Investment Opportunities and Economic Outcomes: Who Benefits From College and the Stock Market?*

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Abstract

Two investments stand out for their power to improve economic outcomes: higher education and stocks. Absent public funding, though, both are seen as the preserve of the wealthy. As a result, higher education in particular is, in many countries, heavily subsidized with the explicit aim of promoting equality of opportunity. However, differences in characteristics are likely to affect individuals' capacity to take advantage of investment opportunities and improve their economic well-being. Our goal in this project is therefore to study the effect of access to college and the stock market on individual earnings, wealth, mobility, and inequality using a model that derives empirically-plausible measures of ex-ante heterogeneity in learning ability, initial human capital, and initial wealth. Does the power of college to increase well-being exceed that of stocks, as large subsidies to the former suggest? Perhaps not: we show that college does improve economic outcomes, but only for those whose ability and preparedness poise them for success. Stocks, on the other hand, may improve economic outcomes for those whose endowments make human capital investment a relatively unattractive option.

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1 Introduction

Two investments stand out for their power to improve economic outcomes: higher education and stocks. Absent public funding, though, both are seen as the preserve of the wealthy. As a result, higher education in particular is, in many countries, heavily subsidized with the explicit aim of promoting equality of opportunity. An important point, however, is that differences in learning ability, preparedness, and wealth are likely to affect individuals' capacity to take advantage of investment opportunities and improve their economic well-being. Our goal in this project is therefore to study the effect of access to college and the stock market on individual economic outcomes. Specifically, we aim to provide quantitatively compelling answers to the following questions: what is the effect of access to college and the stock market on earnings, wealth, and mobility for different US households, who are heterogeneous in their learning ability, their initial human capital stock, and their financial wealth? Are college and the stock market serving as vehicles to allow individuals to escape adverse initial conditions or mainly perpetuating initial disparities in endowments?

To address these questions, we use a model to derive a joint distribution of learning ability, initial human capital stock, and initial financial wealth that reflects empirically-plausible ex-ante heterogeneity in the U.S. economy. The model economy allows households to have access to both college and stocks. We compare outcomes from this baseline economy to outcomes from economies in which the distribution of individual types is retained, but where the options for investment differ. Specifically, we compare lifetime earnings, wealth, mobility, and inequality in the baseline economy to economies that do not feature access to college and/or stocks.

Our study is motivated by the fact that, in recent decades, the wage premium for college-educated individuals relative to high-school completers (and those who have completed some college) has risen dramatically, increasing lifetime income by a factor of roughly two, and stabilizing at a historically high level (Goldin and Katz, 2007). This investment can thus be lucrative for those who complete college and of a magnitude that could in principle erase disparities prevailing prior to enrollment. Moreover, a variety of policies (subsidized student loans and means-tested grants, most importantly) have been enacted precisely to promote equality of opportunity. Indeed, in their landmark work, Goldin and Katz (2009) argue forcefully that increases in human capital have been the engine of equalization in earnings across US households.

A second high-yield investment, especially in the long run, is stock-market equity. Famously of course, the return on this asset is so high that existing work has largely failed to account for it. While stock-market investment is less frequently emphasized than college investment as an agent of opportunity and upward mobility, it is not implausible that it is one. Household participation in the equity market has increased with the growth of defined contribution plans in the US and, a priori, the returns to equity have been measured to be broadly similar to those on human capital (e.g., Cahuc et al., 2014, and references therein). As with college, these returns may well serve to improve economic outcomes.

There are, however, several forces working against the ability of college and stocks to improve economic outcomes. First, favorable endowments raise the expected returns to investment in both assets, while unfavorable ones lower them. In the case of college, learning ability and wealth are positively correlated with the likelihood of college completion. All else equal, this implies that the high return may be available disproportionately to the already well-prepared and financially well-off. As a result, under current wage premia, college may well be a brake on, rather than an engine of, mobility.

In the case of stocks, those with higher initial wealth may again be disproportionately advantaged. While borrowing constraints for student loans may not be tight, given direct policy interventions aimed at broadening credit access for education, the same is not true for stocks. As a result, those with low initial wealth will find it difficult to make leveraged investments in the stock market. Indeed, binding credit limits have been implicated in models aimed at understanding why younger households hold so few stocks: "junior can't borrow" (Constantinides et al., 2002). More recently, Davis et al. (2006) show that even if one allows borrowing to buy stocks, the applicable interest rate is very high, making the de facto return on stocks lowest for those with least initial wealth.[1]

Second, investing in college and in the stock market means bearing risk. College, for its part, carries substantial risk associated with non-completion (Restuccia and Urrutia, 2004; Bound et al., 2010; Johnson, 2013), with partial completion offering relatively little reward. The risk of non-completion is, furthermore, negatively related to household wealth and measures of collegiate preparedness (the latter is proxied in our framework by human capital stock), which themselves are positively correlated. All else equal, this will disproportionately deter those with low wealth and preparedness from investing in college, possibly reducing economic mobility. That the stock market is risky needs less argument. The risk is in fact large, of an order of magnitude higher than that on treasury bills or bonds (Mehra and Prescott, 1985). The ability to bear this risk is likely not uniform in the population. Specifically, the wealth-rich may plausibly be more risk tolerant (in the sense of absolute risk aversion, certainly) than their less-wealthy counterparts, making them more willing to hold greater levels of risky equity. As a result, such agents may be able to remain in–and thereby reap the substantial long-run returns from—stocks. Their initially poorer counterparts will, for the same reasons, be unwilling to take on the risk needed to garner

[1] There is also a recent literature that finds persistent heterogeneity across households in their realized returns to financial investments. See (Fagereng et al., 2016) and references therein.

the high yields, and so remain less wealthy.

Lastly, all individuals in the US appear to face significant uninsurable risk to earnings, with this risk looming largest for the least skilled (see, e.g., Blundell et al., 2008). Thus, if the least prepared are also the least able to acquire college and the labor market insurance it seems to offer, college will serve to intensify the effect of initial disparities and reduce economic mobility. Labor market risk also compounds the risk of borrowing to invest in both college and the stock market, even if leveraged stock-purchases were feasible. As a result, labor market risk in adult life may once again imply that college and the stock market primarily allow the initially well-off to do even better as their poorer, less-prepared counterparts are forced to opt for safer, lower-return investments, thereby reducing mobility.

All of the above suggests that the answer to the question of whether college and stocks improve economic outcomes likely depends on individual *types*. Our first goal in this paper, therefore, is to measure *for whom* access to college and the stock investment yields increases in lifetime earnings, wealth, and mobility. Mobility of course becomes much more important in settings where inequality is higher. Therefore, we also measure overall inequality in each of the environments that we study. Finally, to connect with a longstanding question in the literature, we examine the effect of these two investments on the temporal resolution of inequality, that is, the extent to which inequality is driven by initial endowments versus outcomes over the course of the life cycle.

To this end, we construct a model economy in which individuals differ ex-ante in their ability to learn, their initial human capital stock, and their initial financial wealth. These agents have access to quantitatively disciplined representations of human capital and stock-market investment opportunities. In the case of human capital investment, our model allows for college education, but where that investment is risky, and where the structure of financial aid captures existing need- and merit-based aid programs. Given initial heterogeneity in income and wealth, these features will affect the decisions of investors in college differently. With respect to life after college, our model allows for the accumulation of skills throughout life, consistent with a large body of evidence suggesting that earnings growth over the life cycle reflects in large part human capital accumulation (see, e.g., Altonji et al., 2013). In the case of stock-market investment, our model accounts again for risk.[2] Heterogeneity in household incentives to make investments in either human capital or financial equity is thus at the heart of our approach. The initial heterogeneity in learning ability, human capital stock, and financial wealth is, in turn, quantitatively disciplined by the empirics of earnings over the life cycle and college enrollment and completion behavior.

[2]Note that we do not allow heterogeneity in returns to the risky asset across agents. While evidence for such heterogeneity exists (e.g. (Fagereng et al., 2016)), we abstract from it in our framework because that heterogeneity appears to be only weakly related to observable characteristics.

First, to understand the effect of access to college, we compare lifetime earnings and lifetime wealth in the baseline economy to outcomes in an economy that does not feature access to college. We find that gains from access to college can be large in absolute terms—about 6 percent of lifetime earnings on average—but that variation in these gains is also large: For instance, while for low ability types, access to college has little impact on earnings, among those with the highest ability, we see that college offers a substantial gain in earnings (roughly 10 percent). Furthermore, access to college generates the largest boost to earnings (about 25 percent) for individuals with lowest initial human capital levels and wealth. In terms of mobility over the lifetime, heterogeneity is again substantial: for example, for high-ability types, college increases the probability of moving from the bottom to the top quartile of the earnings distribution by 10 percentage points (from 46 to 56 percent), whereas for low-ability types, college has no impact on lifetime income mobility.

Second, we contrast the role of access to college to that played by access to stocks, another high-return, high risk investment. Results reveal that access to the stock market results in minimal gains to earnings and wealth. Interestingly, however, the opportunity to invest in college, on net, increases lifetime inequality while, perhaps surprisingly, the stock market serves to lower it. Both college and the stock market reduce the contribution of initial conditions to lifetime inequality. College, however, raises the importance of learning ability relative to other initial conditions. Overall, we find that both initial human capital and ability are quantitatively important for lifetime inequality. Initial wealth matters for lifetime wealth inequality, but not for earnings inequality.

1.1 Related work

We build on work that is aimed at understanding the role of human capital when the particulars of college education, in terms of its costs as a function of observable enrollee and household characteristics, are modeled explicitly. Important references in this literature include Arcidiacono (2005); Garriga and Keightley (2007); Chatterjee and Ionescu (2012); Johnson (2013) and Altonji et al. (2015). Recent work of Abbott et al. (2013) is clearly relevant as well. They develop a rich representation of higher education, allowing for a variety of salient features—gender, labor supply during college, government grants and loans (including private loans), and heterogeneity in familial resources—that have bearing on the measurement in which we are interested. An important distinction between our work and theirs is their primary focus on policy counterfactuals, which their detailed general equilibrium formulation permits.[3] Our primary focus is instead on individuals, and the question of for whom access to college and/or the stock market improves

[3]See also Epple et al. (2013) and Cestau et al. (2015) for analysis of higher education policies in the presence of substantial enrollee heterogeneity.

economic outcomes. We therefore adopt a partial equilibrium perspective, but precisely derive the (not-directly-observable) joint distribution of learning ability, initial human capital stock, and initial financial wealth, which, as argued above, is critical to accurately addressing this question.

We are also informed by the work that emphasizes the bias imparted to measured returns to college by the possibility of noncompletion. Hendricks and Leukhina (2014) allow for selection effects and argue that two layers of selection are important: weakly-prepared students disproportionately fail to enroll in college, and those who enroll fail at high rates to complete.[4] Our model allows for both effects to operate, and thereby avoids overstating the payoff to college. With respect to failure risk, our work builds on earlier work of Restuccia and Urrutia (2004) and Akyol and Athreya (2005).[5] More recently, Athreya and Eberly (2013) demonstrate that college failure risk hinders low-wealth individuals, even relatively well-prepared ones, from enrolling in college.

With respect to stocks, our work follows the literature on portfolio choice in life-cycle models (see, for example, Cocco et al., 2005). In spirit, our work is also closely related to Kim et al. (2013), which also features both education and stock market investment.[6]

The remainder of the paper is organized as follows. Section 2 describes the model and Section 3 the data we use to calibrate it. Section 4 summarizes the calibration, with Appendix 7 providing details for the interested reader. The results are reported in Section 5 and Section 6 concludes.

2 Model

Our aim is to quantitatively assess the importance of two specific investments, college and stocks, for economic outcomes. We are interested in how access to these investment opportunities alters outcomes for various types of individuals. We begin with a baseline model that incorporates an array of salient features of both investments. The details are described below.

2.1 Environment

Time is discrete and indexed by $t = 1, ..., T$ where $t = 1$ represents the first year after high school graduation. We allow for three potential sources of heterogeneity across agents: their immutable learning ability, a, their initial stock of human capital, h_1, and their initial assets, x_1. These

[4]See also Arcidiacono (2004).

[5]The possibility of college failure has also been evaluated in work of Stange (2012) and Ozdagli and Trachter (2011).

[6]Indeed, in Athreya et al. (2015), we incorporate the elements of Kim et al. (2013) in a model with human capital investment (though without 4-year college) and show that it can match important life-cycle observations on household stock market participation.

characteristics are drawn jointly according to a distribution $F(a, h, x)$ on $A \times H \times X$.

Each period, agents choose how much to consume and how to divide their time between learning and earning, as in Ben-Porath (1967). Agents also decide how much of their wealth to allocate to stocks, s, versus bonds, b. The latter may be used to either borrow or save. Debt is not defaultable and is subject to a borrowing limit, $-\underline{b}$, where $\underline{b} > 0$.

Agents work and accumulate human capital using the Ben-Porath technology until $t = J - 1$. Agents can also accumulate human capital by choosing (in the first period) to attend college. College can be financed using wealth, x, unsecured debt, b, and non-defaultable, unsecured student-loan debt, d. Agents retire in period $t = J$, after which they face a simple consumption-savings problem.

To capture an important source of risk to human capital, we assume that agents may fail to complete college.[7] At the end of four years in college, the probability of completion—which depends on the agent's innate ability as well as human capital accumulated to that point—is realized. Those who complete college start their working life with human capital h^{CG}, while those who fail to complete start their working life with human capital h^{SC}, where SC denotes "some college", and those who choose not to go to college start their working life at $t = 2$ with human capital h^{HS}.[8]

2.2 Preferences

Agents maximize the expected present value of utility over the life cycle:

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

where $u(.)$ is strictly concave and increasing. Preferences are represented by a standard time-separable CRRA utility function over consumption. Agents do not value leisure.

2.3 Human Capital

Agents can invest in their human capital in two ways—by investing in a college education when young and by apportioning some of their available time to acquiring human capital throughout their working lives.

[7]For example, Bound et al. (2010) report, using NLS72 data, that only slightly over half of all college enrollees graduated within 8 years of enrollment. In addition, according to BPS data, 68.5% of students enroll in four-year colleges, and 89% of college dropouts are enrolled in college for at least three full years.

[8]Note that h^{CG}, h^{SC}, and h^{HS} all vary across individuals.

Both within and outside college, agents accumulate human capital using a Ben-Porath technology. However, the incentives to invest in human capital are different in and outside college, for several reasons. First, the human capital accumulation technology may be more productive in college than outside of it (the elasticity parameter of the human capital production function may be higher in college).[9] This is consistent with the literature that suggests that college offers a highly productive path for human capital accumulation. Second, the opportunity cost of spending time learning is higher on the no-college path than on the college path. Outside college, we assume that earnings are a function of accumulated human capital whereas in college they are not: those who work while in college face a relatively low wage rate that does not differ by type. This assumption is consistent with evidence that the jobs that college students hold do not necessarily value students' human capital stocks. In fact, we assume that working takes time away from human capital accumulation, and that accumulating less human capital decreases the odds of completion. This, too, is consistent with empirical evidence that college jobs do they contribute to human capital accumulation and that students who work while in college are more likely to drop out (see Autor et al., 2003; Peri and Sparber, 2007). Consequently, most college students in the model find it optimal to allocate all of their time to human capital accumulation, which is in line with empirical findings that the majority of full-time students do not work while in college (see Manski and Wise, 1983; Planty et al., 2008). College in the model thus represents a device that can greatly accelerate human capital accumulation but harshly penalizes non-corner solutions for time allocation. Lastly, college students have access to grant funding, which is not available outside of college, as well as to student loan credit that carries a lower rate of interest than the unsecured credit available to all agents. Access to grants and cheaper credit makes funding consumption while spending time accumulating human capital relatively easier on the college path than on the no-college path. Taken together, these factors make human capital accumulation more attractive in college than outside of it during the college years.

2.3.1 Ben-Porath Human Capital Investment

During college and while working, agents accumulate human capital Ben-Porath (as in the classic 1967, model):

$$h_{t+1} = h_t(1-\delta) + a(h_t l_t)^{\alpha} \text{ with } \alpha \in (0,1) \tag{2}$$

Human capital production depends on the agent's immutable learning ability, a, human capital, h_t, the fraction of available time put into it, l_t, and the production function elasticity, α. Human capital depreciates at a rate of δ.

[9]We abstract from this assumption for the current exposition.

2.3.2 College Investment and Financing

Those who invest in college face the risk of noncompletion, which decreases with the level of human capital accumulated during college. Specifically, the probability of completion, $\pi(h_5(h_1, a, l^*_{1,...,4}))$ is an increasing function of the amount of human capital accumulated after completing four years in college, h_5, which in turn increases with the initial human capital stock, h_1, the agent's learning ability, a, and the amount of time $l^*_{1,...,4}$ that she chooses to allocate to human capital accumulation (versus working) while in college.

Those who work in college earn a wage $w_{col}(a)$ per unit of time worked. We assume that the rate increases with ability in order to prevent low-ability students from enrolling in college only to enjoy earnings during college that are higher than what they would have earned had they not enrolled in college. Working during college diverts time from human capital accumulation and therefore increases the probability of non-completion.

There are several possible sources of college financing: savings, x, borrowing, b, earnings from working while in college, and student loans. Agents are allowed to take out student loans up to $d(x) = \min[d_{max}, max[\bar{d} - x, 0]]$, which represents the full college cost, $\bar{d}$, minus any savings, x, up to a student loan limit d_{max}. They choose the loan amount, d, at the beginning of college and receive equal fractions of the loan each period in college. After college, they repay this loan in equal payments, p, which are determined by the loan size, $d(x)$, interest rate on student loans, R_g, and the duration of the loan, P. Consistent with the data, the interest rate on student loans is $R_f < R_g < R_b$, where R_f is the risk-free savings rate and R_b the borrowing rate on unsecured debt.

The return to human capital is in the form of earnings during the working life, which are subject to shocks as described below.

2.4 Earnings

During an agent's working life, their earnings are given by:

$$y_t = w(1 - l_t)h_t z_{it}$$

where w is the rental rate of human capital (which is normalized to 1), $(1 - l_t)$ is the time spent working, and z_{it} is the stochastic component. The latter varies between college graduates, CG, and those with no college, NC (which includes college dropouts and high school graduates). It consists of a persistent component $u_{it} = \rho u_{i,t-1} + \nu_{it}$, with $\nu_{it} \sim N(0, \sigma^2_\nu)$, and a transitory (iid) component $\epsilon_{it} \sim N(0, \sigma^2_\epsilon)$. The variables u_{it} and ϵ_{it} are realized in each period over the life cycle and are not correlated.

2.5 Means-Tested Transfer and Retirement Income

Because these may have an impact on cross-sectional inequality, we allow agents to receive means-tested transfers, τ_t, which depend on age, income, and assets. Following Hubbard et al. (1994) we specify these transfers as

$$\tau_t(t, y_t, x_t) = \max\{0, \underline{\tau} - (\max(0, x_t) + y_t)\} \tag{3}$$

These transfers capture the net effect of the various U.S. social insurance programs that are aimed at providing a floor on income (and thereby consumption).

After period $t = J$, in which agents start retirement, they receive a constant fraction of their earnings in the last working period, $\varphi^i(y_J + \tau_J)$, which they allocate between risky and risk-free investments. We allow the income replacement rate for college graduates to differ from the rate for all other agents.

2.6 Financial Markets

There are two financial assets in which the agent can invest, a risk-free asset, b_t, and a risky asset, s_t.

Risk-free assets

An agent can borrow or save using asset b_t. Savings will earn the risk-free interest rate, R_f. We assume that the borrowing rate, R_b, is higher than the savings rate: $R_b = R_f + \omega$. Debt is non-defaultable and comes with a borrowing limit $\underline{b} > 0$.

Risky assets

Risky assets, or stocks, earn stochastic return $R_{s,t+1}$ in period $t + 1$, given by:

$$R_{s,t+1} - R_f = \mu + \eta_{t+1}, \tag{4}$$

where η_{t+1}, the period $t + 1$ innovation to excess returns, is assumed to be independently and identically distributed (i.i.d.) over time and distributed as $N(0, \sigma^2_\eta)$. We assume that innovations to excess returns are uncorrelated with innovations to the aggregate component of permanent labor income.

Given asset investments at age t, b_{t+1} and s_{t+1}, financial wealth at age $t+1$ is given by

$$x_{t+1} = R_j b_{t+1} + R_{s,t+1} s_{t+1}$$

with $R_j = R_f$ if $b \geq 0$ and $R_j = R_b$ if $b < 0$.

2.7 Agent's Problem

The agent chooses whether or not to invest in college (and, if investing in college, how much student debt to take on), how much to consume, how much time to allocate to learning, asset positions in stocks and bonds (or borrowing), and in order to maximize expected lifetime utility.

We solve the problem backwards starting with the last period of life when agents consume all their available resources. The value function in the last period of life is set to $V_T^R(a,h,x) = u(x)$.

Retired agents do not accumulate human capital. They face a simple consumption-savings problem but may choose to invest in both risk-free and risky assets. The value function is given by

$$V^R(t,a,b,s,y_J) = \max_{b',s'} \{ \frac{c^{1-\sigma}}{1-\sigma} + \beta V^R(t+1,a,b^{'},s^{'},y_J) \} \tag{5}$$

where

$$\begin{aligned} c + b^{'} + s^{'} &\leq \varphi^i (y_J + \tau_J) + R_j b + R_s s \\ b^{'} &\geq \underline{b} \\ s^{'} &\geq 0 \end{aligned}$$

In the above, $R_j = R_f$ if $b \geq 0$ and $R_j = R_b$ if $b < 0$. The only uncertainty faced by retired individuals pertains to the rate of return on the risky asset.

2.7.1 Problem in Working Phase for those with No College

We use $V_J^R(t,a,b,s,y_J)$ from Equation 5 as a terminal node for the adult's problem on the no college path. We solve

$$V^{HS}(t,a,h,b,s,z) = \max_{l,b',s'} \{ \frac{c_t^{1-\sigma}}{1-\sigma} + \beta E V^{HS}(t+1,a,h^{'},b^{'},s^{'},z^{'}) \} \tag{6}$$

where

$$\begin{aligned} c + b' + s' &\leq w(1-l)hz + R_b b + R_s s + \tau(t, y, x) \text{ for } t = 1, .., J-1 \\ l &\in [0, 1] \\ h' &= h(1-\delta) + a(hl)^{\alpha} \\ b' &\geq \underline{b} \\ s' &\geq 0 \end{aligned}$$

2.7.2 Problem in Working Phase for those who Attended College

As before, we use $V_J^R(t, a, b, s, y_J)$ from the retirement phase as a terminal node and solve for the set of choices in the working phase $j = 5, .., J-1$ of the life cycle. We further break down the working phase into a student loan post-repayment period and a repayment period. In the post-repayment period, $t = P+1, ..., J-1$, the problem is identical to the one for working adults on the no-college path.

During the repayment period, $t = 5, ..., P$, agents have to repay their student loans with a per-period payment

$$p = \frac{d(x)}{\sum_{t=1}^{P-5} \frac{1}{R_g^t}}.$$

The value function is given by

$$V^i(t, a, h, b, s, z) = \max_{l, b', s'} \{ \frac{c_t^{1-\sigma}}{1-\sigma} + \beta E V^i(t+1, a, h', b', s', z') \}, i = CG, SC \tag{7}$$

where

$$\begin{aligned} c + b' + s' &\leq w(1-l)hz + R_j b + R_s s + \tau(t, y, x) \text{ for } t = P+1, .., J-1 \\ c + b' + s' &\leq w(1-l)hz + R_j b + R_s s + \tau(t, y, x) - p(x_1) \text{ for } t = 5, .., P \\ l &\in [0, 1] \\ h' &= h(1-\delta) + a(hl)^{\alpha} \\ b' &\geq \underline{b} \\ s' &\geq 0 \end{aligned}$$

$R_j = R_f$ if $b \geq 0$ and $R_j = R_b$ if $b < 0$.

2.7.3 Problem in College

For the college phase $t = 1, .., 4$ of the life cycle we first take into account the risk of dropping out from college and use $V^C(5, a, h, b, s, z) = \pi(h_5)V^{CG}(5, a, h, b, s, z) + (1 - \pi(h_5))V^{SC}(5, a, h, b, s, z)$ as the terminal node. The value function is given by

$$V^C(t, a, h, b, s, z) = \max_{l,b',s'} \left[\frac{c^{1-\sigma}}{1-\sigma} + \beta E V^C(t+1, a, h^{'}, b^{'}, s^{'}, z^{'}) \right] \tag{8}$$

where

$$\begin{aligned} c + b^{'} + s^{'} &= w_{col}(1-l) + R_b b + R_s s + d/4 - \bar{d}/4 \\ l &\in [0, 1] \\ h^{'} &= h(1-\delta) + a(hl)^{\alpha_{col}} \\ d(x) &\leq \min[d_{max}, max[\bar{d} - x, 0]] \\ b^{'} &\geq \underline{b} \\ s^{'} &\geq 0. \end{aligned}$$

For the college period, the rental rate of human capital is set to a relatively low value (see Section 4), which means that human capital is not productive until graduation. This assumption is consistent with evidence that the jobs college students have do not necessarily value students human capital stocks, nor do they contribute to human capital accumulation. The set of skills involved in these jobs is different from the one students acquire in college and use after graduation. An implication of this assumption is that in the model college students find it optimal to allocate all of their time in college to human capital accumulation, a result that is consistent with the empirical findings that the majority of full-time college students do not work while in school. Finally, people who choose to work while in school most likely drop out of college, as numerous studies attest.

Agents are allowed to borrow up to the full college cost minus the expected family contribution that depends on initial assets. Agents use the loan amount and initial assets to pay for college expenses while in college. This feature is important, since it prevents college graduates from having an advantage over the no-college group in having access to government borrowing and using it for consumption over the life-cycle. They pay direct college expenses each period while in college.

Once the college and no-college paths are fully determined, agents then select between going to college or not by solving $\max[V^C(1, a, h, x), V^{HS}(1, a, h, x)]$.

3 Data

In order to map our model to data, we use data on annual earnings from the March Current Population Survey (CPS), on financial assets from the Survey of Consumer Finances (SCF), and on college enrollment and completion rates from the Beginning Postsecondary Student Longitudinal Survey (BPS) 2004/2009 and the National Education Longitudinal Study (NELS:1988).

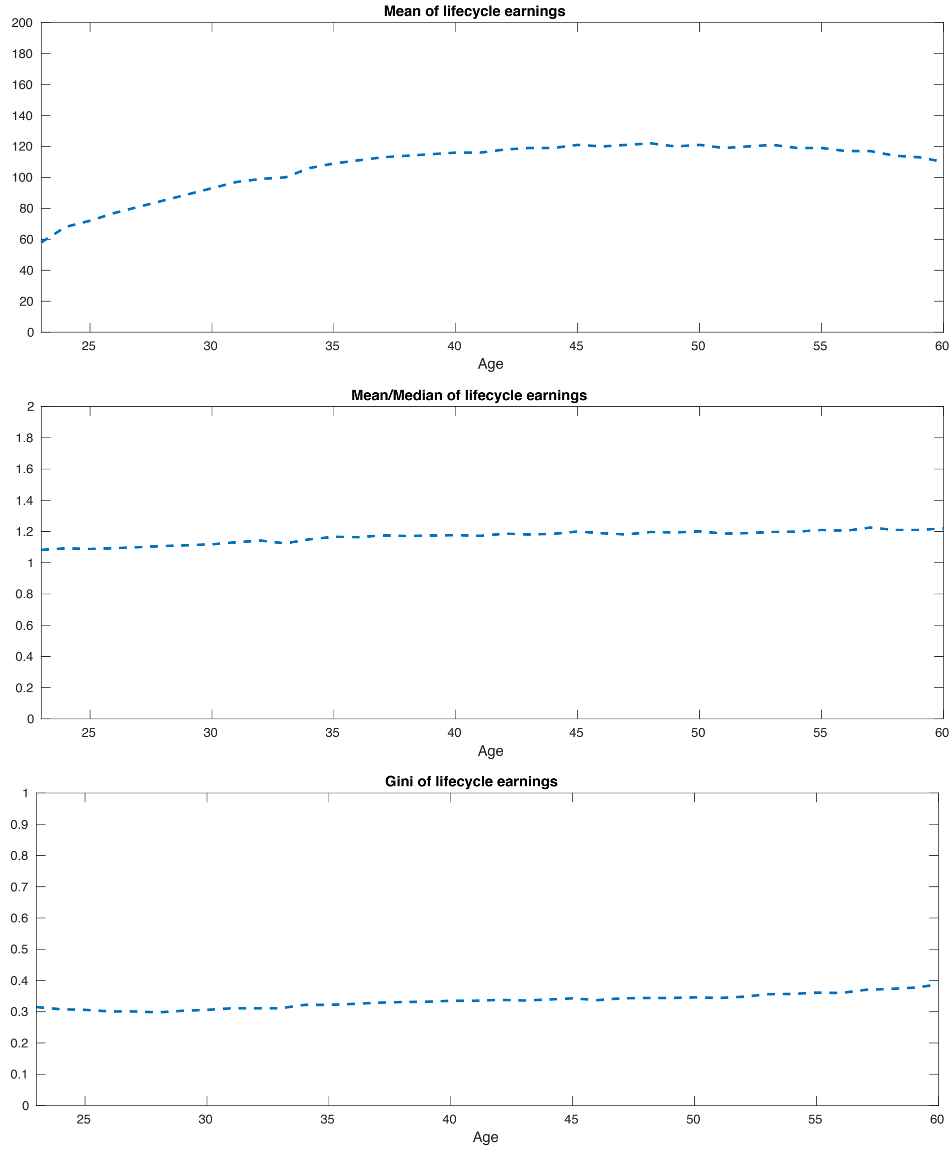
3.1 Life cycle earnings

As described in more detail in the next section, we calibrate our model to match the evolution of mean earnings, earnings dispersion, and earnings skewness over the life cycle. To this end, we first estimate life cycle profiles, for ages 23 to 60 (i.e. the "working life"), of mean earnings, the earnings Gini coefficient, and the mean/median earnings ratio using data from the March CPS, obtained through IPUMS at the University of Minnesota. We use data on annual wage and salary income for male heads of household with at least a high-school diploma (or equivalent) for calendar years 1963-2013 (corresponding to survey years 1964-2014). We restrict our sample to individuals who worked at least 12 weeks in the reference year and earned at least $1,000 (in constant 2014 prices). We use the CPS weights to ensure that each year's sample is representative of the overall U.S. population; additionally, we renormalize the weights in each year in order to keep the population constant at its 2014 value; this way we abstract from issues related to population growth.

We use these data to construct life cycle profiles for mean earnings, the earnings Gini coefficient, and the mean/median earnings ratio. Specifically, for each of these statistics, $s_{t,y}$, we compute $s_{t,y}$ in the data for each combination of age t and calendar year y, and regress $s_{t,y}$ against a full set of year and age indicators.[10] We then take the regression coefficients on the age indicators (we use calendar year 2013 as our base year), and normalize them so that at age 40 the coefficients profile goes through the unconditional average value of $s_{40,y}$ across all years y in our sample. The corresponding normalized age coefficients constitute the life cycle profiles that we use in the calibration. Figure 1 shows the life cycle profiles of mean earnings, the earnings Gini, and the mean/median earnings ratio obtained in this fashion.

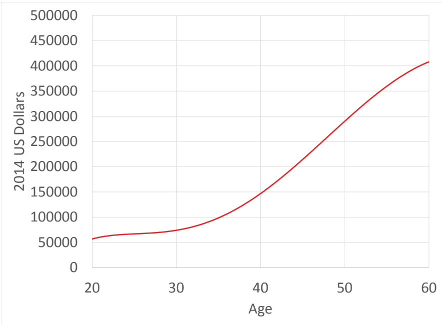
[10] By using a full set of year indicators, this treatment controls for year effects in the construction of the age profiles. We have also computed age profiles controlling for cohort effects, rather than year effects. The behavior of the life cycle profiles is qualitatively similar.

Figure 1: Life-cycle earnings statistics

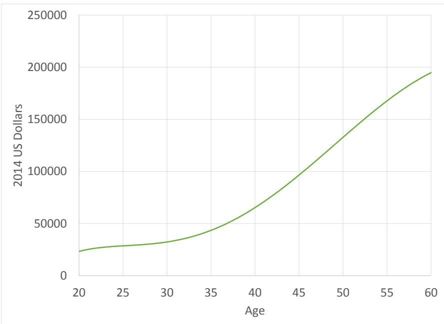


3.2 Life cycle financial assets

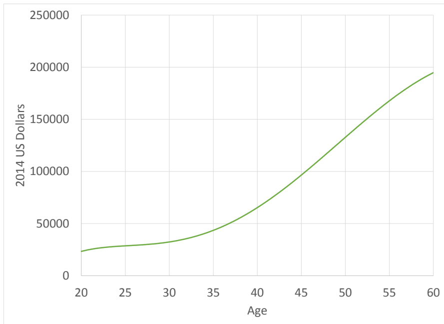
Figure 2: Average Life-Cycle Assets (SCF)



(a) Total



(b) Risky



(c) Risk-free

We use data from the SCF to measure wealth and its composition. Our measure of wealth includes all financial assets. To be consistent with assumptions that we make later, we assume that wealth is comprised of one risky and one risk-free asset. Our measure of risky assets corresponds to a broad measure of households' equity holdings in the SCF, which includes directly held stocks as well as stocks held in mutual funds, IRAs/Keoghs, thrift-type retirement accounts, and other managed assets.

As in the case of earnings, we construct life cycle profiles of asset holdings, controlling for time effects using 2013 as the base year. The results (in 2014 dollars) are reported in Figure 2[11].

[11] Averages for risky and risk-free assets are taken conditional on ownership

3.3 College enrollment and completion

We use data from the Beginning Postsecondary Student Longitudinal Survey (BPS) 2004/2009 and the National Education Longitudinal Study (NELS:1988) to match enrollment and completion rates. Specifically, we estimate correlations of ability and initial wealth, and of initial human capital and initial wealth, to match college enrollment rates for three groups of initial wealth (expected family contributions) based on NELS:1988 data, and to match college completion rates based on the BPS 2004/2009 data set for students who enrolled in college in the year 2003-2004.

The BPS 04/09 is one of several National Center for Education Statistics (NCES)-sponsored studies that is a nationally representative dataset with a focus on post-secondary education indicators. BPS cohorts include beginners in post-secondary schools who are surveyed at three points in time: in their first year in the National Postsecondary Student Aid Study (NPSAS), and then three and six years after first starting their post-secondary education in follow-up surveys. BPS collects data on a variety of topics, including student demographics, school experiences, persistence, borrowing/repayment of student loans, and degree attainment six years after enrollment. Our sample consists of students aged 20-30 who enroll in a four-year college following high school graduation. For demographic characteristics, we use SAT (and converted ACT) scores (see Appendix A) and expected family contribution (EFC) as a proxy for wealth.

The National Education Longitudinal Study (NELS:1988) is a nationally representative sample of eighth-graders who were first surveyed in the spring of 1988. A sample of these respondents were then resurveyed through four follow-up surveys in 1990, 1992, 1994, and 2000. We use the third follow-up survey when most respondents completed high school and report their post-secondary access and choice. As in the BPS, demographic information, including SAT scores and EFC, are available. We use this data set to compute college enrollment rates by EFC. Our sample consists of recent high school graduates aged 20-30 who have taken the SAT (or ACT).

4 Mapping the model to the data

Table 1: Parameter Values: Benchmark Model

Parameter	Name	Value
T	Model periods (years)	58
J	Working periods (after college)	34
β	Discount factor	0.96
σ	Coeff. of risk aversion	5
R_f	Risk-free rate	1.02
R_b	Borrowing rate	1.11
$\underline{\text{b}}$	Borrowing limit	\$17,000
μ	Mean equity premium	0.06
σ_η	Stdev. of innovations to stock returns	0.157
α, α_{col}	Human capital production function elasticity	0.7
g_{NC}, g_{CG}	Growth rate of rental rate of human capital	$0.0013, 0.0065$
δ_{NC}, δ_{CG}	Human capital depreciation rate	$0.01, 0.0217$
ψ_{NC}, ψ_{CG}	Fraction of income in retirement	$0.682, 0.93$
$\underline{\tau}$	Minimal income level	\$17,936
$(\rho_{NC}, \sigma^2_{\nu NC}, \sigma^2_{\epsilon NC})$	Earnings shocks no college	$(0.951, 0.055, 0.017)$
$(\rho_{CG}, \sigma^2_{\nu CG}, \sigma^2_{\epsilon CG})$	Earnings shocks college	$(0.945, 0.052, 0.02)$
$(\mu_a, \sigma_a, \mu_h, \sigma_h, \varrho_{ah})$	Parameters for joint distribution of ability and initial human capital	$(0.44, 0.75, 77, 33, 0.71)$
$\bar{d}$	Total cost of (four-year) college	\$53,454
d_{max}	Limit on student loans (for four years of college)	\$23,000
w_{col}	Wage during college	\$17,700

The parameters in our model include: 1) standard parameters such as the discount factor and the coefficient of risk aversion; 2) parameters specific to human capital and to the earnings process; 3) parameters governing the distribution of initial characteristics; 4) parameters specific to college investment and financing; and 5) parameters specific to asset markets. Our approach involves a combination of setting some parameters to values that are standard in the literature, calibrating some parameters directly to data, and jointly estimating the parameters that we do not observe in the data by matching moments using several observable implications of the model. These are listed in Table 1. The interested reader is directed to Appendix 7 for details on the calibration.

4.1 Model vs. Data

We start by presenting the model predictions for targeted data moments for the baseline economy and then by describing model predictions for key non-targeted data moments.

4.1.1 Targeted Moments

This section presents measures of goodness of fit for the baseline model. Figure 3 shows the earnings moments for a simulated sample of individuals in the model versus the CPS data.[12] As the figure shows, the model does a reasonably good job of fitting the evolution of mean earnings over the life cycle, though the model's profile is a bit less hump-shaped than in the data. The skewness of earnings is a touch lower in the model than in the data. And, for the Gini coefficient, the model matches the data quite well, except perhaps in the last few years of the life cycle.

We next look at the model's predictions for college investment behavior by initial wealth. Table 2 shows college enrollment and completion rates by level of initial financial wealth; where"low" refers to the bottom quartile, "medium" to the two middle quartiles, and "high" to the top quartile of the distribution of initial wealth. As can be seen, both enrollment and completion rates are strongly related to the level of initial wealth, both in the model and in the data.

Table 2: Targeted Moments Data vs Model: Enrollment and Completion

Initial wealth	Benchmark	Data (BPS)
College Enrollment		
Low	25	34
Medium	44	47
High	48	62
College Completion		
Low	49	37
Medium	53	45
High	68	60

4.1.2 Non-Targeted Moments

We now test the model predictions for key non-targeted data moments. First we examine college enrollment and completion behavior by individual chracteristics. Tables 3 and 4 show that both college enrollment and completion rates are increasing in ability and in initial human capital. While there is no direct data counterpart for these predictions, they are consistent with college investment behavior by broad measures of student ability, such as SAT scores and college preparedness.

[12]As a measure of goodness of fit, we use $\frac{1}{3J}\sum_{j=5}^{J}|log(m_j/m_j(\gamma))| + |log(d_j/d_j(\gamma))| + |log(s_j/s_j(\gamma))|$. This represents the average (percentage) deviation, in absolute terms, between the model-implied statistics and the data. We obtain a fit of 8% (where 0% represents a perfect fit).

Figure 3: Life-cycle earnings statistics

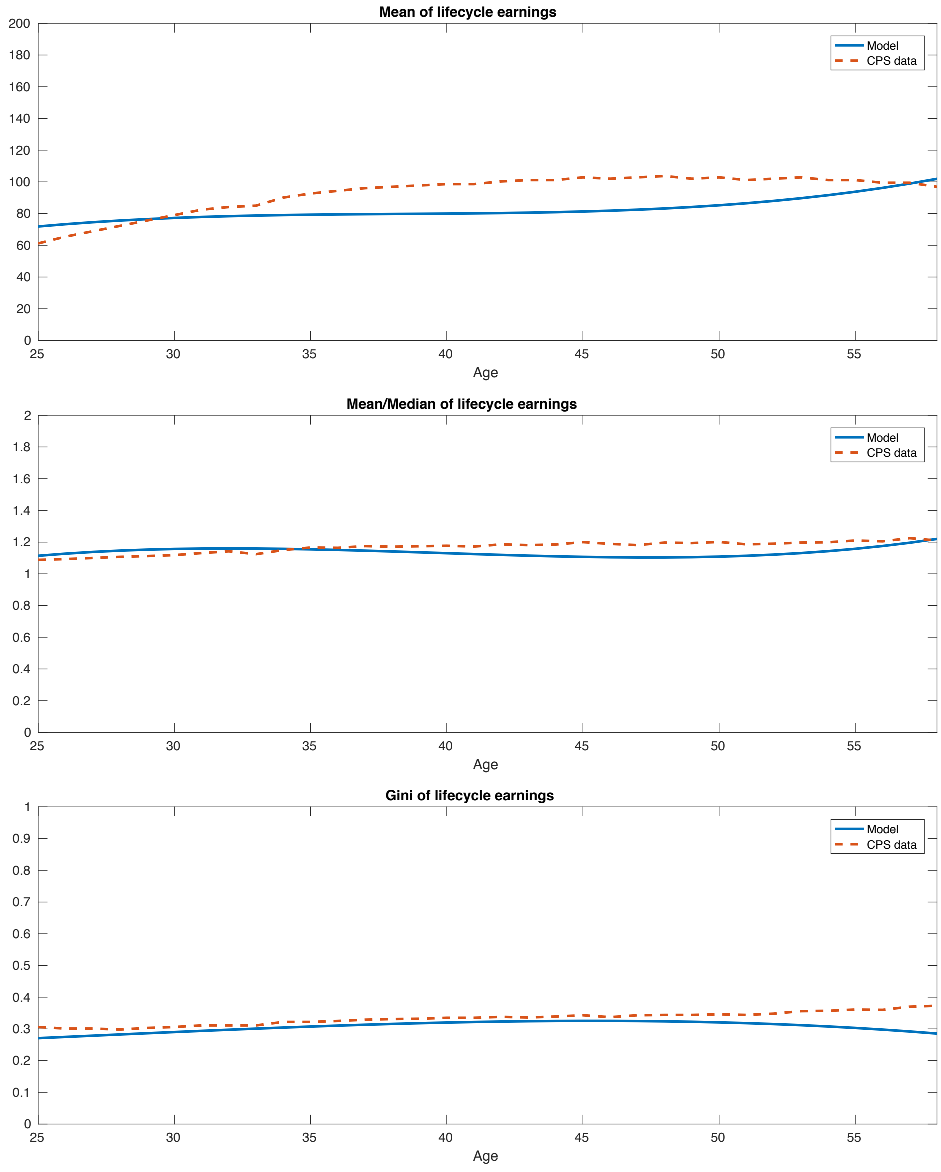


Table 3: Non-Targeted Moments: Enrollment by Characteristics

Characteristic	College Enrollment
Ability	
Low	10
Medium	41
High	73
Human Capital	
Low	22
Medium	44
High	45

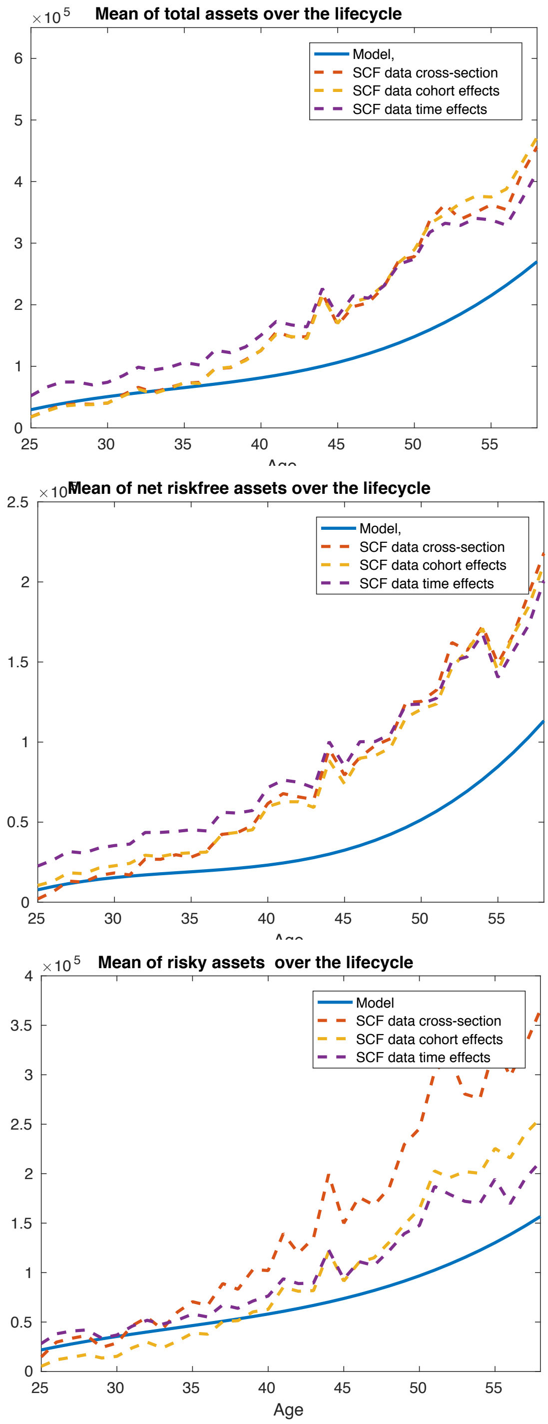
Table 4: Non-Targeted Moments: Completion by Characteristics

Characteristic	College Completion
Ability	
Low	40
Medium	49
High	66
Human Capital	
Low	45
Medium	55
High	68

Second, we look at the model predictions for financial investment behavior. Figure 4 shows the mean wealth accumulation over the life cycle for total assets as well as for risky and risk-free assets.

Overall, the model is quite consistent with the observed financial investment behavior. In particular, despite not being targeted, our model produces empirically consistent estimates of life cycle wealth and its allocation between risky and risk-free assets. In addition, our model's prediction for the stock-market participation rate is consistent with the data, over the *entire* life cycle. This result is driven primarily by the presence of human capital. Human capital is an attractive investment early in life, especially for those with a combination of high learning ability and relatively low initial human capital: the opportunity cost of spending time learning—forgoing earnings—is relatively low, the marginal return to learning is high, and the horizon over which to recoup any payoff from learning is long. Further, anticipating rising earnings over the life cycle, households who invest in human capital early in life will desire, absent risk, to avoid large positive net positions in financial assets when young. As they age and accumulate human capital, these households will find further investment in human capital less attractive as the marginal return

Figure 4: Life-Cycle Wealth Accumulation



decreases and opportunity cost increases. These high earners will then accumulate wealth and participate in the stock market at high rates. This mechanism delivers a profile of aggregate stock market participation that is consistent with data, as illustrated in detail in Athreya et al. (2015).

The same logic carries through for the model predictions by education groups. Figures 5 and 6 show earnings and stock market participation over the life cycle for college graduates and high school graduates. College graduates have higher–and steeper–earnings profiles over the life cycle compared to high school graduates. These higher and steeper profiles reflect college graduates' higher average levels of ability and human capital, which in turn result in higher–and steeper–participation rates in the stock market.

Figure 5: Life-cycle Earnings by Education Groups

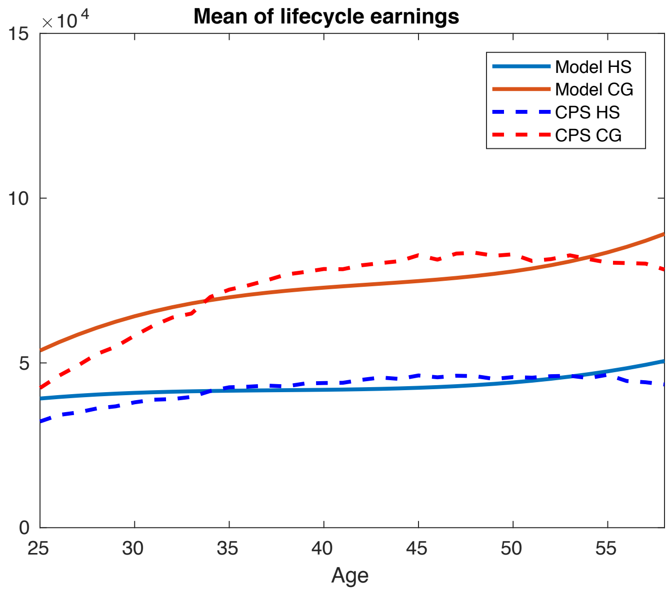
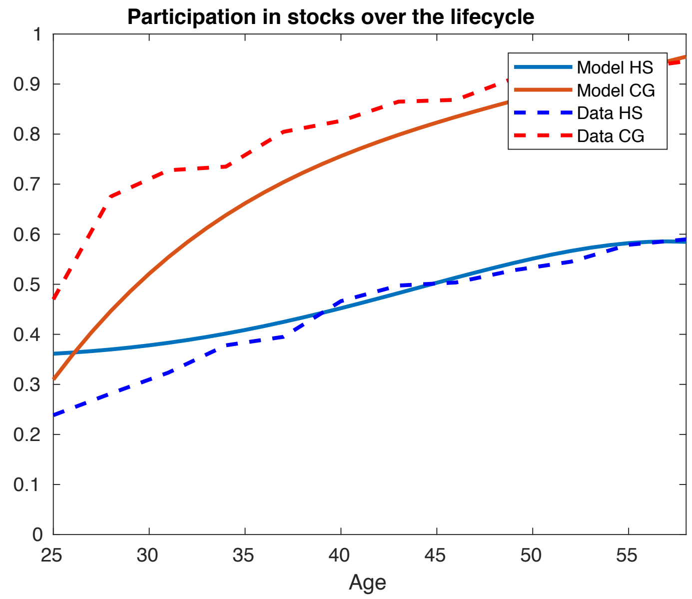


Figure 6: Stock Market Participation over the Life Cycle by Education Groups



5 Results

The goal of this paper is to evaluate, from the perspective of individuals, the implications of access to two high-return but risky investments—college and the stock market—for economic well-being. To achieve this goal, we derive outcomes prevailing in four different environments: (i) our baseline economy in which individuals have access to both college and stocks, (ii) an economy with stocks but no college; (iii) an economy with college but no stocks[13] and (iv) economy with neither college nor stocks.

We use the counterfactual economies described above to evaluate the effects of access to college and stocks on two types of measures of well-being: (1) absolute measures, such as earnings and wealth, and (2) relative measures, such as mobility and inequality. We define the first as the average gain in lifetime earnings and wealth arising from access to a college education and the stock market, respectively. We define mobility as the probability that an individual moves from the bottom to the top quartile of earnings over the course of the working life in each setting. Finally, we measure overall inequality, as well as the contribution of initial conditions (ability, initial human capital, and initial wealth) to inequality in each of the settings we study. In general, the larger the contribution of initial conditions to lifetime inequality, the lower the economic mobility that

[13]These results are to be added.

we would expect to see in a given environment.[14]

5.1 Lifetime Earnings and Wealth

Our baseline model is meant to capture empirically salient investment opportunities and therefore allows for both college and stock-market investment in addition to Ben-Porath-style human capital accumulation. The empirically-disciplined joint distribution of ability, human capital stock, and wealth that we derive from this setting is therefore the appropriate starting point for counterfactual experiments. With this distribution in place, we compare the mean of lifetime earnings and wealth in the baseline economy to the means of these measures arising under each of the alternative investment opportunity sets. Table 5 below presents the results across the three main environments.

Table 5: Investment Opportunities and Mean Lifetime Earnings, Wealth, and Utility (Relative to Benchmark)

Mean of Lifetime	Benchmark	No College/Stocks	No College/No Stocks
Earnings	1	0.942	0.939
Wealth	1	0.86	0.855

The removal of access to college matters substantially, as it generates a 6% mean reduction in lifetime earnings and a 14% mean reduction in lifetime wealth across agent types. On top of this, removing access to stocks leads to a further small decrease in lifetime earnings and wealth. First, the fact that college investment matters more than stock investments for lifetime earnings is not surprising. College, by construction, encourages the accumulation of a large amount of human capital in a short period of time. By contrast, in the economy without college, it is far more costly to rapidly accumulate human capital when young. College, through its effect on human capital accumulation, thus has a first-order effect on earnings. By contrast, stocks operate on earnings only through the secondary effect they have on time allocated to human capital accumulation. Second, the larger reduction in wealth is due to a mechanism that has been identified in a body of earlier work, most notably Hubbard et al. (1994), that generates high implicit taxes on wealth. Specifically, our paper, as most literature on life-cycle consumption and savings, incorporates means-tested transfers that provide an consumption floor. In the economy without college, the shift in the distribution of earnings to the left noted above, leads a larger proportion of agents than in the benchmark to face the high implicit taxes on wealth created by the consumption floor.

The mean effect of the changes above may vary substantially across agent types. In some cases they may be quite large. To see this, we now turn to the implications for mean earnings for various

[14] This connects our work to Huggett et al. (2011).

agent types. For convenience, the results, presented in Table 6, are averaged across all individuals within, respectively, the bottom quartile ("low"), the two middle quartiles ("middle"), and the top quartile ("high") of ability, initial human capital stock, and initial wealth.

Table 6: Investment Opportunities and Mean Lifetime Earnings: What Role for Heterogeneity?

	Benchmark	No College	No College, No Stocks
Ability			
Low	1	1	0.99
Middle	1	0.93	0.92
High	1	0.91	0.93
Initial human capital			
Low	1	0.75	0.76
Middle	1	0.93	0.93
High	1	1	1
Initial wealth			
Low	1	0.77	0.78
Middle	1	0.93	0.93
High	1	1	1

To describe the implications of different environments for specific agent types, we normalize earnings for each agent type in the baseline. Looking first across the distribution of ability, we see that for low ability types, access to college is simply irrelevant: mean earnings are unchanged. By contrast, among those with the highest ability, we see that college offers a substantial gain in earnings (roughly 10%). As expected, college is most valuable for individuals with high ability levels, for whom the returns to college investment are quite large. The effect of access to the stock market on earnings is, of course, indirect and operates through the following channel: the high returns to stock enable households to allocate more time to human capital accumulation without sacrificing consumption. We see, though, that this indirect effect is negligible.

Turning next to the variation across environments experienced by those with different levels of initial human capital, we see that those with low initial human capital experience, at the individual level, an average loss of 25% in mean earnings in the absence of access to college. This is evidence that the intensive, compressed way of acquiring human capital early in life through college is of great value to those with low initial human capital but not as much to individuals with high initial human capital. For the latter, the marginal return to investing in human capital is low and the opportunity cost of making additional human capital investment is high. Thus, for those with high initial human capital, the opportunity to frontload human capital investment is relatively less valuable.

Finally, when looking across wealth levels, we see that access to college generates the largest boost to earnings for those with low initial wealth. Acquiring human capital involves sacrificing current consumption. The presence of the rapid human capital accumulation facilitated by college at an early age in life makes this sacrifice relatively attractive when compared to a setting in which the same human capital level can be obtained only through a much larger investment of time, including when the opportunity cost of learning is high.

5.2 Mobility

Our analysis above aimed at understanding how different individuals (who vary in their initial conditions) gain in absolute terms from access to the option of a college education and the option to invest savings into high-return equity. We now examine, in each of the settings we study, probabilities of moving across the ranks of the (cross-sectional) earnings and wealth distributions over the course of the life cycle.

The above examination of changes in lifetime earnings and wealth for individuals, by definition, did not require reference to any measures of an economy-wide distribution. Our notion of mobility, however, does, since it requires assigning a location to an individual within a distribution—where the latter is necessarily connected to the *aggregate* of decisions by all in the economy. It should therefore be kept in mind that the measures of mobility we report are those that would emerge from changes in the investment opportunity set, all else equal.

The three panels of Figure 7 show the effect of differential investment opportunities on mobility as measured by the proportions of individuals who migrate, between early working life (age 1) and late working life (age J) between the four quartiles of the earnings distribution. Importantly, because earnings are partly endogenous—they depend on time allocation choices—we define earnings as "potential" earnings: That which would accrue to individuals if they worked full time. This allows for a single notion of earnings for each agent type, defined at the beginning of working life.

We see first that mobility in the benchmark economy is lowest "in the tails": Among those who begin in the bottom quartile of earnings, almost two thirds remain there at the end of working life, and among those at the highest quartile when young, 56% remain there when old. The middle quartiles show substantially more mobility. These patterns are in keeping, qualitatively, with empirical evidence on earnings mobility. Turning next to the implications for individuals of losing access to college, we see that mobility is actually, though only slightly, higher at the extremes in the economy. The intuition for this is that college provides those who succeed with a substantial discrete jump in earnings, and consigns those who either do not enroll, or don't complete to a far lower earnings path. In the economy without college, there is no analogous "threshold" that must be crossed to deliver one into higher earnings. Indeed, we see that downward mobility is very low among the rich in the economy with college. By contrast, when agents do not have access to college, the probability of staying in the top quartile is far lower (though still high in absolute terms at 40%). Lastly, the implications for earnings of access to the stock market are essentially minimal. This is natural, as the effect of stock markets on earnings must operate only indirectly, through the redirection of time allocated to earning and learning. These differences in time allocation are minimal (not shown here).

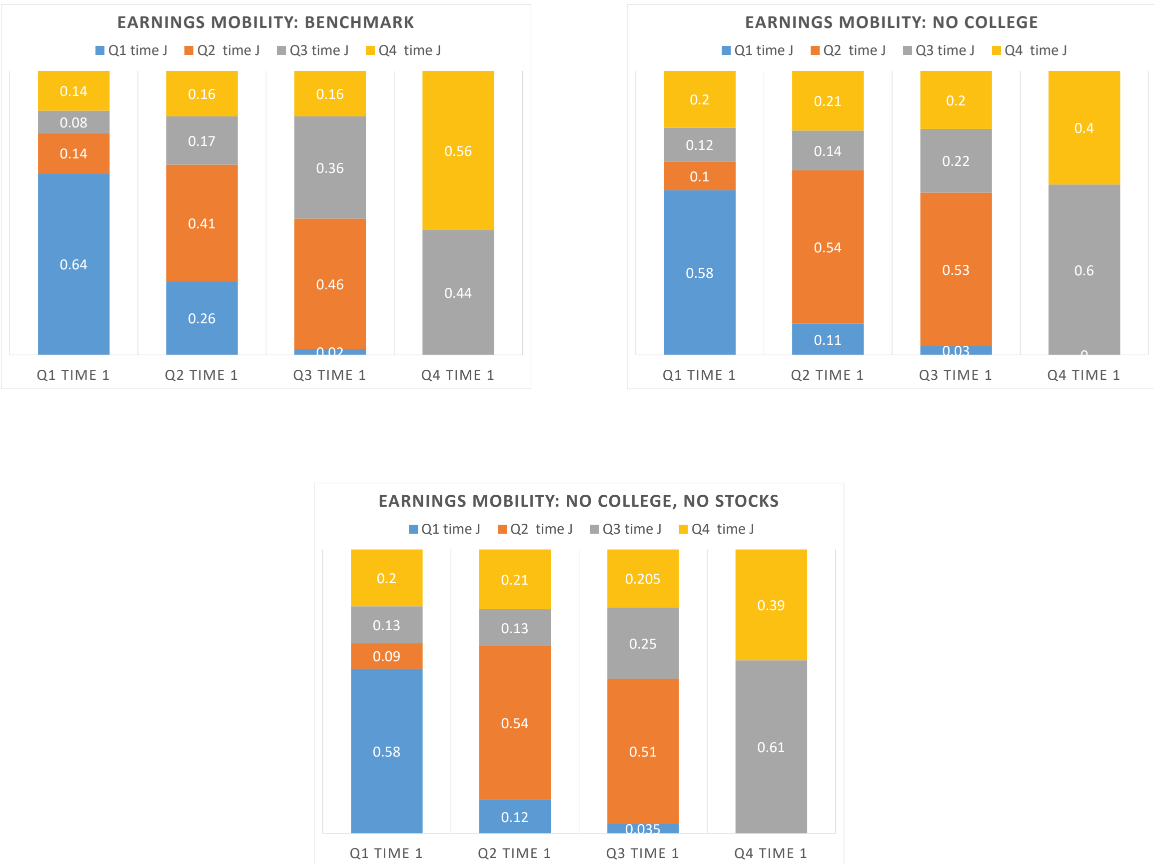


Figure 7: Earnings Mobility Across Environments

The results on mobility that we have presented so far are "unconditional" in the sense that they are silent about "who" experiences what change to mobility across the environs under study. In Table 7, we present results organized by each dimension of initial heterogeneity, averaging over all others. For example, the top row of the table shows—for all agents in the bottom quartile of the ability distribution—the probability of reaching the top quartile of earnings at the end of working life conditional on beginning working life in the bottom quartile of earnings.[15] Beginning with ability, we see that low- and medium-ability households on average have no chance of reaching of the uppermost quartile in any of the economies. However, we see that high ability households have a substantially higher chance of reaching the top quartile when college is available than in either of the other two cases. This illustrates that college makes it even easier for those with high learning ability to escape adverse initial conditions. When comparing the no-college economies with and without stocks, we see that individuals with high learning ability are slightly more likely to reach the top quartile of the earnings distribution in the economy without stocks. In the no college, no stocks economy, the only way for agents to boost income is by boosting earnings, a margin of substitution that is disproportionately easier for those with high ability to exploit. This makes them likelier than other agents in the economy to move up the earnings distribution.

Table 7: Upward Mobility and Heterogeneity

	Baseline	No College	No College, No Stocks
Ability			
Low	0	0	0
Middle	0	0	0
High	0.56	0.46	0.51
Initial Human Capital			
Low	0.14	0.12	0.12
Middle	NaN	NaN	NaN
High	NaN	NaN	NaN
Initial Wealth			
Low	0.14	0.12	0.12
Middle	0.14	0.10	0.11
High	–	–	–

Moving next to the role of initial human capital, we see that those in the lowest quartile of the distribution have only slim chances, in any of the three environs, of reaching the top quartile later in working life. As with the case of ability, the rank ordering of mobility is preserved—the best chance of rising is in the presence of college, and the worst in its absence. The blank entries in the table arise from the fact that initial human capital and earnings are correlated one-for-one (this follows from our definition of potential earnings), leaving no mass of agents with medium- or high-initial capital in the bottom quartile of earnings by definition. Finally, turning to those with low or medium initial wealth, the probability of reaching the top earnings quartile is also highest

[15] "Middle" combines the middle two quartiles and "high" refers to the top quartile of the relevant initial condition.

in the presence of college, though, as was the case for initial human capital, the chances are low in absolute terms.[16]

5.3 Lifetime Inequality and its Resolution

To put our results about economic mobility in context, it is useful to examine inequality and its resolution in all of the environments that we study. Arguably, mobility is of much greater concern in environments where inequality is higher. It is also of interest to examine whether or not mobility enables those with adverse initial conditions to overcome them.

To this end, we now turn to an examination of the implications of the availability of alternative investment opportunities for inequality. We first study aggregate inequality in each economy and then address a longstanding question in the literature: how much of realized inequality in lifetime earnings and lifetime wealth is determined by individuals' initial endowments and how much is determined by events that occur over the course of the life cycle?

We begin by reporting in Table 8 the cross-sectional variance of lifetime earnings and lifetime wealth in each of our economies (normalized to the level in the baseline). Overall, the table shows that the variance is highest in the environment where neither college nor stocks are available and lowest in the environment with stocks but no college. Specifically, the variance of lifetime earnings is about 4 percent higher, and that of lifetime wealth 3 percent higher, in the baseline model (with both college and stocks) than in the model with stocks but no college. Furthermore, the dispersion is higher in the model with neither college nor stocks than in the model with no college but with stocks: the variance is 7 percent higher for lifetime earnings and 6 percent higher for lifetime wealth.

Table 8: Variance of Lifetime Earnings and Wealth (Relative to Benchmark)

Mean of Lifetime	Baseline	No College/Stocks	No College/No Stocks
Earnings	1	0.96	1.03
Wealth	1	0.97	1.03

What drives the differences in the level of lifetime earnings and wealth inequality across these environments? The presence of college generates two forces that work in opposite directions. On the one hand, college gives those with low initial human capital, but with potentially high returns to human capital investment, another avenue by which to increase their human capital and therefore their lifetime earnings and wealth. On the other hand, high-ability individuals stand to gain the

[16]Note that there are hardly any agents in the top quartile of the wealth distribution who are in the bottom quartile of the earnings distribution, so we do not report the numbers for this case.

most from the opportunity to invest in a college education. Since ability and initial human capital are correlated, college can end up most benefiting those who were already initially advantaged. As it turns out, the second channel dominates–the dispersion of lifetime earnings and wealth is higher in the baseline than in the model with stocks but no college.

The presence of stocks also generates two opposing forces. On the one hand, stocks offer an additional investment opportunity to all individuals, including those at the bottom of the earnings distribution (for whom, almost by definition, the investment in the Ben-Porath human capital technology has relatively low returns). On the other hand, individuals with higher earnings and wealth are more likely to participate in the stock market, making it possible for the rich to get richer. As it turns out, in the case of stocks it is the first channel that dominates. As a result, the dispersion of lifetime earnings and wealth is highest in the economy without stocks.

We next decompose the variance of lifetime earnings and wealth into the part that is determined by agents' initial endowments and the part that is determined by events that occur over the course of the life cycle. To do so, we use to a decomposition that follows Huggett et al. (2011) and Storesletten et al. (2005). We first simulate the model for a large number of individuals. For each simulated individual, we compute the present value of lifetime earnings and lifetime wealth (calculated as lifetime earnings plus the value of initial wealth), which we denote by $\Psi(a, h_0, x_0, z)$. We then compute, as before, the cross-sectional variance across the simulated individuals of lifetime earnings and lifetime wealth, and use the decomposition, as in Storesletten et al. (2005), $Var(\Psi) = Var(E[\Psi|a, h_0, x_0]) + E(Var[\Psi|a, h_0, x_0])$, where the contribution of the initial conditions is the ratio $Var(E[\Psi|a, h_0, x_0])/Var(\Psi)$.

The results of this calculation are reported in Table 9. In the baseline model, initial conditions account for about 70% of the cross-sectional variance in lifetime earnings, and about 76% of the cross-sectional variance in lifetime wealth. When college is not available as an investment (but stocks are), initial conditions matter relatively more, accounting for 76% of the variance in lifetime earnings and 84.6% of the variance in lifetime wealth. The numbers are even higher when neither investment is available (that is, when human capital is accumulated only via the Ben-Porath technology and savings can only be invested in the risk-free asset).

Our estimates of the relative importance of initial conditions fall in the middle of the range reported in the literature (a bit larger than those found by Huggett et al. (2011) or Storesletten et al. (2005), and below those found by Keane and Wolpin (1997)). One important reason for the relatively large role of initial conditions in our model is that we obtain a very unequal initial distribution of both initial human capital and ability (e.g. the ability distribution we find is more unequal than that found by Huggett et al. (2011)).[17]

Table 9: Sources of lifetime inequality

Fraction due to initial conditions	Baseline	No College/Stocks	No College/No Stocks
of variance in lifetime earnings	70	76.0	78.2
of variance in lifetime wealth	76	84.6	86.5

This exercise again highlights the two forces that are at play when college is available as an investment option. As mentioned above, college allows people to catch up by greatly enhancing their human capital in one step, so initial conditions may matter less. However, the high risk of investing in college may discourage some people, particularly those with low learning ability or wealth, from making this investment. This would increase the importance of initial conditions. We find that the first of these two forces is more relevant so, on net, the contribution of initial conditions is lower in the baseline economy than in the environments without college.

We next decompose the contribution of initial conditions to lifetime inequality into the relative contributions of ability, initial human capital, and initial wealth. To do this, we first simulate our model economy without shocks and compute the cross-sectional variance of lifetime earnings and wealth. Next, we repeat the simulation, but each time setting one of ability, initial human capital, and initial wealth to their median value, and each time recomputing the cross-sectional variance of lifetime earnings and wealth. For each of the latter simulations, we report the variance of lifetime earnings and wealth as a fraction of the variance in the former simulation. The results are reported in Table 10.

Table 10: Sources of lifetime inequality: initial conditions

Variance in lifetime earnings			
Fraction due to	Baseline	No College/Stocks	No College/No Stocks
h_0	0.37	0.55	0.47
a	0.62	0.39	0.53
x_0	0.01	0.07	0.00
Variance in lifetime wealth			
Fraction due to	Baseline	No College/Stocks	No College/No Stocks
h_0	0.24	0.34	0.29
a	0.43	0.24	0.34
x_0	0.34	0.42	0.37

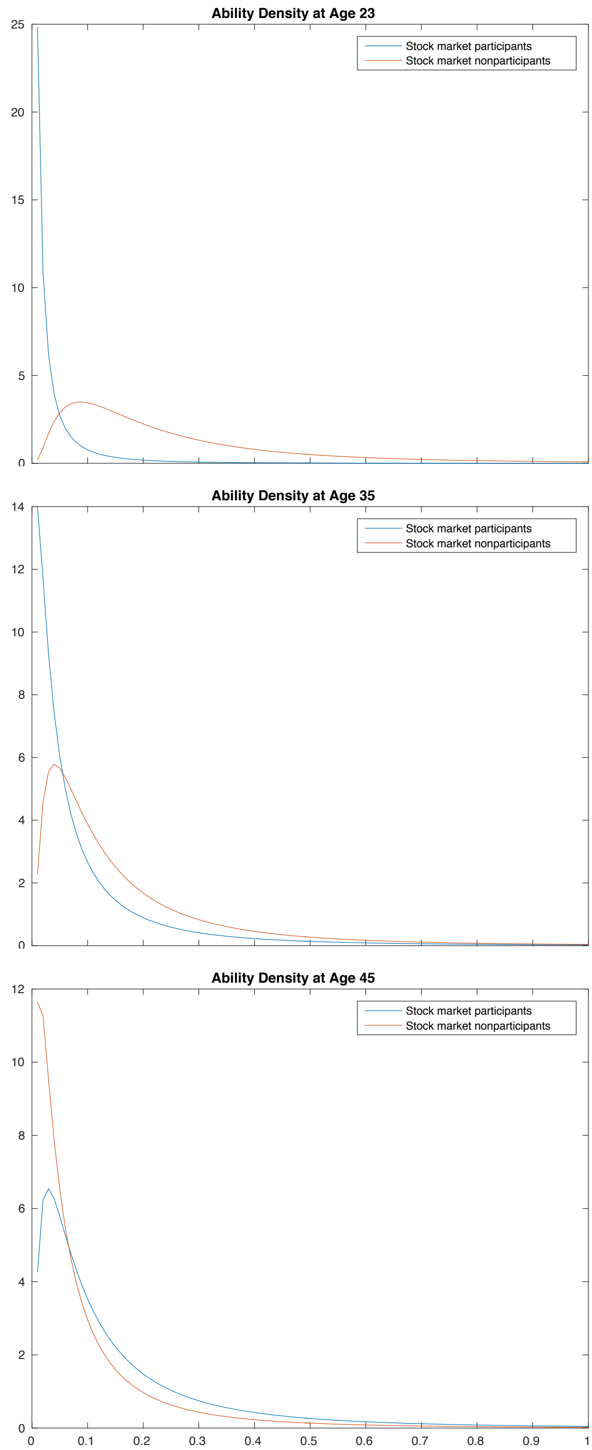
[17] One important difference between their framework and ours is that we explicitly model college. We are exploring other mechanisms that might lead to differences in the dispersion of initial conditions.

First note that in all the environments we consider, both ability and initial human capital are quantitatively important for lifetime earnings inequality. This is because both characteristics shape the incentives to invest in human capital. On the other hand, initial wealth contributes little to lifetime earnings inequality. This is because, unlike ability and initial human capital, initial wealth does not shape the incentives to invest in human capital and consequently does not affect the time allocated to work, which is what generates labor earnings. Initial wealth, on the other hand, does contribute importantly to lifetime wealth inequality since initial asset positions are relevant for wealth accumulation over life.

Comparing across environments, we find that the contribution of initial human capital to lifetime inequality is significantly lower in the baseline model (with college and stocks) than in the model with no college (but with stocks). The contribution of learning ability, however, is higher. This indicates that the disadvantage of being endowed with low human capital early in life can be overcome—at least for those with high learning ability—by investing in college.

In terms of the role played by stocks, comparing the no-college models with and without stocks indicates that the role of initial conditions decreases somewhat in the economy where investment in stocks is allowed. As mentioned earlier, stocks offer an alternative investment opportunity to those agents whose initial endowments make investment in human capital a relatively unattractive option. Indeed, Figure 8 shows that, early in life, those with low learning ability are more likely to participate in the stock market. (Later in life, once high-ability individuals have accumulated sufficient human capital, they are more likely to be participants than low-learning-ability types.)

Figure 8: Ability Distribution of Participants and Non-Participants



6 Conclusion

Our aim is to provide a quantitatively compelling answer to the following questions: what is the effect of access to college and the stock market on earnings, wealth, and mobility for different US households, who are heterogeneous in their learning ability, their initial human capital stock, and their financial wealth? Are the stock market and investment in human capital serving as vehicles to allow individuals to escape adverse initial conditions or mainly perpetuating initial disparities in endowments? We confront these questions with a model economy in which individuals differ ex-ante in their ability to learn, their initial human capital stock, and their initial financial wealth, where the joint distribution of these characteristics is estimated from the data. In the model, agents have access to rich representations of investment opportunities in human capital and financial assets, both of which represent high-yield, but also high-risk, investments. Heterogeneity in household incentives to invest in these opportunities is at the heart of our approach.

Our preliminary results suggest that the benefits from college and the stock market are highly heterogenous. We find that gains from access to college can be large in absolute terms—about 6 percent of lifetime earnings on average—but that variation in these gains is large: for instance, while for low ability types, access to college has little impact on earnings, among those with the highest ability, we see that college offers a substantial gain in earnings (roughly 10 percent). Furthermore, access to college generates the largest boost to earnings (about 25 percent) for individuals with lowest initial human capital levels and wealth. Regarding mobility, heterogeneity is again substantial: for example, for low-ability types, college makes no difference for the probability of moving from the bottom to the top quartile of the earnings distribution over the course of a working life; for high-ability types, college increases the probability of moving from the bottom to the top earnings quartile by 10 percentage points (from 46 to 56 percent).

We contrast the role of access to college to that played by access to stocks, another high-return, high risk investment. Results reveal that access to the stock market results in minimal gains to earnings and wealth. Interestingly, however, the opportunity to invest in college, on net, increases lifetime inequality while, perhaps surprisingly, the stock market serves to lower it. Both college and the stock market reduce the contribution of initial conditions to lifetime inequality. College, however, raises the importance of learning ability relative to other initial conditions. Overall, we find that both initial human capital and ability are quantitatively important for lifetime inequality. Initial wealth matters for lifetime wealth inequality, but not for earnings inequality.

To conclude, does the power of college to increase well-being exceed that of stocks, as large subsidies to the former suggest? Perhaps not: we have shown that college does improve economic outcomes, but only for those whose ability and preparedness poise them for success. We plan, therefore, to assess whether certain individuals would prefer receiving a stock index fund to the current per-capita college subsidy.

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7 Calibration

7.1 Preference Parameters

The per period utility function is CRRA as described in the model section. We set the coefficient of risk aversion, σ, to 5, which is consistent with values chosen in the financial literature. We conduct robustness checks on this parameter by looking at alternative values such as the upper bound of $\sigma = 10$ considered reasonable by Mehra and Prescott (1985) as well as lower values such as $\sigma = 3$. The discount factor used ($\beta = 0.96$) is also standard in the literature. We set retirement income to be a constant fraction of labor income earned in the last year in the labor market. Following Cocco (2005) we set this fraction to 0.682 both for high school graduates and for those with some college education and to 0.93 for college graduates.

7.2 Human capital

We set the elasticity parameter in the human capital production function, α, to 0.7. Estimates of this parameter are surveyed by Browning et al. (1999) and range from 0.5 to 0.9.[18] The human capital depreciation rate is set so that the model produces the rate of decrease of average real earnings at the end of the working life. The model implies that at the end of the life cycle

[18] Later, we will allow agents have access to an improved technology for human capital accumulation while in college, embedded in a higher human capital production function elasticity, $\alpha_{col} = 0.9$.

negligible time is allocated to producing new human capital and, thus, the gross earnings growth rate approximately equals $(1-\delta)$. We obtain $\delta = 0.0114$ for the full sample.

7.2.1 Earnings shocks

To parameterize the stochastic component of earnings, z_{it}, we follow Abbott et al. (2013) who use the National Longitudinal Survey of Youth (NLSY) data using CPS-type wage measures to estimate parameters for the idiosyncratic persistent and transitory wage shocks. For the persistent shock, $u_{it} = \rho u_{i,t-1} + \nu_{it}$, with $\nu_{it} \sim N(0, \sigma_\nu^2)$ and the transitory shock, $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$, they report the following values: For high school graduates, $\rho = 0.951$, $\sigma_\omega^2 = 0.055$, and $\sigma_\nu^2 = 0.017$; for college graduates, $\rho = 0.945$, $\sigma_\omega^2 = 0.052$, and $\sigma_\nu^2 = 0.02$. We use the first set of values for individuals with no college as well as some college education, and the second set of values for those who complete four years of college.

7.3 Distribution of Initial Characteristics: Assets, Ability and Human Capital

The distribution of initial characteristics (ability, human capital, and assets) is determined by seven parameters. These parameters are estimated to match: the evolution of three moments of the earnings distribution over the life cycle (mean earnings, the Gini coefficient of earnings, and the ratio of mean to median earnings); college enrollment rates across three groups of wealth (proxied by expected family contributions); and college completion rates. The estimation proceeds as follows. First, for the distribution of assets, we use data from the Survey of Consumer Finances (SCF) to compute the mean and standard deviation of initial assets to be \$22,568 and \$24,256, respectively (in 2013 dollars). Second, we calibrate the joint distribution of ability and initial human capital to match the key properties of the earnings distribution over the life cycle reported earlier using March CPS data. Third, we estimate the correlations of ability and initial wealth, and of initial human capital and initial wealth, to match college enrollment rates based on NELS:1988 data, and college completion rates based on BPS 2004/2009 data.

The dynamics of the earnings distribution implied by the model are determined in several steps: i) we compute the optimal decision rules for human capital using the parameters described above for an initial grid of the state variable; ii) we simultaneously compute college and financial investment decisions and compute the life cycle earnings for any initial pair of ability and human capital; and iii) we choose the joint initial distribution of ability and human capital to best replicate the properties of the CPS data.

We search over the vector of parameters that characterize the initial state distribution to minimize a distance criterion between the model and the data. We restrict the initial distribution to lie on a two-dimensional grid spelling out human capital and learning ability, and we assume that the underlying distribution is jointly log-normal. This class of distributions is characterized by five parameters.[19] We find the vector of parameters $\gamma = (\mu_a, \sigma_a, \mu_h, \sigma_h, \varrho_{ah})$ that characterizes the initial distribution by solving the minimization problem

$$\min_{\gamma} \left(\sum_{j=5}^{J} |log(m_j/m_j(\gamma))|^2 + |log(d_j/d_j(\gamma))|^2 + |log(s_j/s_j(\gamma))|^2 \right)$$

where $m_j, d_j,$ and s_j are the mean, dispersion, and skewness statistics constructed from the CPS data on earnings, and $m_j(\gamma)$, $d_j(\gamma)$, and $s_j(\gamma)$ are the corresponding model statistics.[20]

We then choose the correlations of ability and initial wealth, and of initial human capital and initial wealth, that best replicate college enrollment rates (by wealth level) and college completion rates (see further details in the next subsection).

7.4 College Parameters

We set the total cost per year of college to $\bar{d} = \frac{\$53,454}{4}$. The limit and interest rate on student loans are $d_{max} = \$23,000$ and $R_g = 1.07$, respectively. We set the wage during college, $w_{col} = \$17,700$ (based on NCES data).

Lastly, the probability of college completion, $\pi(h_5)$, is set based on mapping observed completion rates by cumulative GPA scores in the BPS data to h_5 in the model.[21] In the data, we observe the fraction of the student population that obtained each of the sets of grades listed in the Table below. In the model, we divide the distribution of h_5 into groups according to these percentages, and assign each group the completion probability listed in the first column of the table. For example, an agent in the group with the highest level of h_5 will face a 70% probability of completion.

[19] In practice, the grid is defined by 20 points in human capital and in ability.

[20] For details on the calibration algorithm see Huggett et al. (2006) and Ionescu (2009).

[21] We define the completion rate in the data as the fraction of students who had earned a bachelor's degree by June 2009.

Completion rate	Grades
0.07	grades C and D
0.30	mostly Cs
0.45	mostly Bs and Cs
0.56	mostly Bs
0.67	mostly Bs and As
0.70	mostly As

7.5 Financial Markets

We turn now to the parameters in the model related to financial markets. We fix the mean equity premium to $\mu = 0.06$, as is standard (e.g., Mehra and Prescott, 1985). The standard deviation of innovations to the risky asset is set to its historical value, $\sigma_\eta = 0.157$. The risk-free rate is set equal to $R_f = 1.02$, consistent with values in the literature (McGrattan and Prescott, 2000) while the wedge between the borrowing and risk-free rate is 0.09 to match the average borrowing rate of $R_b = 1.11$ (Board of Governors of the Federal Reserve System, 2014).

We assume a uniform credit limit across households. We obtain the value for this limit from the SCF. The SCF reports, for all individuals who hold one or more credit card, the sum total of their credit limits. We take the average of this over all individuals in our sample and obtain a value of approximately $17,000 in 2013 dollars. Note that, when we take the average, we include those who do not have any credit cards. This ensures that we are not setting the overall limit to be too loose. Lastly, in our baseline model, we assume for the time being that the returns to both risky assets (human capital and financial wealth) are uncorrelated.