The Slowdown in American Educational Attainment

Elisa Keller

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Abstract

Relative to those for high school graduates, lifetime earnings for college graduates are higher for more recent cohorts. At the same time, across successive cohorts born after 1950, there is a stagnation in the fraction of high school graduates that go on to complete a college degree. What explains this phenomenon? I formulate a life-cycle model of human capital accumulation in college and on the job, where successive cohorts decide whether or not to acquire a college degree as well as the quality of their college education. Cohorts differ by the sequence of rental price per unit of human capital they face. My model reproduces the observed pattern in college attainment for the 1920 to 1970 birth cohorts. The stagnation in college attainment is due to the decrease in the growth rate of the rental price per unit of human capital commencing in the 1970s. My model also generates about 80% of the increase in lifetime earnings for college graduates relative to those for high school graduates observed across cohorts.

JEL: I24, J2, J3.
Key words: Education. College attainment. Human capital. Earnings growth.

*Department of Economics, Durham University Business School. Email:elisa.keller.2013@gmail.com. I am indebted to B. Ravikumar and Guillaume Vandenbroucke for their continued guidance and support. Gustavo Ventura provided many beneficial suggestions. I thank Maria Canon, Diego Restuccia, Todd Schoellman, and the participants at the 2011 Midwest Macro Meetings for their helpful comments.


1 Introduction

Throughout American history, almost every generation has acquired substantially more education than its parental generation. This is no longer true. Figure 1 shows the fraction of white males with a high school diploma that went on to complete a four-year college degree (hereafter “college”) for the 1920 to 1970 cohorts, which are grouped by year of birth. The fraction for the 1950 cohort was nearly twice as large as that for the 1920 cohort. However, for cohorts born after 1950, the fraction of high school graduates that completed college remained flat.\(^1\) These trends have been documented by, among others, Altonji, Bharadwaj, and Lange (2008) and Goldin and Katz (2008). In this paper, I ask the following question: What accounts for the trend observed in college attainment of white males and, in particular, the slowdown in college attainment starting with the 1950s cohorts?

I argue that changes in the growth rate of the rental price per unit of human capital (hereafter “price growth”) are crucial for generating the observed pattern of college attainment. I illustrate this point with a simple back-of-the-envelope calculation. Consider the earnings \((E^S_t)\) of full-time workers of education level \(S\) at time \(t\): 
\[
E^S_t = w_t \times h^S_t. 
\]
In this identity, \(h^S_t\) is the quantity of human capital for education level \(S \in \{H, C\}\) (\(H\) stands for high school and \(C\) stands for college) at time \(t\), and \(w_t\) is the price per unit of human capital at time \(t\). Suppose individuals live for two periods and college involves sacrificing current earnings for future human capital, \(h^{C}_{t+1}\). Lifetime earnings of a high school graduate are:
\[
LE^H = w_t \times h^H_t + w_{t+1} \times h^H_{t+1}. 
\]
Lifetime earnings of a college graduate are:
\[
LE^C = w_{t+1} \times h^C_{t+1}. 
\]
Individuals choose the option that yields the highest lifetime earnings. Thus, college is chosen if
\[
LE^C \geq LE^H, \text{ i.e., if } \frac{h^C_{t+1}}{h^H_{t+1}} \geq \frac{w_t \times h^H_t}{w_{t+1} \times h^H_{t+1}} + 1. 
\]
Figure 2 plots college-graduate lifetime earnings relative to high school-graduate lifetime earnings (hereafter “college premium”) for the 1920 to 1970 cohorts and shows that the premium has steadily increased starting with the 1940 cohort.\(^2\) The college premium corresponds to \(\frac{h^C_{t+1}}{h^H_{t+1}}\). Assuming \(\frac{w_t \times h^H_t}{w_{t+1} \times h^H_{t+1}}\) is constant over time,

\(^1\)College attainment also remained flat for cohorts of white males born after 1970, but is not shown in Figure 1 (see Appendix A). Differently from the case of males, college attainment for females rose throughout the century, with only one brief stall during the 1950s cohorts (see Appendix A). This increase, however, was arguably part of a more secular trend in both education and labor force participation influenced by reasons beyond the scope of this paper. Although this paper deals only with the college attainment of white males, general equilibrium price effects induced by the evolving college attainment of other demographic groups and influencing the college decisions of white males are taken into account within the quantitative strategy.

\(^2\)The college premium for a cohort is constructed as the ratio of median earnings for individuals in that cohort that graduated from college relative to those that graduated from high school only. Earnings for cohorts are measured over one year when individuals in the cohort are between ages 33 and 38, depending on data availability. Figure 2 reports the college premium for cohorts grouped in six-year bins. Patterns
the inequality will grow larger, which implies that more people will go to college. This would contradict Figure 1 for those born after 1950. Previous studies find the flat college attainment of those born after 1950 puzzling since the college premium has been increasing (see, among others, Card and Lemieux, 2001, and Castro and Coen-Pirani, 2012). Figure 3 plots the reciprocal of \( \frac{w_t h_t}{w_{t+1} h_{t+1}} \), i.e., gross earnings growth of high school graduates. Earnings growth drops significantly after the 1970s, the same time that the 1950s cohorts graduated from high school. I investigate whether the drop in earnings growth reconciles Figure 2 and Figure 1 for those born after 1950.

As from the simple back-of-the-envelope calculation, earnings are the product of prices and quantities, which are both unobservable. To explore the quantitative role of price growth for the pattern of college attainment, I develop a model of human capital accumulation in college and on the job that identifies prices and in turn produces the observed pattern of US college attainment. The model takes the rental price of human capital \( w \) as exogenous, and produces endogenous patterns of earnings growth and the college premium along with the pattern of college attainment.


similar to those in Figure 2 are reported for other measures of the returns to college. Heckman, Lochner, and Todd (2008) report that cohort-based returns to college increased continuously over time for white men entering the labor market between 1960 and 1985.
capital accumulation à la Ben-Porath (1967) and a college choice. Individuals start off with a high school degree and they differ by their innate ability and their initial human capital. Each individual decides whether or not to acquire college education as well as the quality of his college education. Once schooling is completed, individuals join the labor market and can accumulate human capital on the job. Accumulation of human capital in college requires both time and goods (that is, college quality) as inputs, while accumulation on the job requires only time. Cohorts differ by the sequence of the rental price per unit of human capital (hereafter “price sequence”) they face (a time effect) as well as by the distribution of initial human capital across individuals (a cohort effect). A decrease in price growth influences the college decision in two ways. First, it decreases the returns to human capital investment and, therefore, the returns to college. Second, it increases the opportunity cost of human capital accumulation in college relative to that on the job because of the lower relative price of time. These two effects decrease the incentives to go to college more for individuals with low innate ability.

I use earnings from the National Longitudinal Survey of Youth (NLSY) for the cohorts 1961 through 1964 to calibrate the structural parameters of the model. I calibrate the price sequence and the evolution of the distribution of initial human capital to Integrated Public Use Microdata Series (IPUMS-USA) earnings data for the cohorts 1920 through 1970. The shape of the distribution of individuals’ endowments determines the elasticity of college attainment to changes in the price. Since endowments cannot be directly measured, I follow
the strategy in Huggett, Ventura, and Yaron (2006) and include the college premium as an additional source of discipline. I use the NLSY dataset as it has a fixed-panel structure and allows me to infer endowments from life-cycle earnings.

The model produces three main quantitative findings. First, I find that the rate of growth of the rental price per unit of human capital declines commencing in the 1970s. Price growth declines from 1.7 percent per year before the 1970s to 0.1 percent per year after the 1970s. Second, the model reproduces the observed pattern in US college attainment. For the 1920-1950 cohorts, the fraction of high school graduates attaining college increases from 12 percent to 37 percent in the model and from 18 percent to 38 percent in the data. For the 1950-1970 cohorts, the fraction remains constant at the level of the 1950 cohort both in the model and in the data. The slowdown in college attainment is generated almost exclusively by the slowdown in price growth. Successive cohorts born after 1950 face diminished returns to human capital investment on the job and a flat profile of returns to college quality, as the rental price of human capital grows very slowly after 1970. Third, the model generates 79 percent of the increase in the college premium for the 1920-1970 cohorts. The increase is generated by the slowdown in price growth and both a decreased average and increased dispersion of the initial human capital for successive cohorts born after the mid-1930s. Pre-1970s price growth fuels the increase in college attainment for the cohorts 1920 to 1950, which has a significant selection effect on the average innate ability and average human capital associated with college and high school and reinforces the increase in the college premium. The decline in price growth of the 1970s causes selection into college to depend more on an individual’s innate ability over time, which reinforces the increase in the college premium. As the rental price of human capital at high school graduation increases and its growth over the lifecycle decreases, initial human capital becomes less important for the college decision; and the college decision is ruled more by an individual’s innate ability.

The papers that are the closest to mine are Restuccia and Vandenbroucke (forthcoming), Heckman, Lochner, and Taber (1998), and Guvenen and Kuruscu (2010). Restuccia and Vandenbroucke (forthcoming) study the rise of educational attainment and the evolution of relative earnings across education groups. I consider both the rise and the flattening in college attainment. Heckman, Lochner, and Taber (1998) conduct a qualitative analysis of the dynamics of college attainment and earnings inequality resulting from skill-biased technical change. Guvenen and Kuruscu (2010) perform a quantitative study along the lines of Heckman, Lochner, and Taber (1998). Their results are consistent with the evolution
of earnings inequality, the college premium, and the rise in college attainment. My paper replicates the pattern in earnings inequality, the college premium, and both the rise and the flattening of college attainment shown in the data.

The rest of the paper is organized as follows. Section 2 outlines the model and section 3 calibrates it. Section 4 details the results of the quantitative experiment. Section 5 concludes.

2 Model

I extend the Ben-Porath (1967) framework to include an explicit college decision and to let the rental price per unit of human capital change over time. Time is discrete and runs from \( t = 1, 2, \ldots, T \). The economy is populated by individuals who live for 20 periods. Each period corresponds to two years of calendar time. Individuals enter the model as high school graduates at age 19, which is age 1 in the model. I use \( \tau \) to denote a cohort: cohort \( \tau \) is composed of individuals of age 1 at time \( t + 19 \). I use \( j \) to denote age. Within a cohort, individuals are heterogeneous with respect to their innate ability, \( z \in \mathbb{R}^+ \), and their level of initial human capital \( h_1 \in \mathbb{R}^+ \), where the subscript indicates model age. Innate ability represents an agent’s ability to learn and is fixed over his lifecycle.\(^3\) Endowments are distributed according to a cumulative distribution function, \( \Gamma_\tau(z, h_1) \). This function varies across cohorts on the initial human capital dimension. The marginal distribution of innate ability is time-invariant. Individual types are pairs \( b \equiv (z, h_1) \) on the set \( B = \mathbb{R}^2_+ \). I assume that individuals observe their type before any decision is made and that credit markets are complete and there is no uncertainty.\(^4\)

Individuals are endowed with one unit of time that can be spent either on working or on human capital accumulation. They can accumulate human capital in college and on the job. The college enrollment decision is made by cohorts at age 1. Individuals decide whether or not to attend college as well as the quality of their college education. After schooling is

\(^3\)I interpret innate ability to reflect both endowment at birth and the influence of family background up to age 19, as in Carneiro and Heckman (2002).

\(^4\)I assume a frictionless credit market and abstract from borrowing constraint for two reasons primarily: (i) to keep the model as tractable as possible in order to investigate the role of the rental price per unit of human capital on college attainment, and (ii) in consideration of the evidence that, once family background factors are taken into account, borrowing constraints play only a minor role in the college decisions of the 1957-1965 cohorts, which are among those cohorts experiencing a stagnation in college attainment (see Carneiro and Heckman, 2002).
completed, human capital can be accumulated on the job by subtracting productive time to work. Human capital is homogeneous between and within schooling types. There is one price that clears the human capital market, \( w \). The price grows exogenously at rate \( g_t \). I use \( R \) to denote the gross interest rate that is exogenously given. Each cohort differs by the price sequence it faces and by the distribution of initial human capital.

2.1 No-college Path

Individuals who decide not to go to college join the labor market right after high school graduation at age 1. They maximize the present value of earnings over their working lifetime by dividing available time between human capital accumulation, \( i \), and work \((1 - i)\). The problem for an individual of type \((z, h_1) \in \mathcal{B}\), born in cohort \( \tau \), on the no-college path is given by

\[
\max_{\{i_j\}_{j=1}^{20}} \sum_{j=1}^{20} \left(\frac{1}{R}\right)^{j-1} E_j
\]

s.t. \( E_j = w_{\hat{\tau}+2(j-1)}h_j(1 - i_j) \)

\( h_{j+1} = f(z, h_j, i_j \mid H) + \delta h_j \)

\( i \in [0, 1], \ \hat{\tau} = \tau + 19 \)

given \( h_1 \).

An individual’s earnings at age \( j \), \( E_j \), equal the product of the amount of human capital accumulated up to age \( j \), the price of human capital at age \( j \), and the fraction of time allocated to market work at age \( j \). The cost of human capital investment on the job is forgone earnings. Earnings are adjusted downward by the fraction of time spent in human capital investment. The return to human capital investment is higher future earnings. New human capital is produced by combining the existing stock of human capital with time and innate ability. Following Ben-Porath (1967),

\[
f(z, h, i \mid H) = z(h)^{\beta u}.
\]

\( ^5 \)The model is in partial equilibrium, as I study the college decision given the exogenous rental price per unit of human capital. My approach can be viewed as the reverse of Krusell, Ohanian, Ros-Rull, and Violante (2000)’s approach, who study the evolution of skill prices given exogenous college decisions.
The subscript $H$ denotes the no-college path. The elasticity of human capital investment on the job, $\beta_H \in (0, 1)$, determines the degree of diminishing marginal returns of human capital investment. The productivity of human capital investment depends on an individual’s innate ability. This specification is widely used in both the empirical literature and the human capital literature (see, for example, Mincer, 1997 and Kuruscu, 2006). Finally, notice that nothing is lost when studying human capital accumulation decisions by abstracting from consumption and saving decisions. In particular, the focus on lifetime earnings maximization does not require the assumption of risk neutrality: any concave utility function implies the same human capital investment behavior.

I formulate the problem in the language of dynamic programming. The value function, $V_j(h; z, w \mid H)$, gives the maximum present value of earnings at age $j$ from state $h$ for an individual of innate ability $z$ who faces the life-cycle price sequence $w$. In its recursive formulation,

$$V_j(h; z, w \mid H) = \max_{h', i \in [0, 1]} w_j h (1 - i) + R^{-1} V_{j+1}(h'; z, w \mid H)$$

s.t. $h' = z(h^i)^{\beta_H} + \delta h$.

For $\beta_H \in (0, 1)$ the problem is concave. Standard methods can be used to solve for the value function and the policy function for time investment in human capital $i$.

The first-order conditions for human capital investment and working time imply the Euler equation:

$$w_j h_j \leq z \frac{\beta_H h_j^{\beta_H-1}}{\Delta \text{ in } h} \left( w_{j+1} \frac{(1 + g_j)}{R} \sum_{u=0}^{19-j} \delta^u \prod_{k=1}^{u} \frac{(1 + g_{j+k})}{R} \right),$$

for $g_j = \frac{w_{j+1}}{w_j} - 1$. The equation holds with equality for $i \in (0, 1)$, otherwise individuals spend their entire time on human capital accumulation. In eq. 2, the left-hand side is the marginal cost of human capital accumulation, that is, forgone earnings; the right-hand side is the marginal benefit of human capital accumulation, that is, the present discounted value of the future stream of earnings derived from a marginal increase in the time attributed to human capital accumulation. The amount of time spent accumulating human capital depends on individual characteristics and prices. Individuals with higher innate ability invest more time accumulating human capital on the job and therefore have steeper earnings
profiles. Individuals with higher human capital at high school graduation spend less time accumulating human capital on the job and therefore have flatter earnings profiles. Time allocation decisions are independent from price units. Because the cost of human capital accumulation on the job is forgone earnings, multiplying the price sequence by a positive constant increases the marginal benefit of and the marginal cost of human capital accumulation equally, leaving the trade-off between the two unaffected. The time-allocation decision depends instead on the shape of the price sequence, that is, the rate of growth of the price over the lifecycle. Because human capital investment involves sacrificing earnings today for higher human capital tomorrow, an increase in price growth increases the marginal benefit of human capital accumulation, leaving the marginal cost unchanged. The forward-looking nature of eq. 2 implies that the overall stream of future price growth throughout the lifecycle influences current human capital investment.\(^6\)

The value of the no-college path for an individual of type \((z, h_1) \in B\), born in cohort \(\tau\), is:

\[
V_H(h_1, z, w_\tau) = V_1(h_1; z, w_\tau | H) = \left(\frac{1}{R}\right)^{j-1} w_{\tau+2(j-1)} \left[a_j h_j + b^H\frac{1}{z^{1-\beta_H}}\right],
\]

where \(j\) denotes the first age at which earnings are strictly positive. The constant \(a_j\) represents the discounted lifetime return at age \(j\) to renting out a unit of human capital net of depreciation. For the case of no full-time accumulation on the job, that is, \(j = 1\), the first addend denotes the contribution of initial human capital to lifetime earnings, while the second addend adjusts lifetime earnings for the new human capital accumulated on the job throughout the lifecycle. The constant \(b^H\) is indexed by schooling, \(H\), since it depends on the elasticity of on-the-job accumulation, \(\beta_H\). Both constants \(a\) and \(b^H\) have closed-form solutions when the parameter values satisfy some restrictions. See Appendix B for details.

### 2.2 College Path

Individuals on the college path stay in college for two periods and join the labor market at age 3. When they start college, they pick the quality of their college education. After

\(^6\)I relax the assumption of perfect foresight in Section 4.
graduation from college, they maximize the present value of earnings over their working lifetime by dividing time between work and human capital accumulation, as with the no-college path. The problem for an individual of type \((z, h_1) \in B\), born in cohort \(\tau\), on the college path is given by

\[
\max_{\{i_j\}_{j=3}^{20}, e} \sum_{j=3}^{20} \left( \frac{1}{R} \right)^{j-1} E_j - \left( 1 + \frac{1}{R} \right) e \\
\text{s.t.} \quad E_j = w_{\tau+2(j-1)} h_j (1 - i_j) \\
\quad h_{j+1} = q(z, h_j, e) + h_j, \ j = 1, 2. \\
\quad h_{j+1} = f(z, h_j, i_j | C) + \delta h_j, \ j \geq 3. \\
\quad i \in [0, 1], \ \hat{\tau} = \tau + 19 \\
\quad \text{given } h_1.
\]

A college graduate’s on-the-job human capital accumulation technology differs from the no-college case by the value of the elasticity of human capital investment, \(\beta_C\). I assume that college requires full-time investment, therefore earnings are zero for the first two periods for those in college. Human capital accumulation in college requires innate ability, college quality \(e\), and human capital as inputs. Individuals who invest more on their college quality acquire more human capital while in college given their endowments. Investment in college quality represents all sorts of college expenditures, such as tuition and room and board, as well as the disutility associated with putting a certain effort in learning.\(^7\) I assume that college quality is chosen once and for all at the beginning of college and corresponding expenditures are paid in two equal amounts each period while in college. The in-college human capital accumulation function is\(^8\)

\[
q(z, h, e) = zh^\eta e^{1-\eta}.
\]

Given human capital at college graduation, \(h_3(h_1, e)\), the on-the-job human capital accumulation problem for the college path is identical to the one for the no-college path up to the elasticity of human capital investment on the job, \(\beta_C\). The college quality problem can be formulated as \(\max_e V_3(h_3(h_1, e); z, w_{\tau} | C) - (1 + \frac{1}{R}) e\), for \(V_3\) as in eq. 1 with \(j = 3\).

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\(^7\)The disutility cost of learning can be thought of as the cost of obtaining education in the signaling literature.

\(^8\)Similar functional forms for the technology of human capital accumulation in school have been considered by, among others, Manuelli and Seshadri (2010) and Erosa, Koreshkova, and Restuccia (2010).
first-order conditions are

\[
\left(1 + \frac{1}{R}\right) = \left. \frac{\partial h_3}{\partial e} \right|_{\Delta \text{ in } h_3} \left(1 + \frac{1}{R}\right)^2 \frac{\partial V_3(h_3; z, w_\tau | C)}{\partial h_3},
\]

that is,

\[
\left(1 + \frac{1}{R}\right) = \left. \frac{\partial h_3}{\partial e} \right|_{\Delta \text{ in } h_3} \left(1 + \frac{1}{R}\right)^{j-1} w_{\tau+2(j+2)a_j} \left[ \prod_{u=4}^{j} \left( A \beta C h_{u-1}^{\beta C-1} + \delta \right) \right],
\]

where \( j \) and \( a \) are defined as for the no-college path. The left-hand side of eq. 3 is the marginal cost of increasing college quality — that is, the present value of additional expenses derived from a marginal increase in college quality. The right-hand side of eq. 3 is the marginal benefit of increasing college quality — that is, the present discounted value of the future stream of earnings derived from a marginal increase in college quality. Individuals with higher innate ability and higher initial human capital invest more on college quality. Both a higher initial level and a higher growth over the lifecycle of the price imply a higher optimal college quality. When the price at high school graduation increases, the return to college quality increases proportionally with it, while the cost of college quality remains unaltered. When price growth increases, the benefit of human capital accumulation on the job increases (\( a \) increases in price growth) and so does the return to college quality, while the cost of college quality remains unaltered once again.

The value of the college path for an individual of type \((z, h_1) \in B\), born in cohort \(\tau\), is the discounted value of lifetime earnings net of total expenditures on college quality:

\[
V_C(h_1, z, w_\tau) = V_3(h_C(h_1, e^*); z, w_\tau | C) - \left(1 + \frac{1}{R}\right) e^*,
\]

\[
= \left(1 + \frac{1}{R}\right)^{j-1} w_{\tau+2(j+2)a_j} \left[ \prod_{u=4}^{j} \left( A \beta C h_{u-1}^{\beta C-1} + \delta \right) \right] - \left(1 + \frac{1}{R}\right) e^*,
\]

where \( e^* \) denotes optimal college quality (from eq. 3) and \( b^C \) is indexed by schooling, \( C \), because it depends on the elasticity of on-the-job accumulation as for the no-college case.
2.3 College Decision

Individuals within a cohort choose their education level upon graduation from high school. They do so based on their type, \((z, h_1)\), and the price sequence observed during their lifetime, \(w\). A college education is pursued if and only if

\[
V_C(h_1, z, w) \geq V_H(h_1, z, w).
\]

Let the indicator function \(1(h_1, z, w)\) take the value of 1 if an individual pursues a college education and 0 if he does not. Thus,

\[
1(h_1, z, w) = \begin{cases} 
1, & \text{if } (4) \text{ holds}, \\
0, & \text{otherwise}.
\end{cases}
\]

There are three assumed trade-offs between the college and no-college paths: (i) Human capital is not productive during college education but is when work is chosen. (ii) The technology for human capital accumulation in college is not the same as the technology for human capital accumulation on the job. (iii) The elasticity of human capital investment on the job differs between education levels. Each of these three trade-offs shape the effect of the price sequence on the college decision. The decision rule in eq. 4 can be rewritten as

\[
\left(\frac{1}{R}\right)^2 \left[V_3(h_3(h_1, e^*); z, w | C) - V_3(h_3; z, w | H)\right] \geq \left(1 + \frac{1}{R}\right) e^* + V_1(h_1; z, w | H) - V_3(h_3; z, w | H),
\]

where \(e^*\) indicates the optimal level of college quality, as it results from eq. 3. In eq. 5, on the left-hand side are the gains of college — that is, the additional earnings received from age 3 onwards, and on the right-hand side are the costs of college — that is, total expenses on college quality and forgone earnings. By substituting the functional forms for the value function and earnings:

\[
\left(\frac{1}{R}\right)^2 w_3 \left\{ a_3 \left( h_3^C(h_1, e^*) - h_3^H(h_1, i_1, i_2) \right) + \left( b_3^C z \frac{1}{\gamma_C} - b_3^H z \frac{1}{\gamma_H} \right) \right\} \geq \left(1 + \frac{1}{R}\right) e^* + w_1 h_1(1 - i_1) + \frac{w_2}{R} h_2^H(1 - i_2),
\]
where, for ease of notation, the time subscript on the price is replaced by the age subscript and I focus on the case of no full-time accumulation on the job — that is, $j^* = 1$ for the no-college path and $j^* = 3$ for the college path. Starting from the latter of the three trade-offs, higher price growth over the lifecycle implies higher returns to human capital investment on the job. When the elasticity of human capital investment on the job for the college path is at least as big as that for the no-college path, the returns to college increase as price growth increases (notice the term $b_C^C z^{1-\beta_C} - b_H^C z^{1-\beta_H}$). On the second trade-off, a higher rental price per unit of human capital at high school graduation (henceforth “price level”) increases the net return to college quality, where else it leaves the net return to accumulating human capital on the job unchanged. The cost and benefit of human capital accumulation on the job both increase proportionally with the price level. However, only the benefit of college quality increases with the price level (compare the pair $1/R^2 w_3 a_3 h^C_3$ and $w_1 h_1 i_1 + 1/R w_2 h^H_2 i_2$ to the pair $1/R^2 w_3 a_3 h^C_3$ and $(1 + \frac{1}{\pi}) e^*$. Lastly, on the first trade-off, the opportunity cost of accumulating human capital in college relative to accumulating human capital on the job decreases with higher price growth. The commitment to four-year full-time investment in human capital after high school graduation associated with college becomes relatively less burdensome as price growth increases.

Who goes to college? Individuals with high innate ability go to college. They are more productive learners, both in college and on the job, and therefore obtain higher returns from attending college. An individual’s initial human capital also influences the college choice. Because human capital and college quality are complements in the accumulation of human capital in college, individuals with higher initial human capital face bigger returns to college quality. However, because human capital is not productive during college, individuals with lower initial human capital have a lower opportunity cost of spending four years in college (lower forgone earnings). Notice that the importance of the margin associated with initial human capital in the college decision depends on the lifetime price sequence. As the price level increases and its growth over the lifecycle decreases, initial human capital becomes less and less important in the college decision; and the college decision is ruled more and more by an individual’s innate ability.

The fraction of cohort $\tau$ acquiring a college education is determined from the cumulative

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9This mechanism is related to the reverse causality mechanism from anticipated TFP growth to educational attainment in Bils and Klenow (2000).
distribution of initial endowments $\Gamma_\tau(z, h_1)$:

$$\int_{(z, h_1) \in B} 1(h_1, z, w_\tau) d\Gamma_\tau(z, h_1).$$

3 Calibration

The quantitative strategy consists of setting the model in line with the path of unconditional earnings for the 1920-1970 cohorts and then exploring the model implications for education-specific earnings and college attainment for those cohorts. The approach I follow to set the model’s parameters consists of three steps. First, I set a number of parameters a-priori. Second, I calibrate the parameters that are common to all cohorts (deep parameters) to a number of key moments in the NLSY79 dataset for the early 1960s cohorts. Third and last, I use IPUMS-USA data to infer the evolution of the rental price of human capital over time and that of the distribution of initial human capital across cohorts. The following subsections detail each of these steps.

I use two main data sources: the Integrated Public Use Micro Data Series for the United States (IPUMS-USA by Ruggles, Alexander, Genadek, Goeken, Schroede, and Sobek, 2010) and the 1979 National Longitudinal Survey of the Youth (NLSY79 by Bureau of Labor Statistics, 2002). IPUMS-USA provides quantitative information on long-time changes in earnings; the NLSY79 provides a constant panel that follows a limited number of individuals over time. I focus on a sample of employed white males between the ages of 19 and 58 who have achieved either a high school diploma or a four-year college degree. Since earnings statistics in the data are computed for employed people only, earnings statistics in the model ignore agents with full-time post-schooling investment. The IPUMS-USA data is not a fixed panel, and therefore I compute cohort data by constructing synthetic cohorts. See Appendix A for full descriptions of each data set and further details on sample selection.

3.1 Deep parameters

I assume parameter values for which the literature provides evidence. The parameters that I calibrate without solving the model are reported in Table 1 together with the assigned values. I set the gross interest rate $R$ to 1.04 (annual rate). Estimates of the elasticity of human
capital investment on the job in the literature typically vary from 0.5 to almost 0.95 (see Browning, Hansen, and Heckman, 1999). My specification of the on-the-job accumulation function is a particular case of Heckman, Lochner, and Taber (1998). These authors provide estimates of the elasticity of on-the-job human capital investment at two education levels: high school and four-year college or more. I set $\beta_H = 0.832$ and $\beta_C = 0.871$. I set the depreciation rate, $\delta - 1$, to zero to be consistent with Heckman, Lochner, and Taber (1998). Rupert and Zanella (2012) show that the declining portion of the earnings profile is mainly a result of a decreased labor supply rather than decreased hourly wage.

I calibrate the distribution of initial endowments, the in-college human capital accumulation function and the rental price of human capital in year 1980 to the age variation of unconditional earnings moments, college expenses, college attainment, and college premium for the 1961 to 1964 cohorts. I assume that the distribution of initial endowments, $\Gamma_\tau$, is jointly log-normal. This class of distributions is characterized by 5 parameters, $\{\mu_{\log(z)}, \mu_{\log(h_1)}, \sigma_{\log(z)}, \sigma_{\log(h_1)}, \rho\}$. Thus, the list of parameters that are calibrated within the model are

$$\Lambda = \{\mu_{\log(z)}, \mu_{\log(h_1)}, \sigma_{\log(z)}, \sigma_{\log(h_1)}, \rho, \eta, w_{1980}\}.$$

I calibrate these parameters to the following statistics for the 1961-1964 cohorts:

1. Age variation of unconditional earnings moments: mean, coefficient of variation, and skewness of the distribution of unconditional earnings at six points over the lifecycle, $j \in J = \{23 - 26, 27 - 30, 31 - 34, 35 - 38, 39 - 42, 43 - 45\}$ (Source: NLSY79.)

2. College premium for the 23- to 26-year-old: ratio of median earnings of four-year college graduates to median earnings of high school graduates (Source: IPUMS-USA.)

3. Education composition: fraction of high school graduates with a four-year college degree (Source: IPUMS-USA.)

---

10 The human capital accumulation function in Heckman, Lochner, and Taber (1998) is $z^\eta \delta^S$ for $S \in \{C, H\}$. They work with four ability types and two education levels (high school and 4 years of college or more) and estimate the human capital accumulation function with NLSY79 data on white-male earnings for the period 1979-1993.

11 Huggett, Ventura, and Yaron (2006) show that, in this set-up, in terms of replicating life-cycle earnings dynamics, the gains of going from a parametric to a non-parametric approach for the distribution of initial endowments are not substantial.

12 At this stage only the distribution of initial endowments for the 1961 to 1964 cohorts is calibrated. The marginal distributions of initial human capital for the 1920 to 1970 cohorts are calibrated in the next section with the cohort-specific parameters.
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>VALUE</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model period</td>
<td></td>
<td>2 years</td>
<td></td>
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<tr>
<td>Gross interest rate</td>
<td>$R$</td>
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<tr>
<td>OTJ accumulation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- college</td>
<td>$\beta_C$</td>
<td>0.871</td>
<td>Heckman, Lochner, and Taber (1998)</td>
</tr>
<tr>
<td>- high school</td>
<td>$\beta_H$</td>
<td>0.832</td>
<td>Heckman, Lochner, and Taber (1998)</td>
</tr>
<tr>
<td>- depreciation rate</td>
<td>$1 - \delta$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Calibration. Deep parameters: parameters chosen without solving the model.

4. College expenses: ratio of average tuition and fees and room and board for the period 1982 to 1988 to average earnings of 23- to 26-year-old four-year college graduates, (Source: IPUMS-USA and The College Board, 2007.)

There are a total of 20 targets.\footnote{Earnings in target 1 are normalized to mean earnings at ages 23-26. Because of the choice of units for the price, it is unreasonable to expect the model to match the level of earnings.} Formally, the calibration strategy consists of minimizing the following equation:

$$\min_{\Lambda} \sum_{u=1}^{20} \left( \frac{x_u(\Lambda) - \bar{x}_u}{\bar{x}_u} \right)^2.$$  

For a given $\Lambda$, I compute the model moments, $x_u(\Lambda)$, that correspond to the targets described above, $\bar{x}_u$.

Even though the parameter values are chosen simultaneously to match the data targets, each parameter has a first-order effect on some targets. The elasticity of substitution of the in-college human capital accumulation function is disciplined by data on college expenses. Data on college expenses combine (i) Trends in College Pricing (The College Board, 2007) data on average tuition and fees and room and board for private and public colleges in the United States and, (ii) Goldin and Katz (2008)’s data on the fraction of college students enrolled in public and private universities. The price in year 1980 is important for matching the educational composition. The moments in targets 1 and 2 discipline the distribution of initial endowments. The NLSY79 dataset has a fixed-panel structure and allows me to infer endowments from life-cycle earnings. The argument for identification behind this exercise follows Huggett, Ventura, and Yaron (2006).

The only source of earnings inequality in my model is due to endowments. An individual’s type $(z, h_1)$ implies a profile of human capital accumulation over the lifecycle and therefore
Table 2: Calibration. Deep parameters: parameters computed by solving the model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\mu_{\log(z)}$</th>
<th>$\mu_{\log(h_1)}$</th>
<th>$\sigma_{\log(z)}$</th>
<th>$\sigma_{\log(h_1)}$</th>
<th>$\rho$</th>
<th>$\eta$</th>
<th>$w_{1980}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
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<td>4.472</td>
<td>0.253</td>
<td>0.334</td>
<td>0.758</td>
<td>0.506</td>
<td>1.506</td>
</tr>
</tbody>
</table>

Table 2: Calibration. Deep parameters: parameters computed by solving the model.

a profile of earnings over the lifecycle. Within a cohort, a distribution of types maps into a distribution of earnings over the lifecycle. Thus, initial endowments can be identified through the evolution of the distribution of earnings over the lifecycle. The key assumption is that systematic differences in growth rates are the major driving force behind earnings dynamics over the lifecycle. This assumption is supported by empirical studies that estimate earnings processes from micro data sets (see, for example Guvenen, 2009). I include the college premium as an additional source of discipline. The college premium contains information on the college-selection mechanism in terms of the $(z, h_1)$ types that choose college. Details on the identification of each parameter of the distribution of initial endowments in the context of my model are outlined in Appendix C.

The model is solved numerically. I simulate the earnings and schooling paths of 100,000 individuals in each of the 1961-1964 cohorts. The parameter values are reported in Table 2, while the model’s performance on targets is reported in Table 5 and shown in Figure 13. Overall, the model is successful in matching the data. The mean age-earnings profile is reproduced in its growth and concavity. This results from human capital investment being disproportionately more convenient at younger ages. The life-cycle pattern of the coefficient of variation is well reproduced; however, the level is not. In the model, the coefficient of variation at ages 23-26 is two-thirds of that in the data. Small dispersion in initial human capital and small correlation between innate ability and initial human capital are set to match the college premium. Given the coefficient of variation for initial human capital and the correlation between initial human capital and innate ability, the coefficient of variation for innate ability is chosen to deliver both the level and the lifetime growth of earnings dispersion. Right skewness follows because the incentives for human capital investment increase more than proportionally with an individual’s innate ability (see Huggett, Ventura, and Yaron (2011) extend the Ben-Porath framework of human capital accumulation to consider idiosyncratic shocks to human capital. They find that 38.5 percent of the variance of lifetime earnings is due to idiosyncratic shocks to human capital. The remaining part of the variance is accounted for by initial endowments.)
eq. 7 and recall that $\beta < 1$).

Figure 4: Results. Life-cycle earnings dynamics for high school graduates and for college graduates, 1961-1964 cohorts. Earnings are normalized to mean earnings at ages 23-26. Data (solid lines) vs. Model (dashed lines). Source: NLSY79 and the author.

I assess the merit of the model based on moments that are not targets of the calibration exercise. I pick those moments to my evaluation of the model as a model of life-cycle earnings in a context of a college choice. Figure 4 displays the model performance on the age variation of education-specific earnings moments for the 1961-1964 cohorts. The first panel shows the mean age-earnings profile for high school graduates and that for college graduates. First, notice that in the data the mean age-earnings profile for high school graduates is essentially flat, while that for college graduates has a positive slope. The model generates this fact as a result of positive association between college and innate ability. The
average innate ability of college graduates is 0.2296, while that for high school graduates is 0.1526. The model predicts that, absent heterogeneity in human capital, agents with high innate ability have steeper profiles of human capital accumulation than agents with low innate ability. However, the model overpredicts the difference between life-cycle earnings growth for college graduates and that for high school graduates. Because initial endowments are pinned down and the education composition is matched, earnings growth conditional on education is pinned down.\footnote{One extension of the model carrying the necessary degrees of freedom to match earnings growth for both high school graduates and college graduates features education-specific prices of human capital, i.e., a price for high school human capital and a price for college human capital. I am not pursuing this extension because (i) of the parsimony of the single-price model, (ii) the single price model performs quite well on education-specific earnings moments, and (iii) in the single price model, education-specific earnings moments can be used as a metric of the merit of the model.} The model is consistent with a faster rise in the dispersion of earnings over the lifecycle for college graduates relative to that for high school graduates. This is because college graduates have larger mean and larger dispersion of innate ability than high school graduates and the incentives to human capital investment increase more than proportionally with an individual’s innate ability. Finally, the model generates life-cycle patterns of the asymmetry in the distribution of earnings (earnings skewness) close to the data. The positive association of innate ability with college is the reason for the following: (i) a higher average life-cycle skewness of college graduate earnings relative to that of high school graduate earnings and (ii) a higher rise in the skewness of college graduate earnings over the lifecycle relative to that of high school graduate earnings.

3.2 Cohort-specific parameters

Cohorts exogenously differ by two dimensions: they face different life-cycle price sequences (a time effect) and they face different distributions of initial human capital across individuals (a cohort effect).\footnote{The distribution of innate ability is assumed to stay constant across cohorts. This is possibly a restrictive assumption for the cohorts born between 1920 and 1940 considering the substantial expansion in high school education that happened during this period. Within the framework of this paper, exogenous changes in the distribution of innate ability of high school graduates cannot be separately identified from those in the distribution of human capital of high school graduates due to data restrictions.} I calibrate time and cohort effects to replicate the evolution of unconditional earnings moments, first and second moments, for the 1884 to 1970 cohorts.

Figure 5 shows growth patterns of three earnings moments (solid lines): (i) average earnings for the 1940-2008 period, (ii) coefficient of variation of earnings for the 1940-2008 period, (iii) coefficient of variation of earnings for the 1940-2008 period,
and (iii) average earnings late in the lifecycle for the 1884 to 1958 cohorts. Each trend
can be summarized quite well by two distinct changes in growth rates: (i) pre-1970s and
post-1970s growth for the time-series data and (ii) pre-1933 and post-1933 growth for the
cross-cohort data. I structure the paths of the time effect and the cohort effect in the model
as follows. Trend breaks occur (i) in price growth in year 1970, (ii) in the growth of the
mean of the distribution of initial human capital for the 1933 cohort, and (iii) in the growth
of the standard deviation of the distribution of initial human capital for the 1933 cohort.
More formally, the paths are as follows:

- for price growth: for $x = w$,

$$x_t = \begin{cases} 
  x_{t-1}[1 + g_{x,1}] & t \leq 1969 \\
  x_{t-1}[1 + 0.5(g_{x,1} + g_{x,2})] & t \in [1970, 1979] \\
  x_{t-1}[1 + g_{x,2}] & t \geq 1980,
\end{cases}$$

- for the distribution of initial human capital: for $x = \{\mu_{h_1}, \sigma_{h_1}\}$,

$$x_\tau = \begin{cases} 
  x_{\tau-1}[1 + g_{x,1}] & \tau \leq 1933 \\
  x_{\tau-1}[1 + g_{x,2}] & \tau \geq 1934,
\end{cases}$$

where $\tau$ indicates the year of birth of the cohort.

I calibrate the path of the price, the path of the mean of initial human capital, and the path
of the standard deviation of initial human capital to the earnings moments in Figure 5 (solid
lines). In particular, the calibration targets, $(\dagger)$, are

1. growth of average earnings of white males between the ages of 35-46 for the 1940-1970
   period and the 1980-2008 period (source: IPUMS-USA, Figure 5a),

2. growth of the coefficient of variation of earnings of white males between the ages of
   35-46 for the 1940-1970 period and the 1980-2008 period (source: IPUMS-USA, Figure
   5b), and

3. growth of average earnings between the ages 39-45 and 49-55 for the 1884-1920 cohorts
   and the 1924-1958 cohorts (source: IPUMS-USA, Figure 5c).
Figure 5: Model fit. Earnings: life-cycle growth, cross-sectional growth, and growth of the coefficient of variation. Growth rates are calculated as annual rates. Data (solid lines) vs. Model (dashed lines). Source: IPUMS-USA and author.

There is a total of 6 targets. Even though all the trends are pinned down simultaneously, each pair of targets disciplines primarily the pattern of one variable. Earnings growth toward the end of the lifecycle informs on price growth. The focus on a period late in the lifecycle is based on the model implication that the fraction of time attributed to investment in human capital decreases with age. When investment in human capital is close to insignificant, the growth rate of the price is close to the growth rate of earnings (see Appendix C for details). Cross-sectional earnings growth informs on the evolution of the distribution of initial human

\[\text{This observation is the foundation of the flat spot method proposed by Heckman, Lochner, and Taber (1998) and more recently used by Bowlus and Robinson (2012) for measuring the prices of human capital across various levels of education.}\]
capital. Given a sequence of prices and a sequence of distributions of initial human capital, the model produces a sequence of earnings. Thus, I choose the sequence of distributions of initial human capital (i.e., a sequence of means and standard deviations) to match changes in the first and second moments of earnings data for 35- to 46-year-olds. Formally, the calibration strategy consists of solving a system of 6 equations in 6 unknowns. For a given \( \Gamma = \{g_{1x}, g_{2x}\} x=\{w,\mu_h,\sigma_h\} \), I compute the model moments, \( X(\Gamma) \), that correspond to the targets described above. I then solve for the zero of the function \( F(\Gamma) \) defined by

\[
F(\Gamma) = \tilde{X} - X(\Gamma),
\]

where \( \tilde{X} \) are the targets described above.

I simulate the earnings and schooling path for 100,000 individuals in the 1884-1970 cohorts. Figure 5 shows the performance of the model on targeted moments. The calibrated \( g_w \) pair is \( \{1.67\%, 0.14\%\} \), calculated as annual rates. The calibration implies a slowdown in price growth starting in the 1970s. The calibrated changes in the mean and standard deviation of the distribution of initial human capital are \( g_{\mu_h} = \{0.25\%, -0.05\%\} \) and \( g_{\sigma_h} = \{-3.05\%, 0.99\%\} \), calculated as annual rates. What is the significance of a change in the distribution of initial human capital over cohorts? An individual’s human capital is the amount of knowledge he possesses. Hence, the distribution of initial human capital is a measure of the “quality” of the high school graduates. The calibration implies an increase in the average “quality” of successive cohorts of high school graduates followed by a decline. This pattern is consistent with anecdotal evidence presented by Taubman and Wales (1972) and Bishop (1989) on cognitive skills of high school graduates. Taubman and Wales (1972) observe that test scores of high school graduates decline starting with the late-1920s cohorts, after increasing from the beginning of the century. Bishop (1989) reports a decrease in the

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\(^{18}\)Bowlus and Robinson (2012) find similar patterns, in both direction and magnitude, for the rates of growth of the prices of human capital across various levels of education. Possible reasons for the slowdown in price growth include a slowdown in productivity growth, which influences the demand of human capital. Also, an increase in the supply of human capital following the increase in female labor force participation, the increase in average years of schooling of females and non-white males, and the increase in cohorts size (the baby boom) can also have contributed to the slowdown in price growth.

\(^{19}\)An evident reason for the decline in the quality of successive cohorts of high school graduates is the expansion in high school education that happened between the 1920 and the 1940 cohorts. Among those born in 1920, the fraction of white males with at least a high school diploma was 57 percent. This fraction was 82 percent for those born in 1940. A positive correlation between schooling and innate ability and/or human capital, as it transpires from evidence on tests scores, implies that large changes in high school attainment can potentially have a significant selection effect on the average innate ability and average human capital associated with high school education.
average scores of high school graduates on normed tests, such as the ITED and ITBS, starting with the late-1940s cohorts and following 50 years of uninterrupted improvement. Lastly, the calibration implies that the dispersion of initial human capital increases starting with the early-1930s cohorts. Even though the calibration is set to replicate average changes in earnings dispersion for the pre-1970s and post-1970s periods, the model matches the pattern of earnings dispersion for the various years within each period quite well.

4 Results

The main results of the paper are in terms of college attainment and college premium. In this section, I present the model implications for the patterns of college attainment and college premium for the 1920-1970 cohorts and I investigate the quantitative contribution of changes in the rental price per unit of human capital along with changes in the distribution of initial human capital to those patterns.

College attainment of the 1920-1970 cohorts is shown in Figure 6a and summarized in Table 3, column “Model”. The model generates an increase and subsequent flattening of college attainment. After calibration, the model indicates that 36 percent of the 1961-1964 cohorts earned a college degree, which is close to the data. The fraction of high school graduates
Table 3: Results. College attainment in the United States.

in the 1920-1950 cohorts that earned a college degree increases from 12.3 percent to 36.9 percent in the model and from 17.8 percent to 37.7 percent in the data. The positive trend contracts starting with the early-1950s cohorts. From the 1950 cohort to the 1970 cohort, college attainment decreases from 36.9 percent to 36.6 percent in the model, but increases from 37.7 percent to 39.7 percent in the data. Overall, for the 1920-1950 cohorts, the fraction of college graduates increases cohort-to-cohort on average 8.2 percentage points in the model and 5.9 percentage points in the data. In contrast, that for the 1950-1970 cohorts decreases 0.3 percentage points in the model but increases 0.3 points in the data. The flat college attainment the model generates for the post-1950 cohorts is a critical result of the paper.

College attainment is mostly driven by the path of the rental price per unit of human capital (the time effect). Figure 7 shows a decomposition exercise of the time and cohort effects on the slowdown in college attainment. In a first experiment ("Time effect only"), I keep the initial human capital distribution of each cohort the same, so that the only difference between cohorts is the life-cycle price sequence. The resulting pattern of college attainment is almost the same as that in the baseline exercise. Individuals born in the 1920s face a steeper price sequence than those born in the 1950s and therefore have a higher return to human capital investment on the job. However, those born in the 1950s face also a higher price at high school graduation than that faced by those born in the 1920s. This makes college a better deal for the later cohorts because of the higher return to college quality. Individuals born after 1950 face both diminished returns to human capital investment on the job and a flat profile of returns to college quality, as the rental price of human capital grows very slowly after 1970. Thus, college attainment flattens.

The evolution of the distribution of initial human capital across cohorts (the cohort effect)

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20The distribution of initial endowments across individuals is most important in determining the response of college attainment to changes in the rental price per unit of human capital. See, among others, Athreya and Eberly (2010), whose paper deals with asymmetric returns to college while investigating the magnitude of the response of college attainment to changes in the college premium.
plays only a minor role in the slowdown in college attainment. This is because the first-order
determinant of the decision of attending college is innate ability rather than initial human
capital. Figure 7, “Cohort effect only”, shows college attainment when price growth is kept
constant to its average between pre-1970s growth and post-1970s growth, so that the only
differences between cohorts are the initial human capital distribution and the price at age 1.
College attainment does not slow down in this second experiment.

The timing of the slowdown in college attainment is not well reproduced by the model.
College attainment slows down with the early-1940s cohorts in the model but with the late-
1940s cohorts in the data. A similar result appears for the rise in college attainment. The
greatest increase in college attainment occurs for the 1930s cohorts in the model but for the
1940s cohorts in the data. As pointed out by Cunha and Heckman (2007) expectations of
future price growth may play a major role in choosing to attend college or not. I explore the
possible role of individuals’ expectations on the timing of the slowdown in college attainment
by relaxing the assumption of perfect foresight. I consider the simple alternative scenario of
individuals expecting the price growth observed at high school graduation to persist during
their lifetime. I do not recalibrate the two growth rates of the price since they are irrelevant
for the timing of the slowdown. Figure 8 shows the implied pattern of college attainment.
The timing of the rise and of the flattening of college attainment in the model aligns with
the data under this alternative scenario.
Figure 8: Results. College attainment under naive expectations. Data (solid lines) vs. Model (dashed lines). The light-colored solid lines report HP filtered observations. Source: IPUMS-USA and author.

Figure 6b plots the college premium for the 1920 to 1970 cohorts. The model generates 79 percent of the increase in the college premium for the cohorts 1920 to 1970: the college premium increases 15 percent in the model and 19 percent in the data. The cohort-over-cohort pattern of the college premium in the model follows the data quite nicely. Both in the data and in the model, the college premium persists across successive cohorts born between 1920 and 1970, with the exception of the 1930s cohorts. During the 1930s cohorts, the college premium does not change in the model, and it decreases by 10 percent in the data. Lastly, notice that the model generates an increasing college premium for the cohorts of the slowdown in college attainment, as shown in the data.

The increase in the college premium is generated by a combination of both exogenous forces in the model: the time effect and the cohort effect. Figure 9 shows a decomposition exercise of these two effects on the pattern of the college premium. In a first experiment ("Time effect only"), I keep the initial human capital distribution of each cohort to be the same, so that the only difference between cohorts is the life-cycle price sequence. The resulting college premium increases almost exclusively during the 1920s and 1930s cohorts. The college premium rises

---

21The college premium is defined as median college graduate earnings relative to high school graduate earnings over ages 33 to 38. Several authors have documented that the fall and rise in the college premium in the United States in the twentieth century was largely due to changes among young workers, whereas the college premium among old workers wasn’t very much muted (Murphy and Welch, 1992). In the model, starting in the 1990s, the college premium among older workers rises far less than it does among young workers. In the data, the college premium for old workers starts increasing earlier, in the 1980s. Because younger workers have a larger planning horizon, they respond to a change in prices much more strongly than older workers in the model.
Figure 9: Decomposition exercise. College premium: time effect and cohort effect. Data (solid lines) vs. Model (dashed lines) vs. Model time effect only (dashed, pink line) vs. Model cohort effect only (dashed, red line). Source: IPUMS-USA and author.

18 percent between the 1920 cohort and the 1950 cohort, decreases 2 percent during the 1950s cohorts, and remains flat thereafter. The mean of initial human capital increases from the 1920 to the mid-1930s cohorts, lessening the increase in the college premium that would have otherwise resulted from the time effect. Symmetrically, the mean of initial human capital decreases after the mid-1930s cohorts, pushing up the college premium.

The time effect influences the pattern of the college premium along with the cohort effect. Figure 9, “Cohort effect only”, presents the implied pattern of the college premium when price growth is constant and set to its average between pre-1970s growth and post-1970s growth, so that the only differences between cohorts are the initial human capital distribution and the price at age 1. The resulting college premium decreases between the 1920 cohort and the 1970 cohort. The college premium is the ratio of the median human capital supplied to market work by college graduates relative to that supplied by high school graduates. Price growth has a composition effect on the average human capital of high school graduates and on that of college graduates. Pre-1970s price growth fuels the increase in college attainment, which has a significant selection effect on the average innate ability and average human capital associated with a schooling level. This selection effect has a prominent role in the increase in the college premium during the cohorts 1920s to 1940s. The slowdown in

\footnote{Previous studies highlight the importance of selection on the college premium during times of substantial changes in college attainment; see, for example, Laitner (2000) and Hendricks and Schoellman (2009).}
Figure 10: Results. Marginal distributions of initial endowments, conditional on education. The first column refers to cohorts born between 1931 and 1934, while the second column refers to cohorts born between 1961 and 1964. The first row refers to the distribution of innate ability, while the second row refers to the distribution of initial human capital.

price growth after the 1970s, instead, reinforces the increase in the college premium by strengthening the association between college and innate ability.

Figure 10 shows the distribution of initial endowments, innate ability, and initial human capital, conditional on the education level for two groups of cohorts, 1931-1934 cohorts and 1961-1964 cohorts. While the less-recent group features college graduates with lower innate ability than that of high school graduates, the more-recent group includes perfect positive sorting by innate ability across schooling levels. The initial human capital margin does not

\[ \text{There is no direct way to measure such a change in college selection over time in the data. However, two pieces of anecdotal evidence can be informative. First, Taubman and Wales (1972) report for cohorts born between 1907 and 1950 the average percentile score on IQ tests for those who continue on to college and for those who do not. The trend for the former is positive, while the trend for the latter is negative. Second, Bowen and Turner (1999) document sorting across majors by SAT math and verbal score, and Wiswall and Gemici (2010) document an increase in the fraction of students pursuing majors associated with higher SAT math and verbal scores starting with the late-1940s cohorts.} \]
### Table 4: Earnings growth by education groups.

The column \( \text{Growth 1} \) indicates the average growth rate for the pre-1970s period for cross-sectional data and for the pre-1933 cohorts for life-cycle data. The column \( \text{Growth 2} \) indicates the average growth rate for the post-1970s period for time-series data and for the for the post-1933 cohorts for life-cycle data. The column \( \text{Flattening} \) is the difference between the column \( \text{Growth 1} \) and the column \( \text{Growth 1} \).

<table>
<thead>
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<th>Education Group</th>
<th>Growth 1</th>
<th>Growth 2</th>
<th>Flattening</th>
</tr>
</thead>
<tbody>
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<td>Cross-sectional</td>
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</tr>
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<td></td>
<td>Model</td>
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<td>Life-cycle</td>
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</tr>
<tr>
<td></td>
<td>Model</td>
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<td>0.0036</td>
</tr>
<tr>
<td><strong>College</strong></td>
<td></td>
<td></td>
<td></td>
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<td>Cross-sectional</td>
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<tr>
<td></td>
<td>Model</td>
<td>0.0247</td>
<td>0.0051</td>
</tr>
</tbody>
</table>

Some papers investigate the role of skill-biased technical change — that is, an increase in the price of college graduates’ human capital relative to that of high school graduates’ human capital, in the increase in the college premium (see Acemoglu, 2002, for a review and Restuccia and Vandenbroucke, forthcoming, for a quantitative analysis). Consider a simple version of my model, with no heterogeneity and no human capital accumulation on the job, that is extended to include education-specific human capital prices. Earnings of full-time workers at various education levels are \( E_S = h_S \times w_S \), where \( h_S \) is the quantity of human capital at education level \( S \), and \( w_S \) is the price per unit of human capital at
education level $S$, for $S \in \{C, H\}$. As in the baseline model, $h_C = h_H^e e^{1-n}$. The college premium at each point in time equals the ratio of college-graduate earnings relative to high school-graduate earnings: $\frac{w_C}{w_H} = h_H^{e-1} e^{1-n}$. For a given college quality $e$, a decrease in high school human capital $h_H$, and an increase in the price ratio $\frac{w_C}{w_H}$, both increase the college premium. Because both human capital and prices are unobservable, the two effects are not distinguishable from one another.

Lastly, table 4 reports education-specific patterns of earnings growth for the model (rows “Model”) and the data (rows “Data”). The model follows the major patterns of earnings growth in the data: for both high school and college graduates, cross-sectional earnings growth flattens starting from the 1970s and life-cycle earnings growth flattens with the 1930s cohorts. The model under-predicts the flattening in the cross-sectional earnings growth of college graduates. This is because the rise in college attainment that happens during the 1940s cohorts has a strong selection effect on the average innate ability of successive cohorts of high school graduates choosing college and dampens their cross-sectional earnings growth prior to the 1970s.

5 Conclusion

In this paper I assess the quantitative importance of the growth rate of the rental price per unit of human capital in generating patterns of US college attainment for white males born between 1920 and 1970. I argue that price growth is a key factor in the pattern of college attainment. In particular, a decrease in price growth in the 1970s causes college attainment to remain flat for the cohorts born after 1950 in the US.

Since earnings reflect both the quantity and the price of human capital, the rental price per unit of human capital is not observable. I write a model of human capital accumulation in college and on the job to identify the rental price per unit of human capital and to quantify its importance for the path of college attainment. I calibrate the model to major patterns of earnings growth and earnings inequality, both across time and over the lifecycle, for the 1920-1970 cohorts. The calibration implies a decrease in price growth starting in the 1970s. As price growth decreases, the returns to human capital investment decrease and the opportunity cost of human capital accumulation in college increases relative to that on the job. Hence, college attainment flattens.
One short coming of the model is that it generates a slowdown in college attainment that starts earlier than in the data. In an alternative exercise, I show that individual expectations influence the timing of the slowdown in college attainment. When I assume individuals expect price growth observed at high school graduation to persist during their lifetime, the model replicates the timing of the slowdown in college attainment as shown in the data. However, I only scratch the surface of the potential role of individuals’ expectations on the timing of the slowdown in college attainment.

The slowdown in college attainment is part of a wider phenomenon that involves all levels of education (see Appendix A). For example, Heckman and LaFontaine (2010) report a flattening of high school graduation rates. The mechanism I consider produces symmetric implications across schooling groups and, therefore, is qualitatively consistent with a general flattening of educational attainment. It would be interesting to extend the quantitative analysis in this paper to include levels of education beyond a four-year college degree.

References


A Data

**IPUMS-USA.** I use 1 percent samples for 1940-1970, and 5 percent samples for 1980-2008. I restrict the sample to employed white males. Observations are weighted. My measure of educational attainment is the IPUMS variable EDUC, which distinguishes among nine levels of education, of which I use two: (i) 12 years of schooling (high school, H), (ii) 16 years of schooling (four-year college, C). My measure of earnings is the IPUMS variable INCWAGE. It reports total pre-tax wage and salary income, i.e., money an employee received in the previous calendar year, as midpoints of intervals (instead of exact dollar amounts). I compute real earnings by applying Consumer Price Index (CPI) weights.

**NLSY79.** I restrict the sample to white males with no missing observations on earnings for ages 23 to 45. Among the available cohorts, I focus on cohorts born between 1961 and 1964, to maximize sample size. The final sample contains 403 individuals, 283 high school graduates (highest grade completed is 12th) and 120 4-year college graduates (highest grade completed is 16th). Observations are weighed. My measure of earnings includes wages, salaries, bonuses, and two-thirds of business income. I compute real earnings by applying CPI weights.

**College attainment**

![Graph](image1)

(a) All

![Graph](image2)

(b) Males and females

Figure 11: College attainment in the United States (employed white individuals): fraction of individuals with a high school diploma that went on to complete a four-year college degree. Source: IPUMS-USA.
Educational attainment

Figure 12: Educational attainment in the United States (employed white individuals): fraction of individuals in a cohort by highest degree attained. Source: IPUMS-USA.

B Model Derivations

On-the-job human capital accumulation. If an agent of type \((z, h_1)\) never returns to full-time investment once he stops full-time investment, the on-the-job accumulation problem has a closed form solution. This condition is satisfied if (i) \(\delta \in (0, 1]\), and (ii) price growth does not increase “too much” over the lifecycle. The analytical solution of the on-the-job accumulation problem is as follows:

\[
V_j(h_j; z, w | S) = \begin{cases} 
    w_j \left[ h_j a_j + b_j^S z^{1-\beta_S} \right] & h_j \geq h_j^*(z, w | S) \\
    \frac{1}{R} V_{j+1} \left( z h_j^{\delta_S} + \delta h_j; z, w | S \right) & h_j < h_j^*(z, w | S),
\end{cases}
\]

where \(h_j^*\) is the cutoff level of human capital at age \(j\) under which the individual spends all his time on human capital accumulation. The recursive formulation of the two constants is:

\[
a_j = \begin{cases} 
    1 & j = T \\
    1 + \frac{1+g_j}{R} a_{j+1} & j < T
\end{cases}
\]

\[
b_j^S = \begin{cases} 
    0 & j = T \\
    \gamma \left( \frac{1+g_j}{R} a_{j+1}^{1-\beta_S} \right) + b_{j+1} \frac{1+g_j}{R} & j < T
\end{cases}
\]

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for $T = 20$ and $\gamma = \beta_1^{1-\beta_S} - \beta_S^{1-\beta_S}$. This can be written in non-recursive form as:

$$a_j = \sum_{u=0}^{T-j} \delta^u \prod_{k=1}^{u} \frac{1 + g_{j-k+1}}{R},$$

$$b_j^S = \begin{cases} 
\gamma \left( \frac{1 + \gamma_j}{R} \right)^{1-\beta_S} \left[ \frac{1}{a_j^{1-\beta_S}} + \sum_{u=1}^{T-j-1} \left( a_{j+u+1} \prod_{k=1}^{u} \frac{1 + g_j + k}{R} \right)^{1-\beta_S} \times \right] & j = T, \\
\times \left( \prod_{k=1}^{u} \frac{1 + g_j + k-1}{R} \right)^{1-\beta_S} & j < T.
\end{cases}$$

**College quality.** For an agent of cohort $\tau$ and type $(z,h_1)$, the first order conditions for college quality for the case of no full-time accumulation on the job are:

$$u_1 e^{-\eta^2} \left[ (zh_1^{\eta^{-1}} (1 + g_\tau)^{1-\eta})^{-1} + (e w_\tau)^{\eta-\eta^2} \right]^{-\eta-1} \left[ zh_1^{\eta^{-1}} u_2 + e^{\eta-1} u_3 \right] + e^{-\eta} u_4 = u_5, \quad (6)$$

where

$$\eta w_\tau^{-\eta^2} (1 + g_\tau)^{1-\eta} = u_1 \quad \quad w_\tau (1 + \eta) = u_2 \quad \quad w_\tau^\eta = u_3 \quad \quad w_\tau^{1-\eta} = u_4 \quad \quad \frac{R^2}{(1 + g_\tau)(1 + g_\tau + 2)} \left( 1 + \frac{1 + g_\tau}{R} \right) \frac{1}{(1-\eta)a_3 z h_1^\eta} = u_5$$

The LHS of eq. 6 is decreasing in $e$ and the RHS of eq. 6 is a constant greater than zero for $\eta \in (0,1)$. Moreover, it is true that:

$$\lim_{e \to \infty} LHS = 0, \lim_{e \to 0} LHS = \infty.$$ 

This assures that the solution for $e$ exists and is unique for each type $(z,h_1)$. 

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C Calibration Details

C.1 Deep parameters

Identification: initial endowments. The distribution of initial endowments is identified with the age variation of unconditional earnings moments and the college premium. Earnings of a \( j \)-year-old individual of type \((z, h_1)\), born in \( \tau \), with education \( S \), are

\[
E_j(h_1, z, w \mid S) = w_{\tau+2(j-1)} h_{j-1} - w_{\tau+2(j-1)} i_j h_j,
\]

that is:

\[
w_{\tau+2(j-1)} h_{j-1} = w_{\tau+2(j-1)} h_{j-1} \delta_{j-1} -
\]

\[
w_{\tau+2(j-1)} z_1 \left( \beta_g a_{j+1} \frac{1 + g_{\tau+2(j-1)}}{R} \right)^{\frac{1}{1-\beta_g}} - \sum_{u=1}^{j-1} \left( \beta_g a_{u+1} \frac{1 + g_{\tau+2(u-1)}}{R} \right)^{\frac{1}{1-\beta_g}} \delta_{j-1-u},
\]

for \( a \) as defined in Appendix B. Average innate ability influences the slope of the earnings profile. Agents with higher innate ability allocate more time to human capital accumulation and so have low initial earnings. Later in life, their earnings are higher following higher human capital investment (in college and on the job). The level of initial human capital influences the intercept of an individual’s earnings profile and its concavity. The coefficients of variation of innate ability and initial human capital influence the life-cycle dynamics of earnings dispersion. A lower dispersion in innate ability implies a lower increase in the coefficient of variation of earnings over the lifecycle. When all agents are born with equal innate ability but different initial human capital levels, the model generates a pattern of decreasing earnings dispersion over the lifecycle through human capital accumulation. Dispersion in initial human capital determines the concavity of the life-cycle profile of earnings dispersion. The correlation of innate ability and initial human capital disciplines how the two dimensions of heterogeneity come together to shape life-cycle earnings dynamics. The college premium helps in the identification of the dispersion of initial human capital and the correlation between innate ability and initial human capital.


<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>College attainment</td>
<td>35.26%</td>
<td>35.77%</td>
</tr>
<tr>
<td>College premium</td>
<td>1.365</td>
<td>1.382</td>
</tr>
<tr>
<td>Average college expenditures</td>
<td>41.54%</td>
<td>39.35%</td>
</tr>
</tbody>
</table>

Table 5: Model fit. College attainment, college premium and college expenses.
C.2 Cohort-specific parameters

**Identification: price growth.** When investment in human capital is negligible:

\[ E_j = w_{\tau+2(j-1)}h_j - w_{\tau+2(j-1)}i_j h_j \simeq w_{\tau+2(j-1)}h_j, \]

\[ E_{j+1} = w_{\tau+2(j)}h_j - w_{\tau+2(j)}i_{j+1} h_j \simeq w_{\tau+2(j)}h_j, \]

and therefore \( g_{\tau+2(j-1)} \simeq g_{E_j} \).