons attempting college and the fraction attaining a college degree. It also shows the probability of attaining a degree conditional on staying in college until forced out.

College entry is strongly related to the probability of graduation. The majority of students with graduation probabilities above 0.3 attempt college.

The bottom panel shows the lifetime earnings, discounted to age 1, received for each school outcome. For a given ability signal, completing college increases lifetime earnings by at least \$100,000. However, staying in college for T_c periods without graduating reduces lifetime earnings by at least \$100,000, due to foregone earnings.

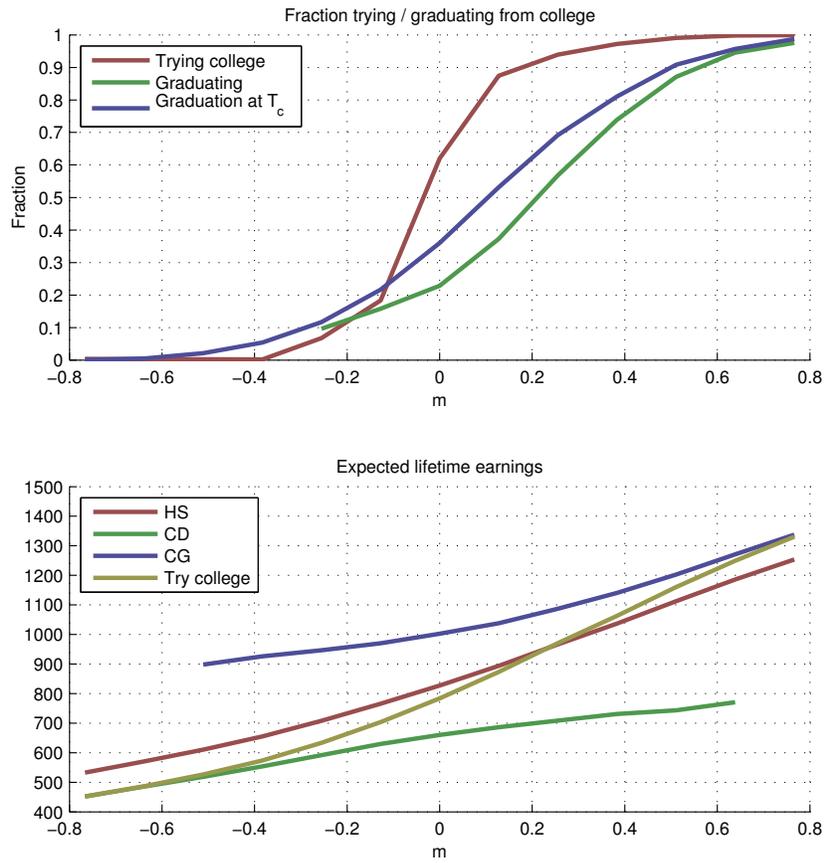
Only students who can expect to graduate with a probability of at least 0.6 increase their lifetime earnings by attempting college. Still, the majority of students who graduate with probabilities of at least 0.3 attempt college. They do so for two reasons: (i) the option value of dropping out after gathering more information about their abilities and (ii) the consumption value of college. An important insight emerges: Since the financial cost of college is typically negative, only students with very low graduation probabilities fail to try college.

School choice at age 1. To illustrate selection into college, Figure 11 shows the value of attending college relative to starting work as a high school graduate. The value gap is expressed as a consumption equivalent. For example, a value gap of 1 means that the household would require a transfer of \$1,000 per year in exchange for giving up the option of attempting college.

Students with better ability signals or lower college costs find it more profitable to try college. The ability signal matters more for the choice in the sense that all agents with the highest ability signal choose college regardless of college costs, while students with the lowest signal do not. College costs only matter for students with intermediate ability signals.

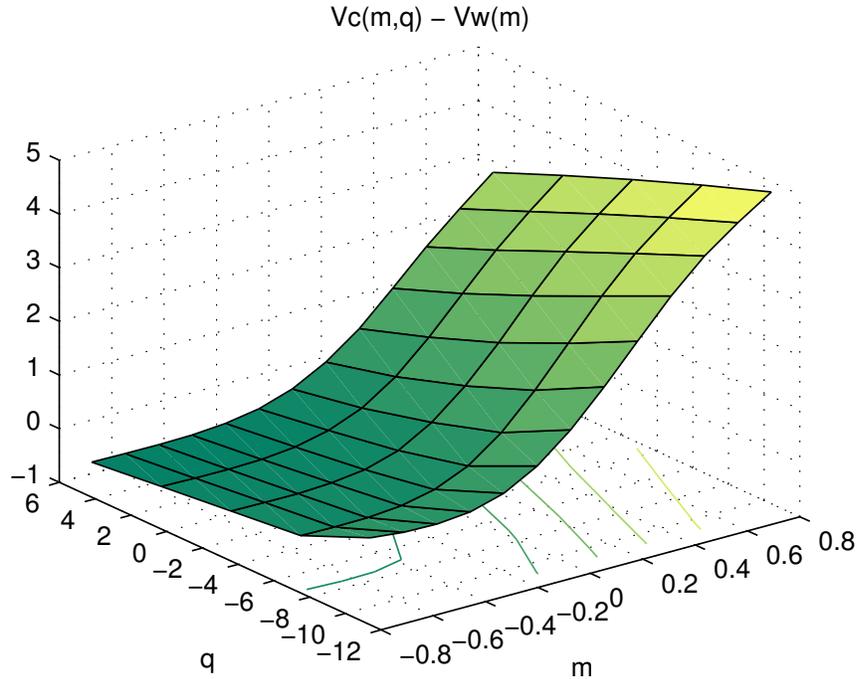
An interesting feature is the strong asymmetry in the value gain from attempting college. High ability agents reap large gains from attending college. Agents receiving the highest

Figure 10: Outcomes By Ability Signal



Note: Lifetime earnings are discounted to age 1 and expressed in thousands of year 2000 dollars.

Figure 11: College Choice At Age 1



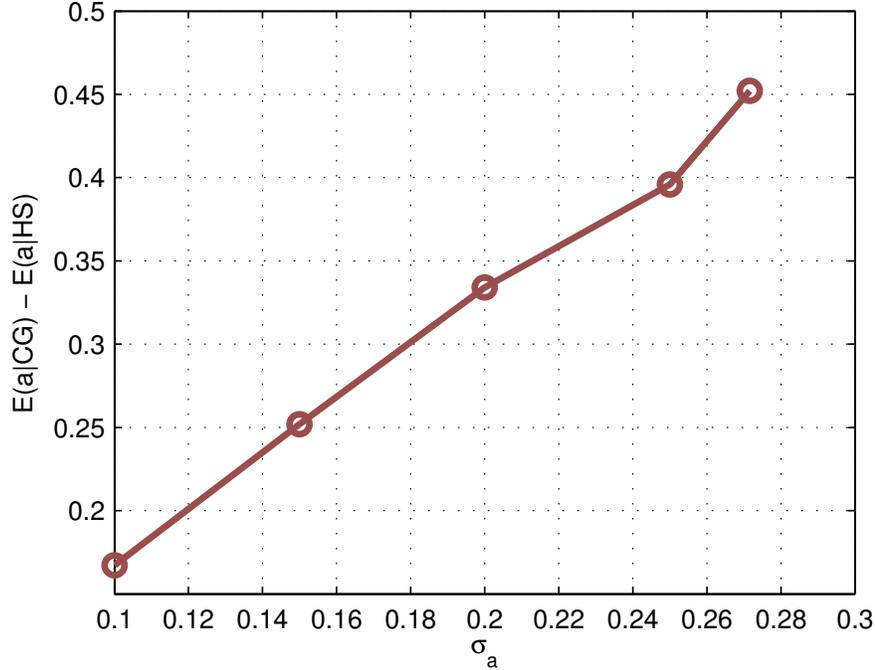
signal are willing to pay about \$5,000 per year for the opportunity to attend college. By contrast, agents in the lowest ability group would attend college in exchange for a payment of only \$500. Of course, most of these students would drop out of college after the first year. This is one reason why the required payment is so small.

This finding raises the concern that college attendance in the model is unreasonably sensitive to changes in tuition. To address this issue, we compute the effect of reducing tuition by \$1,000. A sizeable empirical literature estimates the effects of reducing tuition on college attendance. Dynarski (2003) summarizes this literature as well as her own estimates as follows: a \$1,000 reduction in the cost of attending college (in 1998 prices) leads to a 3 to 4 percentage point increase in attendance. In our model, reducing the cost of college by \$1,000 increases college attendance by only 0.1%.

4.3 Varying Ability Dispersion

A key parameter that determines the contribution of ability selection to the college earnings premiums is the dispersion of abilities, σ_a . We explore lower values of σ_a and ask: (i) How

Figure 12: $E(a|CG) - E(a|HS)$ and σ_a

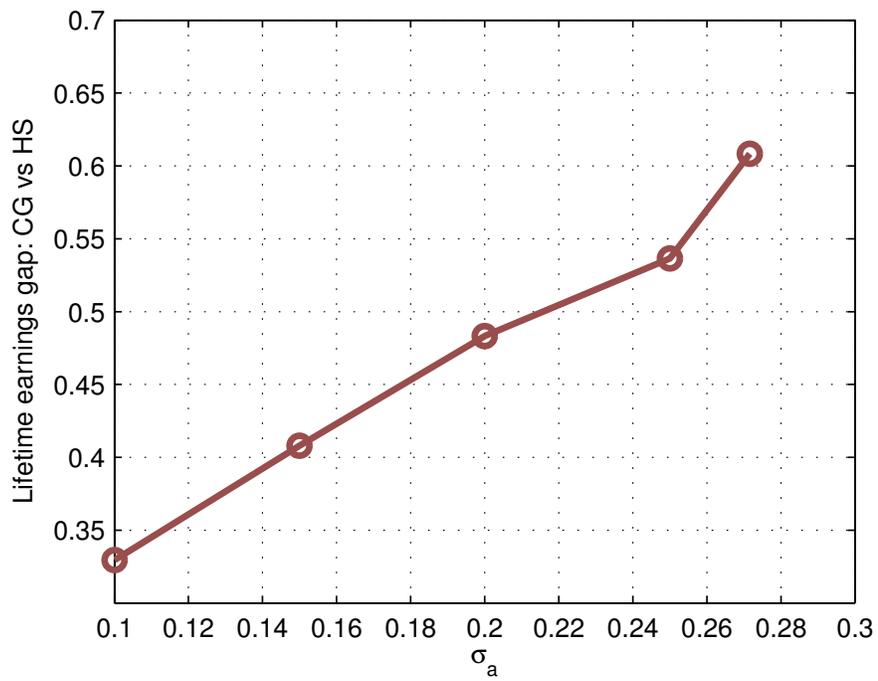


do the conclusions about ability selection change? (ii) Which data moments identify σ_a ?

We recalibrate the model, fixing σ_a at 0.1, 0.15, 0.2, and 0.25. As expected, Figure 12 shows that lower values of σ_a are associated with less ability selection; that is, with lower values of $E(a|CG) - E(a|HS)$. The ability gap falls from the baseline value of 0.45 to 0.25 when $\sigma_a = 0.15$. Interestingly, this is quite close to the ability gap found in Hendricks and Schoellman (2011), whose preferred value is $\sigma_a = 0.15$, even though the model and calibration strategy are quite different. Even this ability gap accounts for about 40% of the measured college earnings premium.

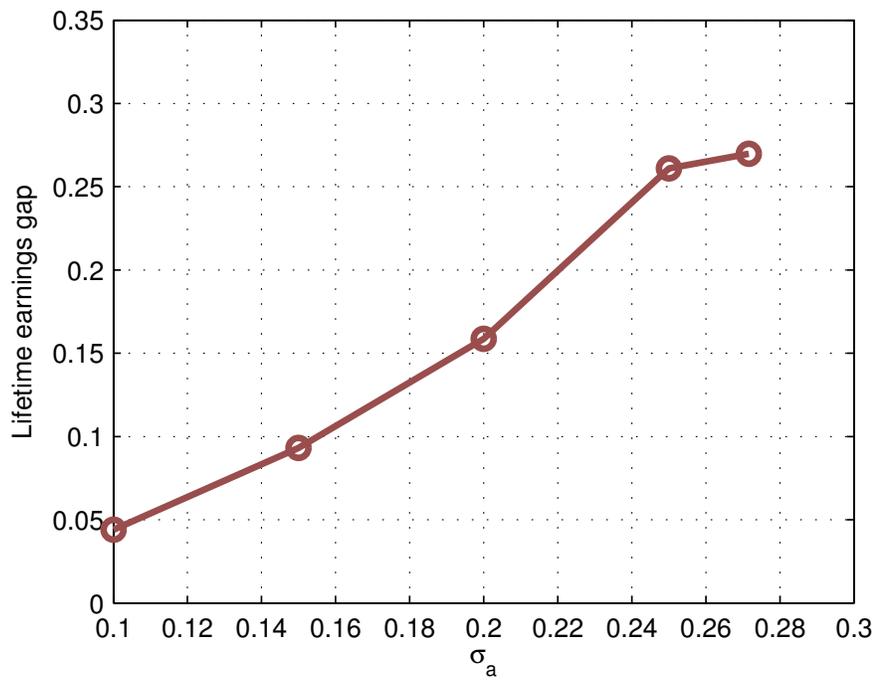
We find two data moments that identify σ_a in the sense that models with lower values of σ_a fail to match these moments. Figure 13 shows that the mean log lifetime earnings gap between college graduates and high school graduates increases strongly with σ_a . Figure 14 shows that the same is true for the mean log lifetime earnings gap between agents in the 9th AFQT decile relative to the 2nd AFQT decile (the gap is averaged over school groups).

Figure 13: College Premium and σ_a



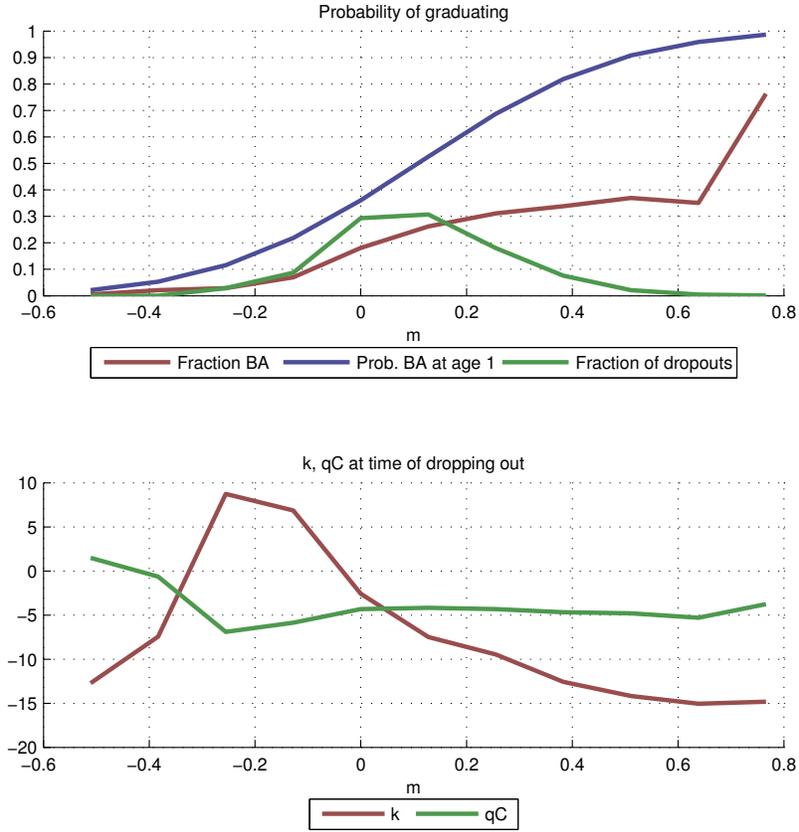
Note: The figure shows the gap in mean log lifetime earnings between college graduates and high school graduates.

Figure 14: Ability Premium and σ_a



Note: The figure shows mean log lifetime earnings of persons in the 9th relative to the 2nd AFQT decile, averaged over school groups.

Figure 15: College Dropouts



4.4 Understanding College Dropouts

Figure 15 offers a first pass at the question: why do students drop out of college?

The top panel shows, for each ability signal, the fraction of dropouts endowed with this signal, the probability of completing at least n_{grad} credits in T_c periods, and the probability of completing at least n_{grad} credits by age T_c as of the time at which each student drops out. The bottom panel shows the mean levels of assets and college costs at the time students drop out.

Most college dropouts are endowed with ability signals near the median ($m = 0$). These students faced graduation probabilities of at least one-third when they started college. By the time they drop out, they received unfavorable grades, so that their graduation probabilities dropped by around half of their age 1 values.

Table 7: Increased Borrowing Limits

	School group		
	HS	CD	CG
Fraction by schooling			
Baseline	0.48	0.24	0.28
Relax borrowing constraints	0.34	0.32	0.35
Mean log ability			
Baseline	-0.16	-0.03	0.30
Relax borrowing constraints	-0.22	-0.07	0.27

A few college dropouts started with favorable ability signals and graduation probability around 0.8. In addition to receiving poor grades, they also exhausted most of their borrowing opportunities. Their mean debt levels are near \$15,000. While these students still face reasonable graduation prospects, continuing in college would be painful as their consumption would be low.

4.5 How Important Are Borrowing Constraints?

A large literature investigates whether borrowing constraints prevent a sizeable number of students from attempting college. To address this question in our model, we recompute individual school choices when borrowing limits are increased 4-fold. All other model parameters remain unchanged.

As shown in Table 7, the fraction of high school graduates who attempt college rises from 52% to 67%. The fraction of college students who drop out remains near 50%. Increased schooling reduces mean log abilities at all levels, but mostly among high school graduates. The college lifetime earnings premium rises by 0.03.

5 Conclusion

To be written.

References

- AKYOL, A., AND K. ATHREYA (2005): “Risky higher education and subsidies,” *Journal of Economic Dynamics and Control*, 29(6), 979 – 1023.
- BELLEY, P., AND L. LOCHNER (2007): “The Changing Role of Family Income and Ability in Determining Educational Achievement,” *Journal of Human Capital*, 1(1), 37–89.
- BORGHANS, L., B. H. H. GOLSTEYN, J. HECKMAN, AND J. E. HUMPHRIES (2011): “Identification problems in personality psychology,” *Personality and Individual Differences*.
- BOWEN, W. G., M. M. CHINGOS, AND M. S. MCPHERSON (2009): *Crossing the Finish Line: Completing College at America’s Public Universities*. Princeton University Press.
- BUREAU OF LABOR STATISTICS; US DEPARTMENT OF LABOR (2002): “National Longitudinal Survey of Youth 1979 cohort,” Produced and distributed by the Center for Human Resource Research, The Ohio State University. Columbus, OH.
- CAMERON, S. V., AND C. TABER (2004): “Estimation of Educational Borrowing Constraints Using Returns to Schooling,” *The Journal of Political Economy*, 112(1), pp. 132–182.
- CHATTERJEE, S., AND F. IONESCU (2010): “Insuring Student Loans Against the Risk of College Failure,” Mimeo. Federal Reserve Bank of Philadelphia.
- CUNHA, F., J. J. HECKMAN, AND S. NAVARRO (2005): “Separating uncertainty from heterogeneity in life cycle earnings,” *Oxford Economic Papers*, 57, 191–261.
- DYNARSKI, S. M. (2003): “Does Aid Matter? Measuring the Effect of Student Aid on College Attendance and Completion,” *American Economic Review*, 93(1), 279–288.
- GARRIGA, C., AND M. P. KEIGHTLEY (2007): “A General Equilibrium Theory of College with Education Subsidies, In-School labor Supply, and Borrowing Constraints,” Mimeo. Federal Reserve Bank of St Louis.
- HECKMAN, J. J., L. LOCHNER, AND C. TABER (1998): “Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents,” *Review of Economic Dynamics*, 1(1), 1–58.

- HECKMAN, J. J., L. J. LOCHNER, AND P. E. TODD (2006): “Earnings Functions, Rates of Return and Treatment Effects: The Mincer Equation and Beyond,” in *Handbook of the Economics of Education*, ed. by E. Hanushek, and F. Welch, vol. 1, chap. 7, pp. 307–458. Elsevier.
- (2008): “Earnings Functions and Rates of Return,” *Journal of Human Capital*, 2(1), 1–31.
- HENDRICKS, L., AND T. SCHOELLMAN (2011): “Student Abilities During the Expansion of U.S. Education, 1950-2000,” Mimeo. University of North Carolina.
- JOHNSON, M. T. (2010): “Borrowing Constraints, College Enrollment, and Delayed Entry,” Mimeo. Yale University.
- KING, M., S. RUGGLES, J. T. ALEXANDER, S. FLOOD, K. GENADEK, B. T. MATTHEW B SCHROEDER, AND R. VICK (2010): “Integrated Public Use Microdata Series, Current Population Survey: Version 3.0. [Machine-readable database],” Minneapolis: University of Minnesota.
- MACURDY, T., T. MROZ, AND R. M. GRITZ (1998): “An Evaluation of the National Longitudinal Survey on Youth,” *The Journal of Human Resources*, 33(2), pp. 345–436.
- MANSKI, C. F. (1989): “Schooling as experimentation: a reappraisal of the postsecondary dropout phenomenon,” *Economics of Education Review*, 8(4), 305–312.
- NAVARRO, S. (2008): “Using Observed Choices to Infer Agent’s Information: Reconsidering the Importance of Borrowing Constraints, Uncertainty and Preferences in College Attendance,” Mimeo: University of Wisconsin.
- NLS USER SERVICES (1992): “NLS79 Profiles of American Youth. Addendum to Attachment 106,” http://www.nlsinfo.org/ordering/display_db.php3.
- STANGE, K. (2011): “An Empirical Examination of the Option Value of College Enrollment,” *American Economic Journal: Applied Economics*.
- TRACHTER, N. (2011): “Option value and transitions in a model of postsecondary education,” Mimeo. Einaudi Institute for Economics and Finance.

A Appendix: CPS Data

A.1 Sample

Our sample contains all men between the ages of 18 and 75 observed in the 1964-2010 waves of the March Current Population Survey (King, Ruggles, Alexander, Flood, Genadek, Matthew B Schroeder, and Vick, 2010). We drop persons who live in group quarters or who fail to report wage or business income.

A.2 Schooling Variables

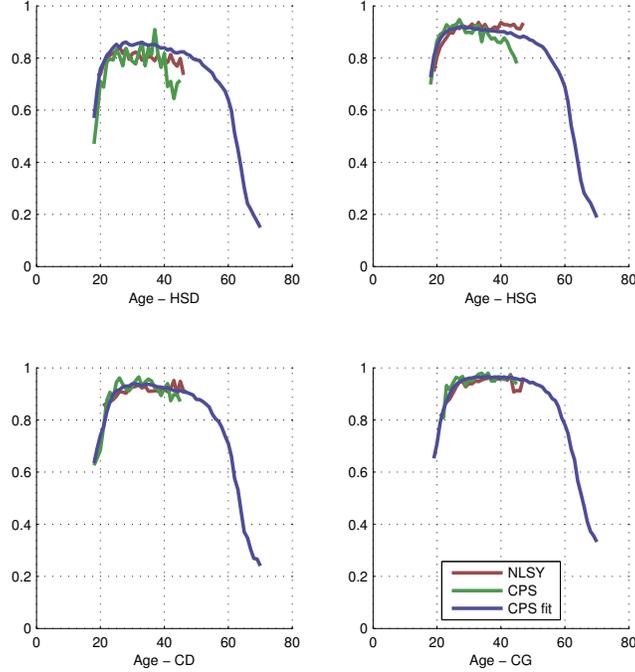
The measure of schooling attainment is inconsistent across surveys. Prior to 1992, we have information regarding the completed years of schooling (`higrade`). This variable specifies whether each given year was attempted and completed. Beginning in 1992, CPS reports education according to the highest degree attained (`educ99`). Hence, for the survey years prior to 1992, we define high school graduates as those completing 12 years (`higrade=150`), college dropouts as those with less than four years of college (`151,...,181`), and college graduates as those with 16+ years of schooling (`190` and above). For the 1992 surveys and all subsequent surveys, we define high school graduates as those with HS diploma or GED (`educ99=10`), college dropouts as those with "some college no degree," "associate degree/occupational program," "associate degree/academic program" (`11,12,13`). College graduates are those with bachelors degree, masters degree, professional degree, doctorate degree (`14,...,17`).

A.3 Age Earnings Profiles

Our goal is to estimate the age profile of mean log earnings for each school group. This profile is used to fill in missing earnings observations in the NLSY79 sample and to estimate individual lifetime earnings.

First, we compute the fraction of persons earning more than \$2,000 in year 2000 prices within each school group. This is calculated by simple averaging across all years and birth cohorts. Denote this fraction by $f(t|s)$ where t is age. Figure 16 shows the resulting profiles. For comparison, we also show the fraction of persons born between 1957 and 1964

Figure 16: Fraction earning more than \$2,000: CPS / NLSY79



Notes: NLSY and CPS show the fraction of persons earning more than \$2,000 in the 1957-1964 cohorts. CPS fit shows the estimated CPS profile $f(t)$.

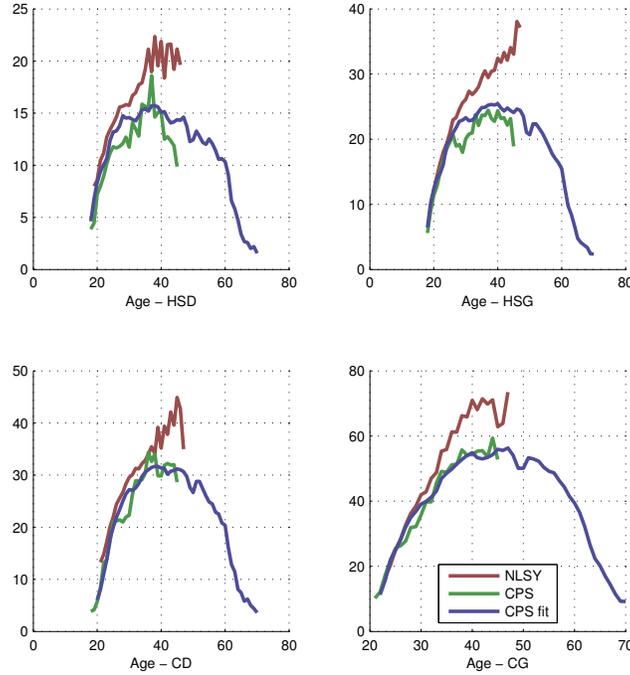
earning more than \$2,000. We estimate this from the CPS and from the NLSY79 sample described in Section B. Overall, the CPS profile $f(t|s)$ is close to the NLSY79 profile almost everywhere.

Next, we estimate the age profile of mean log earnings for those earnings more than \$2,000 per year, which we assume to be the same for all cohorts, except for its intercept. To do so, we compute mean log earnings above \$2,000 for every [age, school group, year] cell. We then regress, separately for each school group, mean log earnings in each cell on age dummies, birth year dummies, and on the unemployment rate, which absorbs year effects. We retain the birth cohorts 1935 to 1980 and ages up to 70 years. We use weighted least squares to account for the different number of observations in each cell.

Finally, we estimate the mean earnings at age a for the 1960 birth cohort as:

$$g_{CPS}(t|s) = \exp(1960 \text{ cohort dummy} + \text{age dummy}(t) + \text{year dummy}(1960 + t))f(t|s) \quad (12)$$

Figure 17: Age-earnings profiles



Notes: The figures show the exponential of mean log earnings by schooling and age in thousands of year 2000 dollars. Earnings are adjusted for the fraction of persons working at each age as described in the text.

For years after 2010, we impose the average year dummy.

Figure 17 shows the fitted age profiles together with the actual age profiles for the 1960 birth cohorts calculated from the CPS and the NLSY79. We find substantially faster earnings growth in the NLSY79 data compared with the CPS data. The discrepancies are modest until around age 30 (year 1990), which is consistent with the validation study by MaCurdy, Mroz, and Gritz (1998). The reason for the discrepancies is not known to us.

B Appendix: NLSY79 Data

The NLSY79 sample covers men born between 1957 and 1964 who earned at least a high school diploma. We drop persons with missing information as detailed below. We observe schooling and earnings from 1978 to 2006. 94% of the sample participated in the AFQT in

Table 8: Summary statistics for the NLSY79 sample

School class	HSD	HSG	CD	CG	All
Fraction	17.8	32.4	26.6	23.1	100.0
Avg.school	10.5	11.9	13.9	17.0	13.4
Range	2 - 12	9 - 12	13 - 20	12 - 20	2 - 20
AFQT percentile	22.6	40.6	54.9	78.8	50.0
<i>N</i>	919	1230	1017	675	3841

Notes: For each school group, the table shows the fraction of persons achieving each school level, average years of schooling and the range of years of schooling, the mean AFQT percentile, and the number of observations.

1980. Table 8 shows summary statistics for this sample.

Since we classify individuals based on their schooling at the beginning of the first 5 year work spell, our sample contains fewer highly educated persons than other studies have found. For example, Hendricks and Schoellman (2011) find that roughly 2/3 of (white) men born around 1960 attempt college in the NLSY79 and in the U.S. Census. Both measures are based on educational attainment observed after age 35.

In each school group we observe a wide range of completed years of schooling. Notably, some high school graduates report only 9 or 10 years of schooling. This likely represents misreporting of either grades attended or degrees earned.

B.1 Schooling Variables

For each person, we record all degrees and the dates they were earned. Because degrees are not consistently reported before 1988, we drop all persons who are not interviewed in either 1988 or 1989.

At each interview, persons report their school enrollments since the last interview. We use this information to determine whether a person attended school in each year and which grade was attended. For persons who were not interviewed in consecutive years, it may not be possible to determine their enrollment status in certain years.

Visual inspection of individual enrollment histories suggests that the enrollment reports

contain a significant number of errors. It is not uncommon for persons to report that the highest degree ever attended declined over time. A significant number of persons reports high school diplomas with only 9 or 10 years of schooling. We address these issues in a number of ways. We ignore the monthly enrollment histories, which appear very noisy. We drop single year enrollments observed after a person's last degree. We also correct a number of implausible reports where a person's enrollment history contains obvious outliers, such as single year jumps in the highest grade attained. We treat all reported degrees as valid, even if years of schooling appear low.

Many persons report schooling late in life after long spells without enrollment. Since our model does not permit individuals to return to school after starting to work, we ignore late school enrollments in the data. We define the start of work as the first 5-year spell without school enrollment. For persons who report their last of schooling before 1978, we treat 1978 as the first year of work. We assign each person the highest degree earned and the highest grade attended at the time he starts working.

We assign each person a school group (high school dropout, high school graduate, college dropout, college graduate) based on the highest degree earned by the time work starts. Persons who attended at least grade 13 but report no bachelor's degree are counted as college dropouts.

Of the 5579 men in the sample we drop 1548 whose schooling variables are incomplete.

B.2 Lifetime Earnings

For each NLSY79 individual, we estimate the present value of lifetime earnings using the following method.

Our measure of labor earnings adds wage and salary income and 2/3 of business income. The consumer price index is used to convert earnings into year 2000 prices. Lifetime earnings are measured as the present value of earnings up to age 70, discounted to age 18. We assume that earnings are zero before age 18 for high school dropouts and high school graduates, before age 20 for college dropouts, and before age 22 for college graduates.

Since we observe persons at most until age 48, we need to impute earnings later in life. For this purpose, we use the age earnings profiles we estimate from the CPS (see Section A). The present value of lifetime earnings for the average CPS person is given by $Y_{CPS}(s) =$

$\sum_{t=18}^{70} g_{CPS}(t|s)R^{18-t}$. The fraction of lifetime earnings typically earned at age t is given by $g_{CPS}(t|s)R^{18-t}/Y_{CPS}(s)$.

For each person in the NLSY79 we compute the present value of earnings received at all ages with valid earnings observations. We impute lifetime earnings by dividing this present value by the fraction of lifetime earnings earned at the observed ages according to the CPS age profile, $g_{CPS}(t|s)R^{18-t}/Y_{CPS}(s)$.

An example may help the reader understand this approach. Suppose we observe a high school graduate with complete earnings observations between the ages of 18 and 40. We compute the present value of these earnings reports, including years with zero earnings, X . According to our CPS estimates, 60% of lifetime earnings are received by age 40 (see Figure 18 below). Hence we impute lifetime earnings of $X/0.6$.

In order to limit measurement error, we drop individuals who report zero earnings for more than 30% of the observed years. We also drop persons with fewer than 5 earnings observations after age 35 or whose reported earnings account for less than 30% of lifetime earnings according to the CPS profile. Table 9 shows summary statistics for the persons for which we can estimate lifetime earnings.

One concern is that the NLSY79 earnings histories are truncated around age 45, which leaves 20 to 30 years of earnings to be imputed. Fortunately, around 70% of lifetime earnings is earned before age 45. This is shown in Figure 18, which displays the cumulative fraction of lifetime earnings received by a given age. This is based on the fitted CPS profiles, $g_{CPS}(t|s)$.

C High School and Beyond Longitudinal Survey and Postsecondary Education Transcript Study

The National Education Longitudinal Studies (NELS) program of the National Center for Education Statistics (NCES) was established to study the educational, vocational, and personal development of young people. Thus far, the NELS program consists of five major studies: the National Longitudinal Study of the High School Class of 1972, High School and Beyond (HS&B), the National Education Longitudinal Study of 1988, the Education Longitudinal Study of 2002, and the High School Longitudinal Study of 2009.

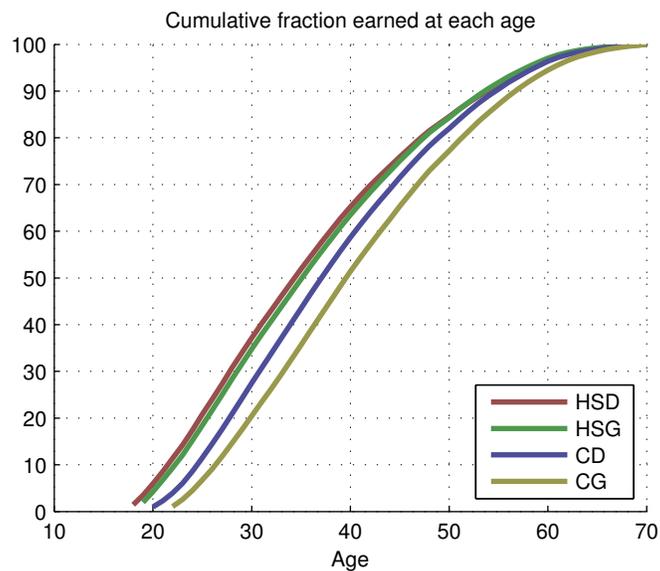
The survey that corresponds most closely to the NLSY79 cohort, the cohort of focus in this

Table 9: Lifetime earnings data

	HSD	HSG	CD	CG
Mean (thousands)	500	683	778	1135
Min	49	10	104	196
Max	1885	2231	2857	3408
Standard deviation (log)	0.54	0.50	0.54	0.50
Fraction zero	6.0	3.0	3.4	2.5
Fraction < 100,000	1.5	0.1	0.0	0.0
Correlation with wage	0.57	0.62	0.72	0.78
N	305	509	453	326

Notes: Mean denotes $\exp(\text{mean log lifetime earnings})$. Correlation with wage denotes the correlation between log lifetime earnings and log wages at age 40. N is the number of observations.

Figure 18: Cumulative fraction of lifetime earnings received by each age



paper, is the HS&B cohort. Precisely, the HS&B survey included two cohorts: the 1980 senior class and the 1980 sophomore class. Both cohorts were surveyed every two years through 1986, and the 1980 sophomore class was surveyed again in 1992. In 1992, i.e., 10 years after high school graduation, postsecondary transcripts from all institutions attended since high school graduation were collected for the sophomore cohort under the initiative of the Postsecondary Education Transcript Study (PETS). The transcript study for the senior cohort was conducted much earlier, in 1984, i.e. only 4 years after high school graduation. Because of the availability of postsecondary education transcript histories for 10 years after high school graduation, we choose to focus on the 1980 sophomore class.

The HS&B data files are available through ICPSR at the University of Michigan (ICPSR 8896). We supplement these with PETS, obtained through a restricted license granted by the National Center for Education Statistics. We restrict attention to sophomores surveyed at least through 1986, which leaves us with 14,825 student records and 17,363 transcripts collected from 4,079 institutions. Hence, while the demographic and financial information (e.g., parental transfers, earnings, school costs, grants) is available for the first four years after high school, college performance and enrollment information is available for ten years after high school.

C.1 Enrollment and Dropout Statistics

The sample is restricted to white males graduating from high school with their class in 1982. We split these students into quartiles according to their high school GPA, which is available for 92% of our sample. For the remaining 8%, we impute high school GPA quartile with the quartile of their cognitive test score. This test was conducted in their senior year and was designed to measure quantitative and verbal abilities.

We use the course-level data and institution-level data derived from postsecondary transcripts to compute, for each student, attempted and earned non-vocational undergraduate credits for each academic year. All postsecondary credits taken prior to the date a bachelor's degree was obtained are considered undergraduate credits. For students that never earned a bachelor's degree, all postsecondary credits are treated as undergraduate. Transfer credits are dropped to avoid double-counting. We count withdrawals that appear on transcripts as attempted but unearned credits. Vocational credits are identified as credits taken at a vocational school (e.g., a police academy, a school of cosmetology or a health

occupation school).

We say someone enrolls in college if they attempt at least 9 non-vocational credits. Using this definition, 53% of the cohort enters college immediately upon high school graduation. Another 3% of the cohort enter in the following year. 55% of immediate entrants obtain a bachelor's degree.

To obtain dropout statistics, we restrict attention to immediate entrants with complete transcript histories. We refer to a college entrant as a year x dropout if he/she enrolled continuously in years 1 through x , enrolled less than part time in year $x + 1$, and failed to obtain a bachelor degree within 5 years. The results reported in the paper are based on the 7 credit hours definition of part time enrollment. The results are not highly sensitive to varying the definition of "part time," as most college students enroll full time. Nearly all college graduates, precisely 86% of college graduates in our sample, exhibit continuous enrollment to graduation. In fact, it is common to treat those with a break in enrollment as permanent dropouts (e.g. Stange, 2010). It is true, however, that a few of those return to school and even graduate. This is why we classify anyone graduating within 5 years as college graduates. We also exclude from the sample those students that obtain a college degree but fall into our definition of dropouts (These are students with enrollment breaks returning to school later and graduating in 6 or more years.).

We compute fractions of college students dropping out in years 1 through 6, overall and by high school GPA quartile. These are used as calibration targets. See the main text for statistics.

C.2 Financial variables

In the second and third follow-up interviews (1984 and 1986), all students are questioned in detail regarding their education expenses, various sources of financial support, and own earnings. We translate all amounts into 2000 dollars using the consumer price index.

We construct total parental transfers as the sum of the school-related transfer and the direct transfer to the student in the form of inkind support and gifts. Precisely, the school-related transfer refers to "payments on [the student's] behalf for tuition, fees, transportation, room and board, living expenses and other school-related expenses."

The direct transfer to the student is the approximate dollar value of inkind support such as room and board (the coresidence benefit), use of car, medical expenses and insurance,

clothing, and any other cash or gifts. The value of the direct transfer to the student is reported in terms of detailed intervals up to \$3000 of current dollars. We proxy its value by using the midpoint value of the relevant interval and \$4000 of current dollars if it falls into the last open interval. The direct transfer variable is available for calendar years only. We allocate it equally across the relevant academic years.

The school-related transfer is available only for the first two academic years after high school graduation. For academic years 8485 and 8586, we proxy it with the school-related transfer for 8384 adjusted by the change in tuition net of grants/scholarships.

We identify as high school graduates those with no postsecondary education history or those with strictly less than 7 nonvocational credits in each of the first four academic years since high school.³ Note this is consistent with our 7 credit part-time definition used above to measure dropout rates.

Tuition and fees and the value of grants are available for each academic year. Grants refer to the total dollar value of the amount received from scholarships, fellowships, grants, or other benefits (not loans) during the academic year.

Student earnings are available at calendar year frequencies. To convert these into academic years for college students, we assume that the relative fractions of year j earnings that are earned in academic years ij and jk are inversely related to the relative number of credits taken in years ij and jk . Simplifying obtains that the proportion of year j income attributed to academic year ij is given by $\alpha_{ij} = cred_{jk}/(cred_{ij} + cred_{jk})$. We attribute half of the 1982 earnings to the 8283 academic year.

³We also worked with the cutoff value of 0. The resulting moments were affected very little.