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## Explaining the evolution of educational attainment in the U.S.

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**by**

**Rui Castro and Daniele Coen-Pirani**

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# Explaining the Evolution of Educational Attainment in the U.S.\*

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## Abstract

We study the evolution of educational attainment of the 1932–1972 cohorts using a human capital investment model with heterogeneous learning ability. Inter-cohort variation in schooling is driven by changes in skill prices, tuition, and education quality over time, and average learning ability across cohorts. Under static expectations the model accounts for the main empirical patterns. Rising skill prices for college explain the rapid increase in college graduation till the 1948 cohort. The decline in average learning ability, calibrated to match the evolution of test scores, explains half of the stagnation in college graduation between the 1948 and 1972 cohorts.

*Keywords:* Educational Attainment, Human Capital, Skill Prices, Inequality, Cohorts.

*JEL Classification:* I24, J24, J31, O11.

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# 1 Introduction

Understanding the evolution of educational attainment is important because of the tight link between investment in education, individual welfare, and wage inequality. In this paper we study the evolution of educational attainment of the 1932–1972 birth cohorts of U.S. white males.<sup>1</sup> The 1932–1948 cohorts experienced a cumulative increase in college graduation rates in excess of 14 percentage points. Strikingly, college attainment has basically not improved since this early expansion. Graduation rates actually declined by 10 percentage points between the 1948 and the 1960 cohorts, followed by a slow recovery. The college graduation rate of the 1972 cohort is still 3 percentage points lower than the graduation rate of the 1948 cohort.

We ask whether a calibrated structural model of education choices in which individuals are characterized by heterogeneous abilities to learn and financial markets are frictionless can explain these and other features of the data. The driving forces of educational attainment are changes over time in skill prices, tuition, education quality, and changes across cohorts in average learning ability. The inter-cohort variation in average learning ability is a novel and central feature of our analysis. Using a variety of standardized achievement tests, assembled and analyzed by the Congressional Budget Office (Koretz, 1986, 1987), we document a substantial decline in test scores for American elementary and secondary school students starting with the cohorts born in the late 1940s-early 1950s.<sup>2</sup> This evidence is used to calibrate the evolution of average learning ability in the model. The timing of this test score decline tends to coincide with the beginning of the stagnation in college graduation rates in the U.S. In addition, while the 1932–48 cohorts experienced a sustained decline in high school dropout rates, the cohorts that followed dropped out of high school at about the same rate as the 1948 one. We view this parallel evolution of college attainment and the high school dropout rate as an indication

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<sup>1</sup>Our focus is on males. For papers studying the educational attainment of women, jointly with their labor supply decision, see e.g. Jones, Manuelli and McGrattan (2003) and Rendall (2010).

<sup>2</sup>Bishop (1989) quantifies the effect of the “historically unprecedented” (in his words) test score decline on U.S. labor productivity growth. He estimates that the present discounted value of the economic losses from the test score decline corresponds to about 3/4 of U.S. GDP in 1987.

that cohort-specific (rather than degree-specific) factors, such as changes in average learning ability, are promising for understanding the data.

The model attributes almost two thirds of the increase in the college graduation rates of the early expansion (1932–1948) cohorts to a rising relative skill price for college graduates in the 1950s and 1960s. Skill prices, however, are inconsistent with the subsequent stagnation in college attainment. The observed skill price variation cannot account for the decline in college graduation rates of the 1948–1960 cohorts, and would predict a strong recovery of college graduation rates for the 1960–1972 cohorts. The model attributes the stagnation of college attainment between the 1948 and the 1972 cohorts to rising tuition and declining average learning ability, in approximately equal parts. Specifically, the college graduation rate of the 1972 cohort would have been 2.5 percentage points higher if average learning ability had remained constant. Moreover, the learning ability channel is the single-most important factor in accounting for the observed *decline* in college graduation rates of the 1948–1960 cohorts.

An important feature of our analysis is static expectations, that is, expectations of future relative skill prices based on *current* skill premiums. Its importance for understanding educational attainment has also been emphasized, among others, by Keller (2014) and Donovan and Herrington (2013). Static expectations prevent agents choosing whether to attend college in the early 1960s from taking into account the decline in returns to college of the 1970s. Therefore, they help generate the early college expansion. By contrast, perfect foresight about the evolution of skill prices in the 1970s would have dampened the incentives to attend college in the 1960s. A similar intuition explains why the model is successful in accounting for the decline in college attainment during 1970s and for the slow recovery during the 1980s.

This paper is related to a growing literature that seeks to uncover the economic forces that explain the evolution of educational attainment in the U.S. The importance of skill prices in this process has been emphasized in recent quantitative work by, among others, Heckman, Lochner and Taber (1998), Topel (1997, 2005), Lee and Wolpin (2010), and Restuccia and Vandenbroucke (2013b).<sup>3</sup> Our results are

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<sup>3</sup>There is also an extensive and well-known literature following the seminal work of Katz and Murphy (1992) and including Topel (1997), Autor, Katz and Kearney (2008) and Goldin and Katz

consistent with these papers, as in our model educational attainment reacts strongly to the incentives provided by higher returns to schooling. Indeed, this mechanism explains the rapid increase in college attainment for the cohorts up to 1948. However, some authors, such as Goldin and Katz (2008, page 347) and Carneiro and Heckman (2003, page 3), have expressed concern about the lack of a stronger reaction of college attainment to the rise in the college premium during the 1980s and have suggested that additional forces should be taken into account.

Differently from these papers, we focus on the *cohort-by-cohort* variation in attainment. This allows us to highlight the cohorts most responsible for the overall attainment gains, and also to evaluate the role of cohort-specific effects, which are central to our analysis. The cohort perspective ties our paper to a number of others. Some use reduced-form empirical models, while others adopt structural approaches. Among the former, Card and Lemieux (2001) regress men’s college graduation rates by cohort on returns to education, cohort size, and tuition.<sup>4</sup> After controlling for these factors, they find evidence of an unexplained “collapse” in the long-run trend in educational attainment for the cohorts of men born after 1950. Aside from methodological differences, our contribution is complementary to theirs, as we emphasize the role played by the decline in average learning ability. In addition, we deal explicitly with the issue of changing selection across schooling levels and the related problem of measuring skill prices separately from wages (Heckman, Lochner and Taber, 1998, and Hendricks and Schoellman, 2014). In the structural literature, three papers (Keller, 2014; Donovan and Herrington, 2013; Gemici and Wiswall, 2014) focus on the evolution of educational attainment by cohort in the U.S. and are, therefore, particularly close to ours. We postpone a detailed discussion to Section 5.3. One aspect of the college attendance decision that has been recently emphasized in the literature is risk (Athreya and Eberly, 2013; Garriga and Keightley, 2013). Our model allows for heterogeneous outcomes associated with schooling attendance, but it does not feature individual-level uncertainty due to, for example, dropout or earnings risk. We discuss the issue of risk more extensively in Section 3.1.

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(2008), arguing that shifts in attainment are a major causal source of variation in returns. Our analysis is consistent with this view, but we focus on the causality working in the opposite direction.

<sup>4</sup>Bound and Turner (2007) and Lee (2005) study the effect of cohort size on college attainment.

The rest of the paper is organized as follows. Section 2 presents the data we seek to explain and the main exogenous forces. Section 3 introduces the model. Section 4 describes the empirical implementation. Section 5 presents the results from the benchmark model. Section 6 concludes. The appendices contain formal propositions and provide additional information about the data and the calibration.

## 2 Empirical Evidence

Section 2.1 presents the stylized facts about the evolution of educational attainment across cohorts in the U.S. Sections 2.2–2.4 provide an overview of the driving forces of educational attainment in our analysis. We focus throughout on the sample of white males, ages 23–65, who are full-time and full-year workers.<sup>5</sup> Our main data sources for educational attainment and returns to schooling are the March Current Population Surveys (CPS), 1964–2010, and the 1950 and 1960 Censuses.<sup>6</sup>

### 2.1 Educational Attainment

We allow for four possible educational categories based on the highest completed grade of school or year of college: 1. more than ninth and less than twelfth grade (“high school dropout”); 2. twelfth grade and/or a high school degree or GED (“high school graduate”); 3. one to three years of college, including two-year college programs, but no four-year college degree (“some college”); 4. at least a four-year college degree (“college graduate”). Figure 1a shows the fraction of individuals in each cohort with a given level of schooling, for the 1932–1972 cohorts.

The data shows a rapid increase in attainment for the 1932–1948 birth cohorts. The proportions of individuals with four-year college degrees and some college rises for these cohorts, while the fraction with only a high school degree is constant or declines, and the proportion of high school dropouts falls.<sup>7</sup> For the 1949–1960

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<sup>5</sup>We obtained very similar dynamics of educational attainment for the entire population of white males.

<sup>6</sup>See Appendix C.2 for details on the sample and the measures of educational attainment.

<sup>7</sup>In Appendix C.1 we discuss and quantify the evidence on the impact of the Korean and Vietnam wars on the evolution of college attainment. Based on our reading of the literature we conclude that these events had a relatively minor impact on the patterns of attainment discussed in this section.

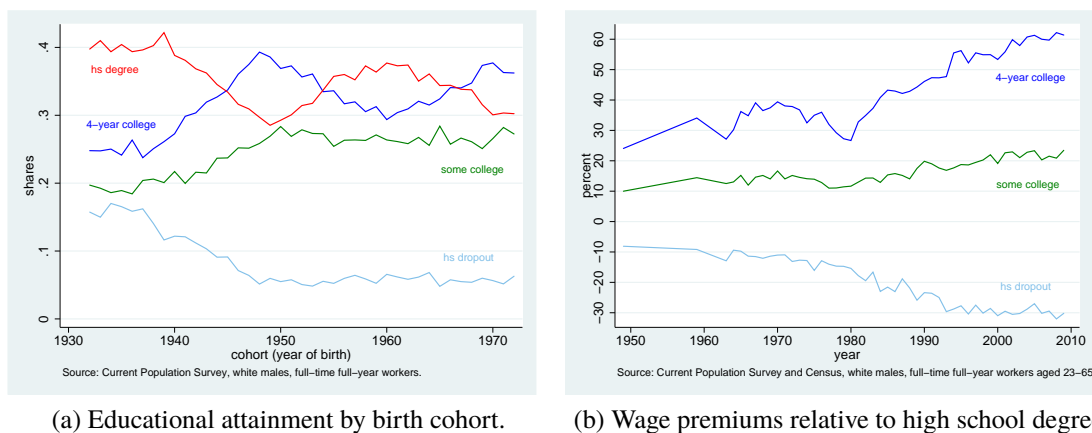


Figure 1: Educational attainment and wage premiums

cohorts, educational attainment in terms of four-year college drops, the fraction with some college stagnates, and the proportion of individuals with only a high school degree rises again. For the post-1960 cohorts the fraction of the population with at least a four year college degree rises again, although at a slower pace than for the earlier period. The fraction with some college and the portion of high school dropouts remain flat, instead. These patterns are consistent with the analysis of many other authors, such as [Topel \(1997, Figure 3\)](#), [Card and Lemieux \(2001, Figure 9.4\)](#), [Carneiro and Heckman \(2003, Figures 1-3\)](#), [Topel \(2005, Figure 2\)](#), [Goldin and Katz \(2008, Figures 7.1, 7.2 and 9.2\)](#). These stylized facts are also evident if we do not restrict attention to full-time and full-year workers but, instead, consider the population of white males at large.

## 2.2 Education Earnings Premiums

Figure [1b](#) shows the evolution of education earnings premiums over time (not cohort). We define education earnings premiums as the coefficients in year-by-year cross-sectional regressions of individual-level log weekly earnings on a full set of dummies for potential experience and dummies for education groups. The education earnings premiums are defined relative to the group with a high school degree. The relative wage of an individual with a four-year college degree increased



slowly during the 1950s until the late 1960s, after which it declined during the 1970s until the year 1980. Since then this relative wage has been increasing steadily. By contrast the relative wage of high school dropouts have declined steadily from the early 1970s to the early 1990s, and have settled down since then. Also these basic trends are well-known and have been documented elsewhere (see, for example, [Autor, Katz and Kearney, 2008](#), Figure 2 and Table 1). While we do not equate average wages with skill prices, the skill prices we compute (see Figure 3 below) display similar qualitative trends as the education earnings premiums of Figure 1b.

## 2.3 Tuition and Education Expenditures

Figure 2a displays the evolution of the average real present value of four- and two-year college sticker price tuition faced by an individual in each cohort at the time of college entry.<sup>8</sup> As Figure 2a shows, tuition in four-year college programs has increased at a faster pace for the cohorts born after 1960 (see for example [Kane, 1999](#)). This trend might have contributed to the relatively slow rise in four-year college attainment for these cohorts. For this reason we include variation in tuition over time in our model economy.<sup>9</sup>

Since the standard [Ben-Porath \(1967\)](#) model of investment in human capital emphasizes time and goods as inputs in the creation of new human capital, we include both in our model. Following [You \(2014\)](#) and others we use the evolution of education expenditures as a proxy for how the quality of education has changed over time. Figure 2b displays the postwar evolution of real expenditures per student in elementary and secondary schools, and two and four-year college programs.<sup>10</sup> The most notable feature is that real per student expenditures rise at the post-secondary schooling levels until 1970, and then either suddenly stagnate or decline. [Kane,](#)

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<sup>8</sup>The interest rate used to discount tuition is five percent per year, as consistent with the calibration of the model. The tuition data, from the Digest of Educational Statistics, represent the average (across public and private institutions) sticker price of two and four years colleges and universities. See Appendix C.3. We use the consumer price index to convert nominal figures into real ones.

<sup>9</sup>We abstract from geographic variation in tuition across states and emphasize its evolution over time. See [Kennan \(2013\)](#) for a model of college choices and migration with many locations.

<sup>10</sup>Nominal expenditures per student are from the Digests of Education Statistics, and deflated using NIPA's Personal Consumption Expenditure price index for education services (Appendix C.4).

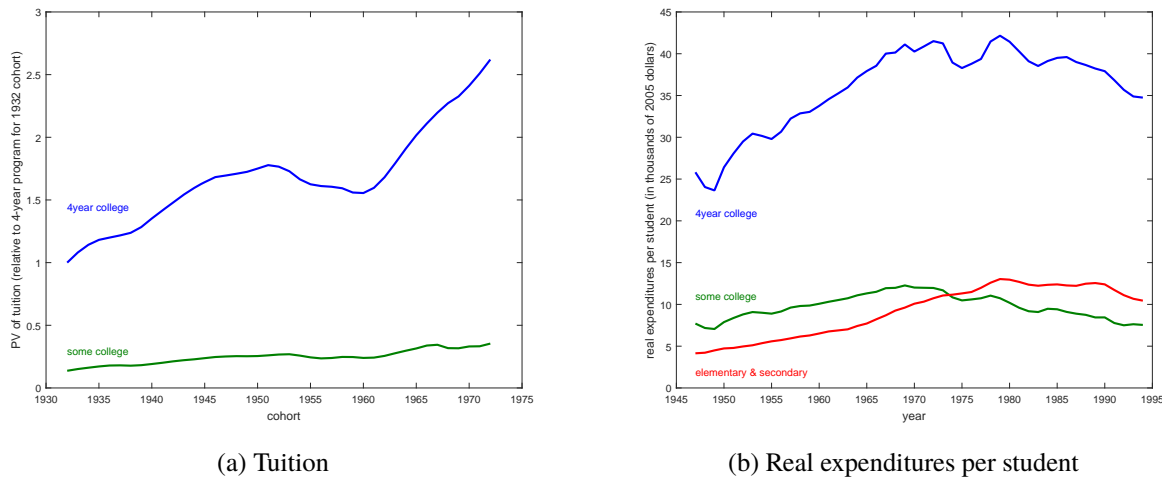


Figure 2: Tuition and education expenditures

Orszag and Apostolov (2005), Bound and Turner (2007), and Fortin (2006), have also highlighted and discussed the changing patterns of per student expenditures.

## 2.4 Evidence on the Evolution of Test Scores

A key ingredient of our analysis is inter-cohort variation in mean learning ability. In order to calibrate the evolution of mean learning ability across cohorts we rely on two related and lengthy studies published by the Congressional Budget Office (CBO), Koretz (1986, 1987).<sup>11</sup> These studies summarize the available evidence on the trends in standardized test scores of elementary and secondary school students across birth cohorts and grades. As we discuss in Section 4.1.3, our calibration strategy consists of inferring changes in mean learning ability across cohorts by matching the corresponding evolution of test scores measured at age 15, as documented by the CBO. We now discuss in detail the relevant evidence on test score decline.

Three relevant trends emerge from the data analyzed by the CBO. First, a variety of test scores show a progressive decline starting with the late 1940s-early 1950s

<sup>11</sup>These studies were commissioned to the CBO by the U.S. Subcommittee on Education, Arts, and the Humanities of the Senate Committee on Labor and Human Resources. See also Hanushek (1986) for a discussion of these trends.

cohorts. Second, the decline in test scores is only clearly evident in later grades, especially after grade 4. Third, the decline stops with the early 1960s cohorts.<sup>12</sup>

**The decline phase** Numerous standardized tests show a progressive decline in performance starting with the cohorts born in the late 1940s-early 1950s and ending with the cohorts born in the early to mid 1960s. Tables III-1, III-2 and C-1 in [Koretz \(1986\)](#) provide a summary of the evidence on the timing and extent of the decline in a variety of tests and subject areas. The largest decline in test scores is recorded by the ACT (social studies) according to which the median student in the cohort at the end of the decline would have scored at the 29th percentile in the cohort at the beginning of the decline. College entrance exams such as the ACT or SAT, however, suffer from obvious selection biases. Therefore, in our analysis we focus on the composite score on tests taken by 8th graders. In addition to being free from selection issues, the 8th grade test concords well with the timing of our model because it measures skills accumulated prior to the age when schooling choices are made. The specific 8th grade test reported by the CBO is the Iowa Test of Basic Skills (ITBS).<sup>13</sup> The decline in the 8th grade ITBS-composite begins with the 1953 cohort and ends with the 1963 cohort. The magnitude of the decline is 0.3625 standard deviations, making the median 8th grader in the 1963 cohort perform at the level of the student in the 36th percentile in the 1953 one.<sup>14</sup>

The data analyzed by the CBO refer to populations that include both male and female students as well as whites and minority students alike. [Koretz \(1986, page 68\)](#) contains a brief discussion of these trends for males and females separately,

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<sup>12</sup>We focus explicitly on the decline in test scores for the 1953–1963 cohorts. Figure IV-3 of [Koretz \(1986\)](#) also shows the evolution of test scores for the 1940–1953 and the 1963–1971 cohorts. According to this evidence, test scores had been increasing up to the 1953 cohort and display a partial recovery following the 1963 one. Our model is able to account for both of these trends because of changes over time in school quality. See footnote (49).

<sup>13</sup>Although the latter is a standardized test currently used by numerous school districts throughout the U.S., the CBO data refers to Iowa students only. The reason is that the *entire* population of 8th graders in that state has consistently taken the ITBS over the course of several decades, making it possible to compare scores over time. The test score decline on the ITBS is, however, also evident in national samples. See Figure 4.1 and Table 4.3 in [Iowa Testing Programs \(2010\)](#).

<sup>14</sup>The timing of the decline is from Table III-1 in [Koretz \(1986\)](#), while its magnitude is computed by averaging the declines for the subjects that make up the composite score using data from Table C-1 of the same publication.

although such comparison is limited by data availability. The upshot is that the decline was sizable for both groups, although the exact magnitude varied by sex depending on the subject. The report also makes clear (page 75) that composition effects associated with race are not driving the decline, as black students experienced smaller and shorter declines in test scores than whites.

An important point that the CBO report (Koretz, 1986, page 32 and Appendix B) discusses is whether the decline phase of test scores reflects year or cohort effects. While the available evidence on this issue is limited, the report concludes that “the cohort model fits the data more closely than does the period model” (page 118). Our reading of the educational attainment data in Figure 1a tends to support this conclusion. The 1948 cohort marks not only the peak in four-year college attainment in our sample, but also the bottom in high school dropout rates. The stagnation in college attainment for subsequent cohorts has its counterpart in the lack of further declines in high school dropout rates. This points to the possibility that cohort-specific factors play an important role in accounting for the evolution of educational attainment. We elaborate on this point in Section 5.2.

**Test score decline by grade** A key question that we need to address in order to calibrate our model is whether the evidence on test score decline is symptomatic of a reduced ability to learn during individuals’ school years or, alternatively, of a lower level of human capital at the time when school begins (around ages 6–7). In the rest of the paper we favor the former interpretation over the latter based on the available data on test scores across cohorts and grades. The main feature of the test score data by grade is that there is little or no evidence of a decline in test scores across cohorts in the early grades. For example, Figure IV-3 of Koretz (1986) shows essentially no change in the grade 4 ITBS between the 1953 and the 1963 cohorts (if anything there is a very slight increase). While Koretz (1986) presents only a figure and not the exact test score numbers for grade 4, we obtained some quantitative information for the earlier grades from Table 4.3 of Iowa Testing Programs (2010). The information reported is for median differences in test scores between a handful of years, and is measured in 1995 National Grade Equivalent “Months.” Table 4.3 of Iowa Testing Programs (2010) shows that, in grade 4, the 1960 cohort performed

*better* than the 1945 cohort by a 2.9 month equivalent. A similar pattern emerges for grade 3.<sup>15</sup> Thus, the decline in test scores observed for the later grades was not present early on. The CBO evidence is therefore consistent with a decline in learning ability rather than early human capital.

**The end of the decline** The decline in the 8th grade ITBS-composite ends with the 1963 cohort. Koretz (1986, page 46) also discusses an upturn phase in which test scores started to rise beginning with the mid-1960s cohorts. By the 1972 cohort, the last in our analysis, the 8th grade ITBS composite score recovers to about two-thirds of its peak reached by the 1953 cohort (Figure IV-3 in Koretz, 1986).<sup>16</sup>

**Candidate explanations** The CBO reports also assess the evidence in favor of alternative explanations for the test score decline (Koretz, 1987, Table 1). These fall into three broad categories. First, there are educational factors associated with measures of teacher quality (experience and education) and changes in content of coursework and homework. Second, there are societal factors such as the changing ethnic composition of the population of students, desegregation of schools, changes in the number of children per family, and the rise in single-parent households. Last, there are changes in the composition of the population of students taking the college admission tests (SAT and ACT). The CBO analysis shows that, first, there is no *single* cause that appears to explain the trend in test scores. Many of the factors listed above contribute to the aggregate trend, although the contribution of each is typically small. Among the potentially important factors, the rise in average family size associated with the baby boom stands out. Moreover, the CBO concludes

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<sup>15</sup>As a matter of comparison, in grade 8 the 1963 cohort was behind the 1949 cohort by an equivalent of 6.1 months of schooling.

<sup>16</sup>The evidence on the upturn is mixed if one considers other available data. The nationally representative National Assessment of Educational Progress (NAEP) data (see Hanushek, 2003, Figure 1) also shows a consistent decline in science and math test scores for 17 years old students between 1969 (1952 cohort) and 1982 (1965 cohort). By the 1972 cohort (the last we study), the math score has completely recovered to the value achieved by the 1956 cohort, while the science score is still significantly lower than its 1952 cohort counterpart. Similarly, the SAT verbal scores for the 1972 cohort of males are basically identical to the corresponding ones for the 1962 cohort, while the SAT math scores, instead, show only a slight improvement between these two cohorts (see Profile Report of Total Group, 2013).

that a number of factors - such as changes in teacher quality, the rise in single-parent households, and the rise in female labor force participation - probably did *not* contribute significantly to the trends, while others, like changes in coursework in K-12 education, cannot be quantified because of lack of data.

### 3 Model

Consider a simple partial equilibrium model where agents differ in terms of birth cohort, learning ability, and taste for education. Financial markets are frictionless, so education choices are not constrained by an individual's financial resources.

#### 3.1 Basic Elements of the Model

We study the education choices of individuals in different cohorts indexed by  $\tau$ . An agent's life starts at age  $a = 7$  when the individual is enrolled in his first year of school.<sup>17</sup> Between ages 7 and 16 individuals are supported by their parents and attend school, allowing them to accumulate human capital without making any economic choice. Schooling choices are made at age 17, when an agent has the option of continuing his high school education or start working. This is also the age at which the individual becomes financially independent from his parents. Upon leaving school individuals start working and continue accumulating human capital through experience all the way to age  $A$ , at which point the individual dies.<sup>18</sup>

**Human Capital Accumulation** Human capital is accumulated through schooling and experience. There are four schooling levels, denoted by  $j$ . Each level is characterized by a length of study  $S_j$  during which the individual is assumed not to be able to work in the labor market. Specifically, the schooling levels are: four-year college and above ( $j = 1$ ) involving a total of  $S_1 = 16$  years of school; some college

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<sup>17</sup>In practice, children in the U.S. start first grade between ages 6 and 7. Starting school at age 7 implies that an individual graduates from a four-year college at age 23 after 16 years of schooling. This assumption is inconsequential for any of our results.

<sup>18</sup>We do not include a retirement period in the model. Given the fact that education choices are made at age 17 and that individuals discount the future this assumption is quantitatively innocuous. For the same reason we abstract from changes in the duration of working life across cohorts.

( $j = 2$ ) involving  $S_2 = 14$  years of school; high school degree ( $j = 3$ ) for a total of  $S_3 = 12$  years of school; and high school dropout ( $j = 4$ ) involving  $S_4 = 10$  years of school.<sup>19</sup> During the years in which the agent is enrolled in schooling level  $j'$ , human capital of an individual born in year  $\tau$  with learning ability  $\theta$  accumulates according to the law of motion:

$$h_{\tau a+1} = \theta h_{\tau a}^\gamma \left(x_{\tau+a}^{j'}\right)^\varphi + (1 - \mu) h_{\tau a}, \quad (3.1)$$

for  $a = 7 - 22$ .<sup>20</sup> Thus, for example, an agent whose final schooling level is  $j = 1$  (four year college) will be enrolled in school level  $j' = 4$  at ages  $a = 7 - 16$ , in school level  $j' = 3$  at ages  $a = 17$  and  $18$ , and in school level  $j' = 1$  at ages  $a = 19 - 22$ . Similarly for the other choices.

The rest of the notation is as follows:  $\mu$  is the rate of depreciation and the first-term on the right-hand side of equation (3.1) is the investment at age  $a$  for an individual attending school level  $j'$ . The latter increases with an individual's ability to learn  $\theta$ , with the previously accumulated human capital  $h_{\tau a}$  and with the quality of education  $x_{\tau+a}^{j'}$  the individual has been exposed to when attending school level  $j'$ . Empirically, as discussed in Section 4.1.2, we proxy education quality by expenditures per student. Thus, education quality is allowed to vary by schooling level  $j'$  (e.g. it can differ in college relative to high school) and, for given schooling level, by cohort  $\tau$ .<sup>21</sup> The initial human capital at age 7,  $h_{\tau 7}$ , is a parameter and is assumed to be the same for all agents in all cohorts, as discussed in Section 2.4.

The learning ability parameter  $\theta$  is distributed in the population according to a cumulative distribution function  $G_\tau(\theta)$ . We interpret  $\theta$  in a broad sense (see Carneiro and Heckman, 2002) to reflect both innate ability and the influence that family background would have on it by age 7. Motivated by the evidence discussed in Section 2.4, in the quantitative version of the model (Section 4.1.3) we allow

<sup>19</sup>Individuals cannot delay a certain schooling level. For example, they have to start college at age 18. Other papers, such as Lee and Wolpin (2010) and Gemici and Wiswall (2014) allow for more flexibility in this dimension.

<sup>20</sup>Notice that calendar time  $t$  is related to birth cohort and age by the following equation:  $t = \tau + a$ .

<sup>21</sup>We do not allow agents to choose the quality of schooling. Allowing for endogenous schooling expenditures would likely amplify the effect of the decline in mean ability on educational attainment, because of the complementarity in human capital accumulation between school quality and ability.

average learning ability to vary across cohorts.

After completing education level  $j$ , an agent with learning ability  $\theta$  is endowed with human capital  $h_{\tau 7+S_j}^j(\theta)$ . Starting from that point, if he begins to work, his human capital evolves exogenously over time according to:

$$h_{\tau a}^j(\theta) = h_{\tau 7+S_j}^j(\theta) \exp \left( \delta_1^j (a - S_j - 7) + \delta_2^j (a - S_j - 7)^2 \right) \text{ for } a = 7 + S_j, \dots, A, \quad (3.2)$$

where  $\delta_1^j$  and  $\delta_2^j$  are the parameters governing the returns to experience. Notice that they are allowed to depend on the schooling level  $j$ , but not on calendar year.<sup>22</sup>

**Preferences** Individuals' preferences have two components. The first reflects consumption over the life-cycle while the second reflects preferences for specific education choices. An agent in cohort  $\tau$  with ability  $\theta$ , and schooling preferences  $\xi_i \equiv (\xi_i^1, \xi_i^2, \xi_i^3, \xi_i^4)$ , maximizes the present discounted value of utility as of age 17, defined as:<sup>23</sup>

$$\sum_{a=17}^A \beta^a \ln c_{\tau a}^j + \sigma \left( \xi_i^j + \bar{\xi}^j \right), \quad (3.3)$$

where  $c_{\tau a}^j$  denotes consumption and the parameter  $\beta$  is the constant discount factor. The random variable  $\xi_i^j$  represents individual  $i$ 's preferences for schooling-level  $j$ .<sup>24</sup> These shocks are independent across degrees  $j$  for the same individual  $i$ . We also assume that each  $\xi_i^j$  is independently distributed in the population according to a standard type-I extreme value (or Gumbel) distribution. Each individual  $i$  is assumed to observe the vector of shocks  $\xi_i$  at age 17 before making education and consumption choices. The parameter  $\bar{\xi}^j$  is degree-specific but constant across individuals and over time. It captures the average taste for degree  $j$  in the population.

<sup>22</sup>The returns to experience do not depend on the ability to learn parameter  $\theta$  after conditioning on schooling. This specification is consistent with some of the earlier literature (You, 2014; Gemici and Wiswall, 2014). The main advantage of this modelling choice is that it allows us to estimate the majority of the parameters that govern the evolution of skill prices over time before solving the model (Section 4.1.1). See Kong, Ravikumar and Vandenbroucke (2015) for a model of college choice in which returns to human capital accumulation while working depend on agents' ability.

<sup>23</sup>The age at which agents maximize utility does not affect their schooling choices and is therefore irrelevant for our results.

<sup>24</sup>To save on notation, we omit the subscript  $i$  from consumption and human capital choices.



Finally, the parameter  $\sigma \geq 0$  determines the relative importance of degree-specific preferences relative to the present value of utility from consumption (economic fundamentals) in determining schooling choices. The preference parameters are relevant for quantitative purposes. The idiosyncratic preference shock  $\xi_i$  breaks the strict sorting of education choices on learning ability and allows for a degree of ability mixing within each schooling level.<sup>25</sup> It also ensures that attainment levels are always strictly positive, and respond smoothly to variations in exogenous variables. The average psychic rewards from education  $\bar{\xi}^j$  allow us to target the average attainment levels in the data. The model's task is to account for the attainment *dynamics* across cohorts, given the average attainment levels. As  $\sigma$  increases, exogenous preference-related factors become more important in explaining agents' education choices relative to economic factors such as the returns to skill. In the limit, as  $\sigma \rightarrow \infty$ , economic factors become irrelevant.

**Expectations** In order to make their consumption and schooling decisions at age 17, individuals in each cohort  $\tau$  need to formulate expectations about the path of skill prices,  $\{w_{\tau+a}^j\}_{a=7+S_j}^A$  for all  $j$ , they will face during their lifetime. We consider two alternative specifications for the formation of expectations.

The first is perfect foresight: agents are assumed to know the future realization of the series of skill prices at the time they make education choices. The assumption of perfect foresight is obviously strong, as it endows agents with the ability to predict skill prices trend shifts that are largely unexpected to researchers and policymakers.<sup>26</sup> It is, therefore, common in the literature to consider expectations of future skill prices based on skill prices observed by the agent at the time of education choices.

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<sup>25</sup>In other related models of education choice, such as Willis and Rosen (1979), Lee and Wolpin (2010), and Gemici and Wiswall (2014), individuals are characterized by a comparative, rather than absolute, advantage in certain schooling levels. Our model of ability is therefore a special case of those more general specifications. In our model, degree-specific taste shocks prevent perfect sorting on ability in education choices. In practice, given the available data, it might be difficult to distinguish between these alternative approaches.

<sup>26</sup>As an example, in the 1970s - a period with declining college premiums - the academic debate on college attainment centered around the issue of whether Americans were "overeducated" (Freeman, 1976). It might be difficult to argue that individuals making college decisions during the 1970s were able to anticipate the large increase in returns to schooling that would start taking place just a few years later.

Departures from perfect foresight are often shown to improve the fit of the attainment data, at least in some dimensions (e.g. Keller, 2014; Donovan and Herrington, 2013).

We thus consider a second specification of expectations, which we label “static.” We postulate that agents in cohort  $\tau$  make their schooling plans by assuming that skill prices will remain constant at the level  $w_{\tau+17}^j$  they observe when they make schooling decisions. This is the age in the model when individuals have the opportunity to dropout of high-school. Given the way we measure the level of skill prices in the data, based on cross-sectional information, this assumption is akin to supposing agents base schooling decisions on the contemporaneous cross-sectional skill premiums. This is the assumption entertained by Card and Lemieux (2001) and Topel (1997). We make the following two ancillary assumptions, which allow us to simplify our analysis and concentrate on the role of skill price expectations: (i) individuals commit to schooling decisions based on the perceived prices, and cannot change their choices later on when new information becomes available;<sup>27</sup> and (ii) individuals are able to perfectly forecast the tuition and school quality levels that are relevant for their own education choices.

Denote by  $\widehat{w}_{\tau+a}^j$  the skill price associated with education choice  $j$  expected at age  $a$  by an agent who is a member of cohort  $\tau$ . Under perfect foresight, it is the case that  $\widehat{w}_{\tau+a}^j = w_{\tau+a}^j$ , while under static expectations  $\widehat{w}_{\tau+a}^j = w_{\tau+17}^j$ .

**Budget Constraint** An individual of cohort  $\tau$  and learning ability  $\theta$  that makes education choice  $j$  faces the following lifetime budget constraint:

$$\sum_{a=17}^A R^{-a} c_{\tau a}^j = \sum_{a=7+S_j}^A R^{-a} (1 - \lambda) \widehat{w}_{\tau+a}^j h_{\tau a}^j(\theta) - Z_{\tau}^j, \quad (3.4)$$

where  $R$  is the exogenous gross interest rate,  $\lambda$  is the labor income tax rate, which we assume to be constant, and  $Z_{\tau}^j$  is the present value of tuition for any individual in cohort  $\tau$  who picks schooling option  $j$ . We assume that secondary schooling is publicly financed so that tuition is paid only by individuals attending college

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<sup>27</sup>Planned consumption decisions will instead differ from actual ones, depending on the skill price realizations. Our ancillary assumption ensures that this won't affect schooling decisions.

( $Z_\tau^4 = Z_\tau^3 = 0$ ). The present value of tuition  $Z_\tau^j$  is defined as:

$$Z_\tau^j = \sum_{a=7+S_3}^{S_j} R^{-a} z_{\tau+a}^j, \text{ for } j = 1, 2$$

where  $z_{\tau+a}^j$  represents the yearly tuition for an individual in cohort  $\tau$  choosing either a two ( $j = 2$ ) or a four-year ( $j = 1$ ) college.

We assume frictionless financial markets, with no borrowing constraints. We abstract from borrowing constraints not because we do not think they might be important for education choices. Instead, we choose to start out with the simplest possible model. As further motivation, since we study the decisions of the 1932–1972 cohorts, we are unaware of available evidence on the prevalence of borrowing constraints for these cohorts, especially the earlier ones. [Cameron and Heckman \(2001\)](#) have studied the college attendance of the NLSY 1979 cohorts (1957–1964 cohorts) and found that for these cohorts credit constraints play a minor role in explaining differential rates of college attendance between whites, blacks and hispanics. They emphasize the role played by factors associated with parental background, rather than short-run parental liquidity, in determining college attendance.<sup>28</sup>

The budget constraint (3.4) also embeds a number of other simplifying assumptions. First, individuals are assumed to work the same exogenous amount of time per year, so there is no endogenous labor supply choice. Thus, the model is more appropriate for investigating the education choices of demographic groups - such as men - characterized by a relatively stable labor supply over the life-cycle. It is also well known that, empirically, higher education is correlated with higher labor supply. In order to partially address this issue in the data we restrict attention to the evolution of educational attainment among (male) full-time and full-year workers.<sup>29</sup> Second, we postulate a simple environment in which individual earnings are

<sup>28</sup>However, using the NLSY 1997 (1980-84 cohorts), [Belley and Lochner \(2007\)](#) document a positive correlation between parental income and college attendance even after controlling for measures of ability such as the AFQT score. This suggests borrowing constraints may have started to become more important for the younger cohorts in the NLSY 1979.

<sup>29</sup>[Lee and Wolpin \(2010\)](#) and [Gemici and Wiswall \(2014\)](#) allow for endogenous labor supply in related models that include both male and female agents. [Restuccia and Vandenbroucke \(2013a\)](#) focus on the decision problem of school attendance and the intensive margin of labor supply to

deterministic. Allowing for idiosyncratic earnings shocks would not modify the individual schooling decisions as long as asset markets are complete, as we assume. However, the presence of time trends in the parameters governing the stochastic process for idiosyncratic earnings shocks might affect the computation of the evolution of skill prices. Unfortunately, there is no data set that would allow us to track such evolution across the large number of cohorts we consider. We therefore opt for a simpler setting without idiosyncratic shocks.<sup>30</sup> Third, all agents begin their life with zero wealth and the present value of tuition  $Z_t^j$  is assumed to be the same for all agents in the same cohort.<sup>31</sup> Cross-sectional heterogeneity along these dimensions would contribute to increase the dispersion in schooling choices among individuals with the same learning ability. The model rationalizes this dispersion by assigning a larger weight (i.e. a higher  $\sigma$ ) to preference shocks in schooling decisions. The more important question for our purpose is, however, whether variation across cohorts in average wealth, grants, scholarships, and their distribution in the population affect the evolution of educational attainment. Again, lack of comprehensive data across cohorts on these variables limits our empirical investigation of these channels.

### 3.2 Consumption and Schooling Choices

Individuals maximize utility (3.3) subject to the budget constraint (3.4). They choose a preferred level of schooling and a consumption profile over the life-cycle. Consider the latter problem first. For simplicity, we assume that the discount factor is such that  $\beta R = 1$ , which implies constant consumption over the life-cycle. The

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explain the joint evolution of educational attainment and hours worked.

<sup>30</sup>Relaxing the assumption of complete markets would allow college dropout risk and earnings risk to affect education choices (Athreya and Eberly, 2013; Garriga and Keightley, 2013). This is a potentially important channel, but we are unaware of data on earnings and college dropout risk across different cohorts (starting with the 1932 one) that could be used to quantify its impact on the evolution of educational attainment.

<sup>31</sup>Differences in effective tuition among individuals would emerge because of grants, scholarships, or inter-vivos transfers conditional on schooling choices. With frictionless financial markets, the only channel through which initial wealth affects schooling choices is by reducing the differences in lifetime consumption among alternative levels of schooling. Therefore, wealthier agents base their schooling choices more on the idiosyncratic taste shock than on the present discounted earnings associated with a given level of schooling. Inter-vivos transfers from parents to children that are conditional on the latter's schooling choices will, instead, act as a direct subsidy to the schooling level targeted by parents.

planned consumption level of an individual of cohort  $\tau$  and learning ability  $\theta$  making school choice  $j$  is then:

$$c_{\tau}^j(\theta) = \frac{\sum_{a=7+S_j}^A R^{-a} (1 - \lambda) \widehat{w}_{\tau+a}^j h_{\tau a}^j(\theta) - Z_{\tau}^j}{\sum_{a=17}^A R^{-a}}. \quad (3.5)$$

Notice that the planned consumption choice that is relevant for the selection of a preferred education level is the one based on expected - rather than realized - skill prices. Replace  $c_{\tau}^j(\theta)$  into the utility function to obtain an indirect utility function (exclusive of  $\xi_i$  and  $\bar{\xi}^j$ ):

$$V_{\tau}^j(\theta) = \ln(c_{\tau}^j(\theta)) \sum_{a=17}^A \beta^a.$$

An individual  $i$  of ability  $\theta$  and preference vector  $\xi_i$  is going to select the education level that solves the following problem:

$$\max_j \left\{ V_{\tau}^j(\theta) + \sigma \left( \xi_i^j + \bar{\xi}^j \right) \right\}.$$

It is straightforward to show that, everything else equal, an individual with higher learning ability will tend to stay in school longer because he experiences higher human capital growth while in school (Proposition 1 in Appendix B proves this result for the case  $Z_{\tau}^j = 0$  for all  $j$ ).

Idiosyncratic schooling preference shocks, however, give rise to some mixing of choices, so that some low ability individuals obtain a college degree and some high ability ones drop out of high school. The well-known properties of the type-I extreme value distribution imply that the proportion of individuals of type  $\theta$  in cohort  $\tau$  who choose schooling level  $j$  is:

$$P_{\tau}^j(\theta) = \frac{\exp \left( V_{\tau}^j(\theta) / \sigma + \bar{\xi}^j \right)}{\sum_k \exp \left( V_{\tau}^k(\theta) / \sigma + \bar{\xi}^k \right)}. \quad (3.6)$$

Given that preference shocks are assumed to be uncorrelated with learning

ability, individuals with higher learning ability are more likely to be found in higher schooling levels (Proposition 2 in Appendix B proves this result for the case  $Z_{\tau}^j = 0$  for all  $j$ ).<sup>32</sup> For the same reason, a decline in average learning ability across cohorts tends to reduce average schooling attainment. In the next section of the paper we calibrate the model in order to quantify the importance of the forces driving the evolution of educational attainment.

## 4 Empirical Implementation

Section 4.1 describes our three-step calibration procedure. Section 4.2 discusses the predictions of the model for the educational attainment and education premiums of the two cohorts (1932 and 1972) used in the calibration process.

### 4.1 Setting the Model's Parameters

The empirical approach we follow in order to set the model's parameters and measure skill prices over time consists of three steps. First, we use cohort-level data to identify the evolution of skill prices over time, up to their initial level. Second, we set a number of parameters a-priori. Third and last, we calibrate the remaining parameters and the initial level of skill prices in order to match a number of key moments in the data. The following subsections describe each of these three steps.

#### 4.1.1 Step 1 - Evolution of Skill Prices and Experience Profile

We exploit variation over time in the average earnings of individuals of a given schooling group and cohort to identify the evolution of skill prices and to partially identify the returns to experience parameters. The challenge in trying to infer skill prices from earnings is the fact that variation in earnings over time alone, might reflect not just variation in skill prices but also cohort effects, namely changes in the distribution of ability among individuals who choose a given education level and changes in the quality of education. We solve this identification problem by tracking

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<sup>32</sup>Due to this selection effect, earnings premiums associated with higher education levels reflect in part sorting by individuals with heterogeneous abilities instead of different skill prices (Taber, 2001).

the evolution of average earnings of members of the *same* cohort and education group over time.<sup>33</sup> While this approach allows us to compute the growth rates of skill prices over time, it does not pin down their initial levels (Section 4.1.3 describes how these levels are determined).

Formally, let  $w_t^j \bar{h}_{\tau t}^j$  represent the average earnings in period  $t$  of workers who belong to cohort  $\tau$  and make schooling choice  $j$ . Taking the logarithm of  $w_t^j \bar{h}_{\tau t}^j$  and using equation (3.2) yields the following expression for average earnings of a given cohort and schooling choice:

$$\ln w_t^j \bar{h}_{\tau t}^j = \ln w_t^j + \ln E \left[ h_{\tau 7 + S_j}^j(\theta) | \tau, j \right] + \delta_1^j (t - \tau - S_j - 7) + \delta_2^j (t - \tau - S_j - 7)^2. \quad (4.1)$$

The latter depends on the skill price at time  $t$ , the average human capital at the end of school-level  $j$  (the second term on the right-hand side of equation (4.1)), and the accumulation of experience. Taking the first difference (over time) of equation (4.1), the log of average human capital at the end of school-level  $j$  cancels out because it does not depend on time. Therefore, the growth rate of average earnings for individuals in cohort  $\tau$  can be decomposed as follows:

$$\ln \frac{w_{t+1}^j \bar{h}_{\tau t+1}^j}{w_t^j \bar{h}_{\tau t}^j} = \ln \frac{w_{t+1}^j}{w_t^j} + \delta_1^j + \delta_2^j (2(t - \tau - S_j - 7) - 1), \quad (4.2)$$

where the first term on the right-hand side is the growth rate of skill prices, and the other two terms represent the growth rate of human capital due to the accumulation of experience. The growth rate of average earnings between periods  $t$  and  $t + 1$  for a given cohort  $\tau$  of agents is assumed to be measured with error:

$$e_{\tau t+1}^j = \ln \frac{w_{t+1}^j \bar{h}_{\tau t+1}^j}{w_t^j \bar{h}_{\tau t}^j} + u_{\tau t+1}^j, \quad (4.3)$$

where  $e_{\tau t+1}^j$  denotes the observed growth rate and  $u_{\tau t+1}^j$  is the classical measurement

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<sup>33</sup>Bowlus and Robinson (2012) also infer skill prices from earnings growth by allowing for cohort effects induced by either selection or quality changes. Rather than tracking cohorts over time, their strategy relies on identifying “flat-spots” in age-earnings profiles, as in Heckman, Lochner and Taber (1998).

error. In order to obtain a smooth profile of skill prices we specify  $\ln(w_{t+1}^j/w_t^j)$  as a cubic polynomial in time. Replacing the cubic polynomial in time and equation (4.2) into equation (4.3) yields the regression equation we estimate:

$$e_{\tau t+1}^j = \delta_1^j + \alpha_0^j + \alpha_1^j t + \alpha_2^j t^2 + \alpha_3^j t^3 + \delta_2^j (2(t - \tau - S_j - 7) - 1) + u_{\tau t+1}^j, \quad (4.4)$$

where  $\alpha_k^j$ , for  $k = 0 - 3$ , are the parameters of the cubic polynomial and the first year in the data, 1949, corresponds to  $t = 0$ . We run a separate regression for each schooling level.

Several remarks are in order. First, as can be noticed from equation (4.4),  $\delta_1^j$  is not separately identified from the constant term  $\alpha_0^j$  in the cubic polynomial because earnings by cohort can increase either due to the evolution of skill prices or to the accumulation of experience. We identify  $\delta_1^j$  in Section 4.1.3 by requiring the model to match a number of additional moments. Second, the parameter  $\delta_2^j$  and the coefficients  $\alpha_k^j$ , for  $k = 1 - 3$  can instead be identified and estimated using ordinary least squares. Differently from  $\delta_1^j$ , the parameter  $\delta_2^j$  can be identified because slower earnings growth for an older cohort with the same schooling level between two periods cannot be explained by the common evolution of skill prices. Instead, if (say) the earnings profile is concave ( $\delta_2^j < 0$ ), the older cohort must have smaller earnings growth than the younger one.<sup>34</sup> Third, the structure of the data underlying equation (4.4) is an unbalanced panel of earnings growth by cohorts over time. The dependent variable  $e_{\tau t+1}^j$  is constructed as the weighted (by weeks worked) average of weekly earnings of full-time full-year white male workers in a given cohort  $\tau$  and schooling level  $j$ .<sup>35</sup> Thus, even if our goal is to explain the attainment data for the 1932–1972 cohorts, in order to estimate the parameters in equation (4.4), we include individuals who belong to the cohorts 1884–1986 as long as they satisfy the

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<sup>34</sup>The point estimates of the curvature parameters  $\delta_2^j$  are reported Appendix D together with the experience profiles by education group. The estimated  $\delta_2^j$  are all negative, which is consistent with a hump-shaped profile of earnings over the life-cycle.

<sup>35</sup>The unbalanced nature of the panel comes from the fact that, consistently with our model, individuals stop working at age 65 and four-year college graduates start working at age 23. The data surveys are the 1950 and 1960 Census and the 1964–2010 March CPS. Notice that since the Census earnings data refer to the years 1949 and 1959 we assume a constant growth rate of earnings for each cohort and education level in that decade. This assumption plays no role in our results.



sample selection criteria. This approach, which is consistent with our theoretical setup, allows us to increase the number of data points used to estimate the growth rate of skill prices over time. The sample used to estimate equation (4.4) has 2,623 cohort-time observations for each schooling level  $j$ .

Figure 3 displays the series of skill prices relative to the skill price associated with a high-school diploma, or  $w_t^j/w_t^3$ , across calendar years. These ratios are normalized to take a value of one in 1949, and pertain to the version of the model with static expectations.<sup>36</sup>

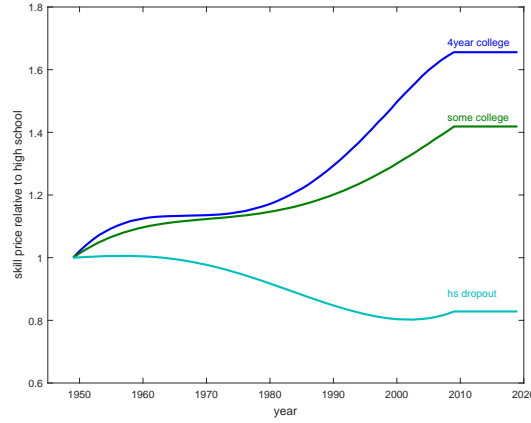


Figure 3: Skill Prices (relative to high school)

The evolution of the estimated skill prices is qualitatively consistent with the evidence from Figure 1b. The dynamics of the relative skill price associated with a four-year college degree may also be summarized in three sub-periods. First, it increases relative to high school in the 1950s and early 1960s. Second, it stagnates starting in the mid-1960s and during the 1970s. Third, after 1980, the relative skill price of individuals with a four-year college degree increases dramatically.

<sup>36</sup>As mentioned in the text, the skill price series cannot be estimated completely outside of the model because in the regression equation (4.4) only the sum  $\delta_1^j + \alpha_0^j$  is identified and not the two components individually. To compute the series of skill prices we need to calibrate the full model (see Step 3). The skill price series corresponding to the version of the model under perfect foresight are similar to those in Figure 3. They are available upon request.

### 4.1.2 Step 2 - Parameters Set A-Priori

Step 2 of the calibration procedure consists of setting some parameters a-priori based on available evidence:

- Life-span:  $A = 65$ , assuming that individuals retire at age 65.
- Gross real interest rate:  $R = 1.05$ . A standard value used by Heckman, Lochner and Taber (1998).
- Discount factor:  $\beta = 1/R$ .
- Labor income tax-rate:  $\lambda = 0.15$  (Heckman, Lochner and Taber, 1998).
- The three parameters of the human capital accumulation equation (3.1) are from You (2014). Specifically, the elasticity of human capital formation to school quality,  $\varphi$ , is set equal to 0.06.<sup>37</sup> The curvature of the human capital accumulation technology,  $\gamma$ , is set equal to 0.85.<sup>38</sup> The depreciation rate of human capital is  $\mu = 0$ .
- Psychic cost of high-school dropouts is normalized to zero without loss of generality:  $\bar{\xi}^4 = 0$ .
- Initial human capital is set to one for all cohorts.
- The distribution of ability, conditional on cohort  $\tau$ , is lognormal:  $\theta \sim LN(\mu_{\theta\tau}, \sigma_\theta)$  with mean  $\mu_{\theta\tau}$  and standard deviation  $\sigma_\theta$ . Without loss of generality we normalize to one the mean for the first cohort,  $\mu_{\theta 1932} = 1$ .

### 4.1.3 Step 3 - Calibration of Remaining Parameters

In the third and last step we calibrate the remaining fourteen parameters. These are  $\left(\sigma_\theta, \sigma, \{\bar{\xi}^j\}_{j=1}^3, \{w_0^j\}_{j=1}^4, \{\delta_1^j\}_{j=1}^4\right)$ , plus an additional parameter,  $\mu_{\theta 1963}$ , that represents average learning ability of individuals in the 1963 cohort (more on this

<sup>37</sup>Recall that our proxy for school quality are education expenditures per student at different levels of schooling shown in Figure 2b.

<sup>38</sup>Our results are not sensitive to a specific choice of  $\gamma$  in the range  $[0.5, 1]$ .

below). To calibrate these fourteen parameters we focus on the following sixteen moments (their empirical counterparts are listed in Table 3):

- 1.-2. Share of workers in the 1932 and 1972 cohorts with (only) a high school degree.
- 3.-4. Share of workers in the 1932 and 1972 cohorts with some (1–3 years) college.
- 5.-6. Share of workers in the 1932 and 1972 cohorts with a four-year college degree.
- 7.-8. High school dropout earnings premium (relative to high school) among 27 year old workers in the 1932 and 1972 cohorts.<sup>39</sup>
- 9.-10. Some college earnings premium (relative to high school) among 27 year old workers in the 1932 and 1972 cohorts.
- 11.-12. Four-year college graduation earnings premium (relative to high school) among 27 year old workers in the 1932 and 1972 cohorts.
13. Cumulative aggregate earnings growth observed between 1959 and 2009, among all workers in cohorts between 1932 and 1972.<sup>40</sup>
14. Standard deviation of log weekly earnings among 37 year old workers in the 1932 cohort.<sup>41</sup>
15. Ratio between the present value of four-year college tuition faced by individuals in the 1932 cohort and the average earnings of high-school dropouts by

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<sup>39</sup>We consider earnings premiums by age 27 since the first earnings data for individuals with a college degree from the 1932 cohort are from the 1960 Census. These pertain to the year 1959, when individuals born in 1932 are 27 years old.

<sup>40</sup>The choice of 1959 as first year again reflects the fact that, for individuals born in 1932, earnings information for all schooling degrees is first available in the 1960 Census.

<sup>41</sup>Our model abstracts from labor earnings uncertainty, among full-time full-year workers. We follow Guvenen and Kuruscu (2010) in adjusting the total cross-sectional variance of log earnings in the data by an estimate of the variance of labor earnings shocks, both persistent and transitory. Guvenen and Kuruscu (2010) report an estimate of the variance of such shocks to be 0.135, based on Guvenen (2009). Our target for the cross-sectional standard deviation of log earnings is thus  $\sqrt{0.4452^2 - 0.135}$ , where 0.4452 is the total standard deviation of earnings in our data, inclusive of shocks. We focus on age 37 to compute inequality in 1969, using the 1970 Census. This year corresponds to the beginning of Guvenen’s (2009) sample.

members of this same cohort in their first year of work. Notice that, up to this normalization, the four and two-year college tuition data we feed into the model correspond to the ones depicted in Figure 2a.

16. The timing and the magnitude of test score decline discussed in Section 2.4. The main feature of the empirical evidence reviewed by the CBO (Koretz, 1986) is a steady decline in median test scores between the 1953 and the 1963 cohorts. We take the peak-to-trough magnitude of the decline to be equal to 0.3625 standard deviations, under the usual assumption that test scores are distributed as a standard normal distribution. Such decline places the median student in the 1963 cohort in the 36th percentile among students in the 1953 cohort. The decline by 0.3625 standard deviations equals the decline on the ITBS-composite administered to 8th grade students (Section 2.4). In order to map these statistics into our model we assume that there is a monotonic and stable functional relationship between observed test scores and (unobserved) human capital at age 15 (end of 8th grade) in the model. Let  $E_\tau [\log h_{15}^j(\theta)]$  and  $V_\tau [\log h_{15}^j(\theta)]$  denote the mean and variance of log human capital at age 15 among agents in the  $\tau$  cohort. Thus, the evidence on the decline in average test scores between the 1953 and 1963 cohorts can be formalized as:

$$\frac{E_{1963} [\log h_{15}^j(\theta)] - E_{1953} [\log h_{15}^j(\theta)]}{\sqrt{V_{1953} [\log h_{15}^j(\theta)]}} = -0.3625. \quad (4.5)$$

This moment identifies the average learning ability, denoted by  $\mu_{\theta 1963}$ , of individuals in the 1963 cohort. Since the ability decline is, consistently with the evidence, assumed to occur at a roughly constant pace, we specify the evolution of average learning ability  $\mu_{\theta \tau}$  across cohorts as

$$\mu_{\theta \tau} = \begin{cases} 1 & \tau \leq 1953; \\ 1 - (1 - \mu_{\theta 1963}) \frac{\tau - 1953}{1963 - 1953} & 1953 < \tau \leq 1963; \\ \mu_{\theta 1963} & \tau > 1963. \end{cases} \quad (4.6)$$

Thus, average learning ability is constant between  $\tau = 1932$  and  $\tau = 1953$ ,

declines at a constant pace between  $\tau = 1953$  and  $\tau = 1963$ , and is again constant for later cohorts.<sup>42</sup>

Moments 1–12 anchor the model to the first and the last cohorts in the sample forcing it to account for their educational attainment and education premiums. These moments help to identify the utility cost parameters  $\{\bar{\xi}^j\}_{j=1}^3$ , the relative earnings parameters (three among each of  $\{w_0^j\}_{j=1}^4$  and  $\{\delta_1^j\}_{j=1}^4$ ), as well as the preference parameter  $\sigma$ . The latter governs the elasticity of educational attainment to variation in skill prices, and is identified by the variation in educational attainment between the 1932 and the 1972 cohorts. Moments 13–15 help to identify the dispersion in learning abilities  $\sigma_\theta$ , the level of earnings (one among  $\{w_0^j\}_{j=1}^4$ ) and the overall growth in earnings (one among  $\{\delta_1^j\}_{j=1}^4$ ). Moment 16 identifies the parameter governing the inter-cohort variation in average learning ability,  $\mu_{\theta 1963}$ . The calibration procedure involves searching for the set of parameters that minimizes the sum of squared percent deviations between model and the data moments.

Holding the parameters set a-priori constant, we carry out step 3 of our calibration procedure for each of the two skill price expectation scenarios, static and perfect foresight.<sup>43</sup> The parameters set a-priori are listed in Table 1 and the calibrated ones in Table 2.

$A$	$\beta$	$R$	$\gamma$	$\mu$	$h_7$	$\lambda$	$\bar{\xi}^4$	$\mu_\theta$	$\varphi$
65	0.95	1.05	0.85	0.00	1.00	0.15	0.00	1.00	0.06

Table 1: Parameters Set A-Priori

Table 3 summarizes the moments used to calibrate the parameters and their predicted values. Overall, both versions of the model fit the moments very well, with an average percentage difference between model and data moments well below

<sup>42</sup>As discussed in footnote (49), the model can account for the rise in test scores for the pre–1953 cohorts and for their partial recovery for the post–1963 cohorts without relying on exogenous changes in average learning ability.

<sup>43</sup>Under perfect foresight, we assume that individuals expect skill prices to remain constant at the 2009 level when their working life extends beyond 2009. Any growth in earnings after that date comes only from the experience profile. Notice that post-2009 prices are only relevant for the decision of a few of the later cohorts. Given the fact that the last cohort we study was born in 1972 and that future earnings are discounted, this assumption is fairly innocuous.

Parameter	Model Version	
	Static	Perfect Foresight
$\sigma$	4.4084	4.8814
$\sigma_\theta$	0.0552	0.0550
$\bar{\xi}^1$	0.3767	-0.3324
$\bar{\xi}^2$	0.7073	0.1523
$\bar{\xi}^3$	0.7640	0.6912
$w_0^1$	0.0009	0.0009
$w_0^2$	0.0015	0.0015
$w_0^3$	0.0030	0.0030
$w_0^4$	0.0053	0.0053
$\delta_1^1$	0.0666	0.0668
$\delta_1^2$	0.0595	0.0588
$\delta_1^3$	0.0527	0.0525
$\delta_1^4$	0.0512	0.0511
$\mu_{\theta 1963}$	0.9562	0.9563

Table 2: Calibrated Parameters

three percent. The main difference in terms of calibrated parameters between the two versions pertains to the preference parameters  $(\sigma, \bar{\xi}_1, \bar{\xi}_2, \bar{\xi}_3)$ . Tastes for schooling play a more important role under perfect foresight because in this case the incentives to attend college are stronger and rise faster over time. Notice also that according to the calibration, average learning ability drops by about four percent, in both versions of the model, between the 1948 and the 1963 cohorts.

## 4.2 Educational Attainment and Returns to Schooling for the 1932 and 1972 Cohorts

In order to understand the mechanics of the model, it is useful to discuss its predictions for the educational attainment of the 1932 and 1972 cohorts used in the calibration. We focus on static expectations, since the next section shows it performs better in accounting for the evolution of educational attainment than perfect foresight. Figure 4 illustrates the selection of heterogeneous individuals across

Moments	Data	Static	P. Foresight
<i>Educational attainment, 1932 cohort</i>			
1. High school	0.3976	0.3975	0.3990
2. Some college	0.1971	0.1991	0.2001
3. Four-year college	0.2479	0.2456	0.2446
<i>Educational attainment, 1972 cohort</i>			
4. High school	0.3024	0.3025	0.3007
5. Some college	0.2724	0.2696	0.2669
6. Four-year college	0.3623	0.3656	0.3656
<i>Education premiums (relative to high school), 1932 cohort</i>			
7. High school dropout	0.9261	0.9283	0.9328
8. Some college	1.0650	1.0160	1.0050
9. Four-year college	1.1546	1.1980	1.2064
<i>Education premiums (relative to high school), 1972 cohort</i>			
10. High school dropout	0.7485	0.7482	0.7453
11. Some college	1.1084	1.1553	1.1652
12. Four-year college	1.5741	1.5061	1.4881
13. Earnings in 2009 relative to 1959, all cohorts	1.7022	1.6970	1.6964
14. Std deviation log weekly earnings, 1932 cohort	0.2513	0.2517	0.2520
15. Present value of 4 year college tuition relative to earnings of high school dropout in 1949	0.8772	0.8786	0.8793
16. Decline in median test scores, from 1953 to 1963 cohort (ITBS avg, grade 8, in standard deviations)	0.3625	0.3625	0.3626
Fit (avg Euclidean percentage deviation from data)		0.0220	0.0272

Table 3: Targeted Moments

different schooling levels and how changes in the driving forces of the model over time have led to changes in educational attainment. Specifically, Figure 4a presents the ratio of expected discounted lifetime earnings as of age 17 for an individual of ability  $\theta$  who chooses education level  $j$ , relative to expected discounted lifetime earnings of an individual of the same ability with a high school degree ( $j = 3$ ). For each  $j$ , the solid line corresponds to the 1932 cohort while the dashed line aligned

with it corresponds to the 1972 cohort. Figures 4b and 4c present the proportions of individuals in the 1932 and 1972 cohorts who choose a schooling level  $j$  as a function of ability, i.e.  $P_{1932}^j(\theta)$  and  $P_{1972}^j(\theta)$ , together with the population densities of abilities. Consistent with our calibration, the ability distribution of the 1972 cohort is shifted to left compared to the 1932 cohort.

Figure 4a shows that the relative lifetime earnings associated with attending college rather than high school increase with an individual's ability, while the opposite is true for dropping out of high school. Consistently, Figures 4b and 4c show that the probability of dropping out of high school is highest among low ability agents. Notice that, for any two education levels, the fraction of individuals choosing the highest one increases with ability.<sup>44</sup> As a corollary, ability selection is stronger for the lowest and the highest degrees, with a relatively high (low) propensity of low (high) ability types to drop out of high-school, and the reverse for college graduation.

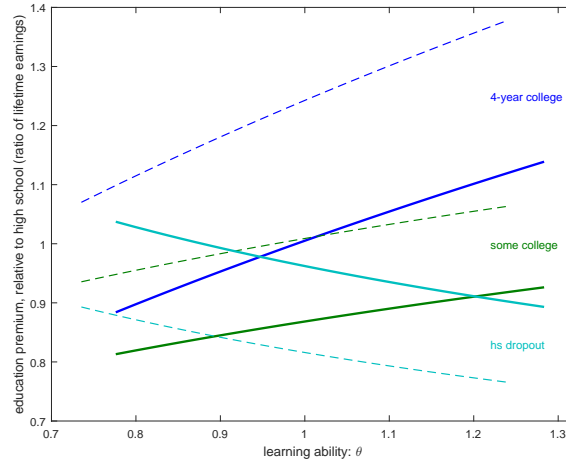
Individuals from different cohorts but with the same ability and preference shocks make different education choices because they face different streams of skill prices, tuition, and education expenditures. Figure 4a shows an increase over time in the returns to a four-year college degree, for all ability levels, as measured by the ratio of lifetime earnings by age 17. Consequently, in Figures 4b and 4c we observe an increase in the propensity to graduate from a four-year college, conditional on ability.<sup>45</sup> Comparing these two figures we also observe that the increase in four year college attainment between the 1972 and the 1932 cohorts is more pronounced for the higher ability types. That is, we observe a stronger selection into college by ability as the monetary reward from this choice goes up. However, as more individuals attend college, average college and high school ability tend to fall, so the net effect on average ability of college and high school graduates is, in principle, ambiguous. Based on the model's results, average ability falls within each group, but the decline is larger for the high school group, leading to an increase in the relative

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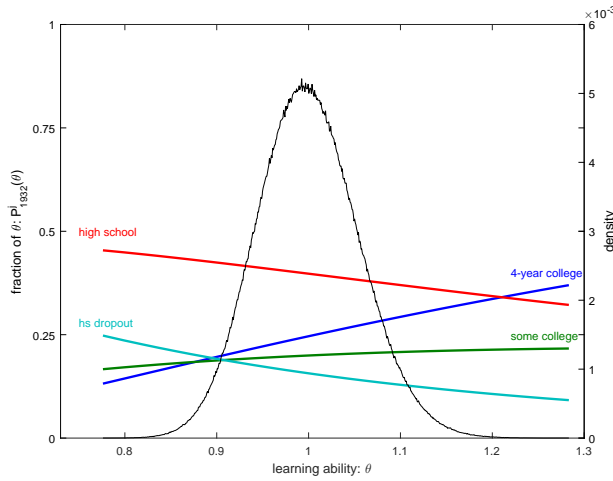
<sup>44</sup>Proposition 2 in Appendix B proves this result for the case  $Z_\tau^j = 0$  for all  $j$ .

<sup>45</sup>College graduation increases also unconditionally, as the model's parameters are calibrated to match the magnitude of the increase in four-year college attainment between the 1932 and 1972 cohorts. In this section we focus on variation in returns to schooling over time as the primary determinant of the increase in educational attainment. Section 5.1 provides a decomposition of the contribution of the various driving forces to the evolution of educational attainment.

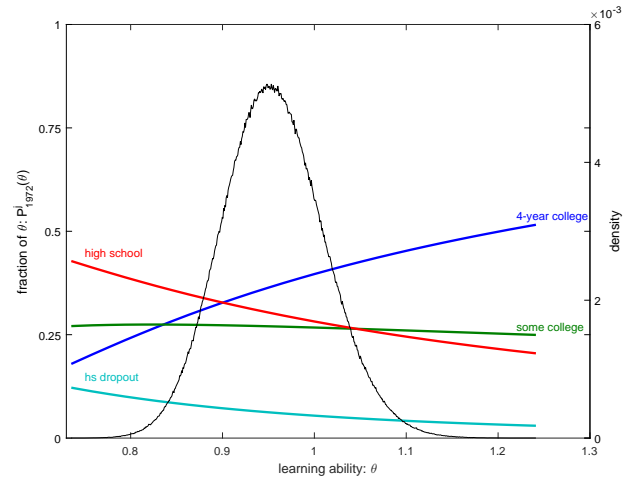




(a) Education earnings premiums by ability, 1932 cohort (solid) vs 1972 cohort (dashed)



(b) Attainment by ability, 1932 cohort



(c) Attainment by ability, 1972 cohort

Figure 4: Returns to schooling and attainment in the model, 1932 and 1972 cohorts

ability of a college graduate in 1972. This selection effect is, however, small: the ratio of average ability among four-year college graduates relative to average ability among high-school graduates increases slightly from 1.008 to 1.011 between the 1932 and the 1972 cohorts.

## 5 Results

We begin with the model’s prediction for the evolution of educational attainment between the 1932 and 1972 cohorts. Section 5.1 then evaluates the impact of each individual driving force. Section 5.2 considers an alternative approach to identifying the decline in mean learning ability. Finally, Section 5.3 presents a detailed comparison of our results with the existing literature.

We evaluate the model’s performance based on its predictions for the educational attainment and education premiums of the 1933–1971 cohorts, not targeted in the calibration. Figure 5 displays educational attainment and education premiums (at age 27) by birth cohort, in the data and in the model, for each expectations scenario, perfect foresight (Figures 5a and 5b) and static expectations (Figures 5c and 5d). The model accounts relatively well for the dynamics of education premiums under both scenarios (Figures 5b and 5d). The key factor behind the evolution of education premiums is the dynamics of skill prices (Figure 3).<sup>46</sup> However, the two versions give rise to very different predictions for the inter-cohort evolution of educational attainment, with static expectations fitting the data better. We reach this conclusion by focusing first on four-year college and then on the other schooling levels.

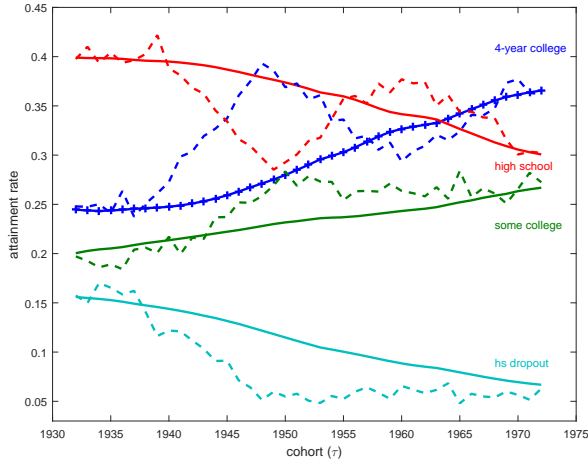
Consider four-year college graduation rates. A natural way to organize the data is to consider separately the 1932–1948 cohorts, characterized by a dramatic increase in graduation rates, and the 1948–1972 cohorts for whom graduation rates stagnated. Table 4 reports the average (per cohort) percentage point change in graduation rates for these two groups in the data and in each version of the model. College graduation rates increased at an average pace of 0.91 percentage points per cohort for the 1932–1948 cohorts, and declined slightly for the 1948–1972 cohorts at an average pace of 0.13 points per cohort. The table further distinguishes between the 1948–1960 and the 1960–1972 sub-groups because, as discussed in Section 2.1, the former one is characterized by a remarkable decline in graduation rates (0.83 points per cohort) while the latter experienced a slow recovery (0.57 points per cohort).<sup>47</sup>

The model under perfect foresight predicts a pattern of college graduation across

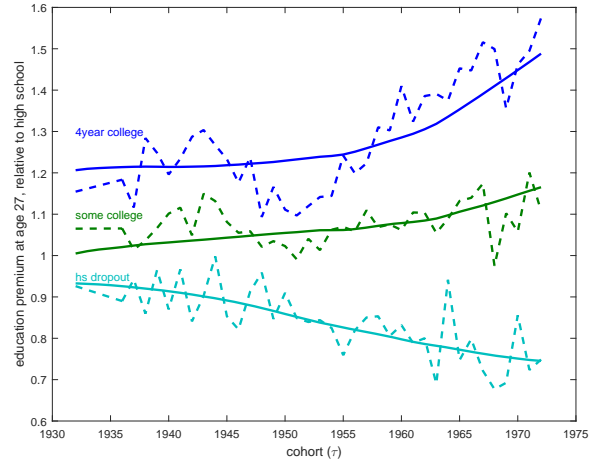
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<sup>46</sup>While Figure 3 displays skill prices for the calibration under static expectations, the corresponding figure for perfect foresight is similar.

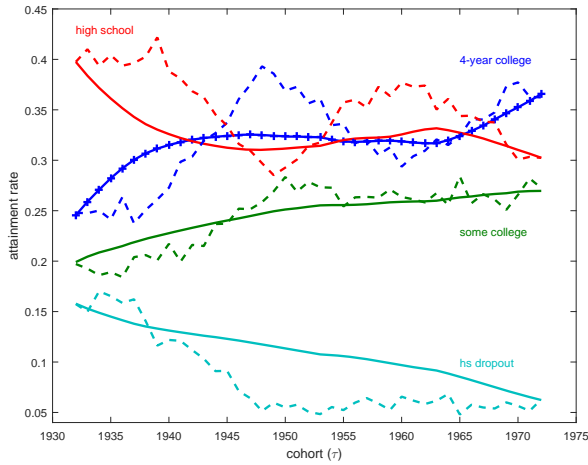
<sup>47</sup>The recovery is slow relative to the pace of expansion experienced by the 1932–1948 cohorts.



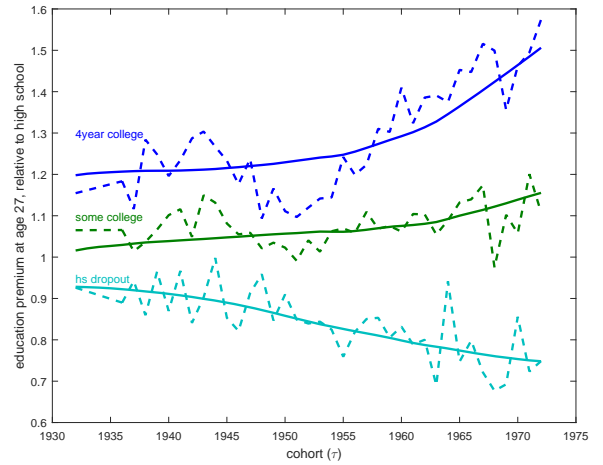
(a) Attainment (perfect foresight)



(b) Education Premiums (perfect foresight)



(c) Attainment (static)



(d) Education Premiums (static)

Figure 5: Predictions of the model with static expectations and the model with perfect foresight; model (solid, 4-year college highlighted with +) vs data (dashed).

cohorts that is almost the opposite of the data. The model's college graduation rates display the slowest growth for the 1932–1948 cohorts, at a pace of 0.17 percentage points per cohort, and the fastest for the 1948–1972 cohorts, at a pace of 0.39 percentage points per cohort (Figure 5a). Moreover, according to the model, the 1948–1960 cohorts should have achieved the fastest growth in graduation rates.

This prediction is very counterfactual as in the data these cohorts experience a rapid *decline* in college graduation rates.

	Cohorts			
	1932–1948	1948–1972	1948–1960	1960–1972
<i>Model version</i>				
Perfect foresight	0.17	0.39	0.46	0.32
Static expectations	0.50	0.17	-0.05	0.39
<i>Data</i>	0.91	-0.13	-0.83	0.57

Note: Entries are average percentage point increases in four-year college attainment per cohort.

Table 4: Accounting for the change in four-year college attainment across cohorts.

Static expectations, instead, generate a pattern that is, at least qualitatively, in line with the data. In the model, as in the data, college expansion is fastest among the 1932–1948 cohorts while it stagnates for the 1948–1972 ones. The model is also successful in generating a reduction in four-year college attainment for the 1948–1960 cohorts, and a slow recovery for the 1960–1972 ones. From a quantitative perspective, the version of the model with static expectations accounts for about 55 percent of the observed increase in college graduation rates for the 1932–48 cohorts. In the data college graduation rates decrease slightly for the 1948–1972 cohorts at a pace of 0.13 percentage points per cohort, while the model predicts a slight gain of 0.17 percentage points per cohort.

The main reason why the version of the model with static expectations fits the college graduation data better than the perfect foresight one is that it ties schooling decisions to *contemporaneous* values of skill prices. Consider, for example, the rapid increase in college attainment experienced by the 1932–1948 cohorts. The relative skill price of college increases by about 13 percent relative to its high school degree counterpart between the years 1949 and 1965. Under static expectations, the 1932–1948 cohorts make their college choices based on this period of increasing relative college skill prices. By contrast, under perfect foresight, schooling decisions are based on the present discounted value of skill prices (and earnings, more generally). The latter does not provide a sufficient incentive for agents in the 1932–1948 cohorts to significantly increase their college graduation rates as the pattern of increasing

college skill prices between the years 1949 and 1965 is averaged with the flat profile of college skill prices observed during the 1970s. For the same reason, under static expectations, the 1948–1960 cohorts do not increase their college attainment when faced with the stagnation in college skill prices of the 1970s, while the same cohorts, under perfect foresight, display strong gains in college attainment driven by the expectation of rising college skill prices in the 1980s.

It is because of the key role played by the other driving forces – tuition, quality of education, and average learning ability – that the model is able to generate an overall stagnation in college attainment for the 1948–1972 cohorts. The next section discusses these effects.

The second dimension along which we evaluate the model is the attainment dynamics of the remaining education levels. The data shows gains in the fraction of individuals with some college and a dramatic drop in the proportion of agents with only a high school degree for the 1932–1948 cohorts. Both of these measures tend to be stagnant between the 1948 and the 1972 cohorts. The model with static expectations accounts for these patterns.

We conclude this comparison by constructing a comprehensive measure of the model’s fit of the educational attainment data: the average squared deviation of educational attainment predicted by the model from the data. The version of the model with static expectations displays an average (across education levels and cohorts) deviation from the data of about 2.9 percentage points, while the version with perfect foresight has a higher average deviation of about 3.6 percentage points. Thus, since the former version provides an overall better fit of the educational attainment data, in what follows we restrict attention to the case of static expectations.

## **5.1 The Role of Tuition, Education Quality and Decline in Average Ability**

In order to understand the role played by each mechanism in the model with static expectations, we perform a decomposition of the evolution of educational attainment, focusing on four-year college graduation rates. We first turn off all of the model’s driving forces, so that college attainment is constant across cohorts.

Then, we turn on each mechanism sequentially, starting with skill prices, followed by inter-cohort changes in mean ability, the dynamics of schooling expenditures, and finally tuition changes. The last step reinstates all the ingredients of the full model, and therefore corresponds to the static expectations version discussed in the previous section. Figure 6 and Table 5 present the results.<sup>48</sup> We now discuss the contribution of each mechanism.

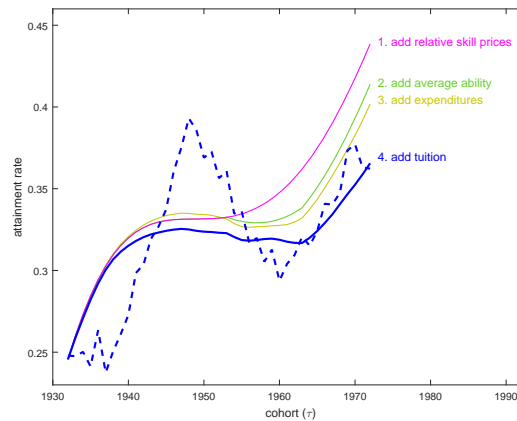


Figure 6: Contribution of the model's driving forces to four-year college attainment; experiments (solid) and data (dashed).

Experiment	Cohorts			
	1932–1948	1948–1972	1948–1960	1960–1972
1. Add relative skill prices	0.54	0.45	0.13	0.76
2. Add mean ability	0.00	-0.10	-0.14	-0.07
3. Add education quality	0.02	-0.06	-0.06	-0.07
4. Add tuition	-0.06	-0.11	0.01	-0.23

Note: Entries are average percentage point increases in four-year college attainment per cohort, relative to the case in which the model ingredient is not operative.

Table 5: Contribution of the model's driving forces to the change in four-year college attainment.

<sup>48</sup>These counterfactual exercises are performed in partial equilibrium, so each time we activate a new driving force the previous ones are unaffected.

**Relative Skill Prices** Figure 6 and Table 5 illustrate two points regarding the contribution of relative skill prices to the evolution of college attainment. First, the rise in the relative skill price of college almost fully accounts for the expansion in college graduation rates predicted by the model for the 1932–1948 cohorts. Second, changes in skill prices alone would predict a large increase in college graduation rates between the 1948 and the 1972 cohorts, instead of the stagnation observed in the data and the absolute decline between the 1948 and 1960 cohorts. The reason why the model driven by skill prices alone produces counterfactual predictions for attainment is that, given a stable elasticity of attainment to changes in relative skill price, college graduation rates respond strongly to the post-1980 rise in college skill prices. Our model is able to generate stagnation of attainment between the 1948 and the 1972 cohorts by introducing additional exogenous driving forces which have both a direct effect on college attainment and also reduce the elasticity of attainment with respect to skill price changes. We turn to each of these forces next.

**Decline in Average Ability** We let average ability decline according to the benchmark calibration, affecting the post-1953 cohorts. Lower average ability produces two effects on college attainment. First, this mechanism is central in driving the decline in college attainment experienced by the 1948–1960 cohorts. It causes attainment to drop by 0.14 percentage points per cohort for a cumulative decline of almost two percentage points. Second, the lower average ability of the post-1948 cohorts reduces the elasticity of college attainment to variation in skill prices, so it helps to account for the slow recovery of the 1960–1972 cohorts. Quantitatively, this second effect reduces college graduation by about 0.07 percentage points per cohort for the 1960–1972 cohorts, i.e. a cumulative effect of about one percentage point. In summary, the decline in average ability plays a critical role in generating the overall stagnation in college attainment of the 1948–1972 cohorts. Its role is comparable to that played by the rise in college tuition.

**Changes in Education Quality** Real education expenditures in both elementary and secondary and college education increased over time until the early 1970s (Figure 2b), followed by a period of stagnation and even decline. Notice that in our model

improvements in the quality of elementary and secondary education increase human capital when an agent graduates from high school and thus *reduce* his incentives to engage in further studies.<sup>49</sup> By contrast, improvements in college quality increase college graduation rates because they increase the marginal return from investing in human capital. This observation explains the contribution of education quality to the evolution of four-year college graduation rates across cohorts. Specifically, between the 1932 and the 1948 cohorts rising education quality has a cumulative effect on college graduation rates of about a third of a percentage point. This small effect is attributed to the offsetting impact of rising quality of elementary, secondary, and college education. In contrast, later cohorts, especially the 1960–72 ones, experienced a decline in college quality and a constant quality of elementary and secondary school, leading to a cumulative negative effect of about 0.8 percentage points for these cohorts.

**Tuition Costs** Figure 2a shows that tuition increased between the 1932 and 1972 cohorts, contributing to an overall decline in four-year college graduation rates (Figure 6). As for education quality, the magnitude of changes in tuition varies across cohorts. The rising tuition faced by the 1932–1948 cohorts reduce college graduation by about one percentage point. The declining tuition faced by the 1948–1960 cohorts, instead, barely mitigates the drop in college graduation attributed to lower average ability. Finally, the sharp rise in tuition faced by the 1960–1972 cohorts, of about 66 percent, plays a significant role in explaining the slow response of attainment to rising college skill prices. The rise in tuition reduces the increase in college attainment of these cohorts by 0.23 percentage points per cohort, for a cumulative effect of about 2.8 percentage points.

A natural question is whether the model-implied elasticity of attainment to changes in tuition is consistent with the empirical evidence. The answer is affirmative, but the implied elasticity is at the low end of what has been estimated in the

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<sup>49</sup>Our model predicts a gain in test scores of about 0.48 standard deviations for the 1940–1953 cohorts, driven exclusively by rising elementary and secondary education expenditures (recall that average learning ability is constant for these cohorts). The data counterpart of this increase is 0.36 standard deviations. The model also correctly predicts a partial recovery in test scores of 0.17 standard deviations for the cohorts 1963–1972, against 0.2 in the data. The test score data are from Figure IV-3 in Koretz (1986).



literature reviewed by Kane (2006). He reports a range of estimates about the effect of \$1,000 (1990 dollars) increase in tuition on college enrollment (not attainment). The studies occurred in periods between the late 1980s and the late 1990s, where average tuition varied between \$3,000 and \$4,000 (in 1990 dollars), so the \$1,000 figure represents a 25-33 percent increase in tuition. The estimated range of impact is between 2 and 5 percentage points decline in enrollment per \$1,000 dollar increase in tuition. By comparison, in our model a 33 percent rise in tuition gives rise to an average drop in college graduation of about 1.4 percentage points for the 1960–1972 cohorts. This number is comparable with the 2–5 percentage point decline in college *enrollment* cited by Kane (2006). We conclude this discussion with two caveats. First, our tuition data refers to sticker price tuition due to limitations in the available time-series of net tuition. Hence, it is possible that we are overstating the extent to which net tuition has actually increased over time.<sup>50</sup> Second, our model abstracts from credit constraints. Binding credit constraints would increase the elasticity of attainment to tuition.<sup>51</sup> Their importance for college attainment of individuals from low-income households is debated in the literature (for alternative views see e.g. Kane, 1999; Carneiro and Heckman, 2002, 2003).

## 5.2 An Alternative Calibration Strategy

We introduce an alternative strategy to identify the extent of inter-cohort variation in average learning ability. Our main motivation is that test scores might be an imperfect measure of learning ability. Instead of relying on test scores, as in Section 4.1.3, we now use variation in observed high-school dropout rates to identify variation in  $\mu_{\theta\tau}$ . We base our calibration on the observation that the 1948 cohort marks not only the peak in four-year college attainment, but also the bottom in high school dropout rates (Figure 1a). The stagnation in college attainment for subsequent cohorts has its counterpart in the lack of further declines in the high

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<sup>50</sup>Student aid has gained importance in recent decades. For example, Figure 13A of The College Board (2013) documents the expansion of the Pell Grant program since the mid-1970s, most notably in the number of recipients.

<sup>51</sup>The conclusion about the effects of tuition on attainment in the absence of credit constraints is similar to the one reached by Jones and Yang (2011) in the context of a general equilibrium model of investment in education in which the cost of college evolves endogenously over time.

school dropout rates.<sup>52</sup>

To translate these ideas into a calibration strategy, we consider the same specification for  $\mu_{\theta\tau}$  as in equation (4.6), except that average ability starts declining after the 1948 cohort, instead of the 1953 one. We then calibrate the model under static expectations. The procedure and targeted moments are the same as in Section 4.1.3, with the exception of moment 16 (measured decline in test scores). This moment is, instead, replaced by eight moments representing the high school dropout rates of cohorts born at five year intervals between 1935 and 1970. This alternative approach identifies the decline in  $\mu_{\theta\tau}$  from the inter-cohort pattern of high school dropout rates. Skill prices alone would suggest a larger decline in high school dropout rates between the 1932 and 1963 cohorts than observed in the data. The decline in average learning ability reconciles the model with the data in this dimension. The new set of parameters is reported in Table 7 in Appendix E, and the fit of the model in matching the targeted moments is in Table 8. Figure 7 plots the predicted evolution of educational attainment and compares it with the data.

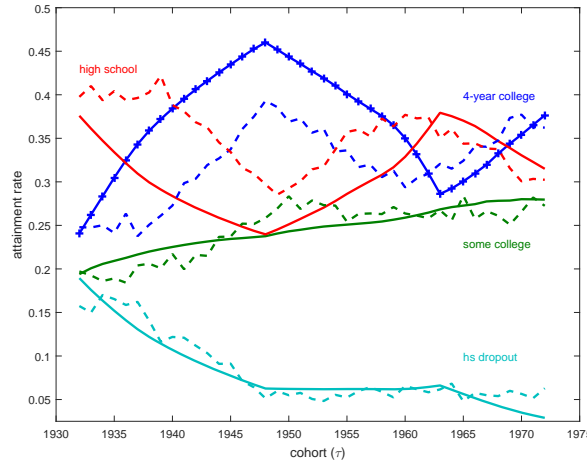


Figure 7: Educational attainment: alternative calibration (solid, 4-year college highlighted with +) vs data (dashed).

The model now produces the same qualitative pattern of college attainment as the benchmark in Figure 5c. However, it generates a more pronounced pattern for

<sup>52</sup>Notice that there is no mechanical way in which these two series are related.

both the early increase in college attainment and the absolute decline between the 1948 and the 1960 cohorts.<sup>53</sup> The larger decline in college attainment is achieved through a larger reduction in average learning ability ( $\mu_{\theta 1963} = 0.6651$ ) compared to the benchmark (Section 4.1.3). The fit measure discussed at the end of Section 5 reveals that, on average, this version of the model displays a 4 percentage point deviation from the data, a somewhat worse fit than the model with static expectations.

### 5.3 Relationship with the Literature

The existing literature highlights some of the forces leading to the increase in educational attainment. Most papers focus on the *overall* increase in U.S. college graduation rates between the early 1930s and the early 1970s cohorts. A few of them also attempt to explain the stagnation in male college attainment starting from the late 1940s cohorts. We organize our discussion around these two approaches.

Consider, first, the long-run perspective. Most papers assign a prominent role to *relative* skill prices (Lee and Wolpin, 2010; Restuccia and Vandenbroucke, 2013b; You, 2014; Gemici and Wiswall, 2014). We share this view. Relative skill prices are also the main force generating incentives for higher schooling achievement in our model (Section 5.1). By contrast, Keller (2014) and Donovan and Herrington (2013) rely on alternative mechanisms. Keller (2014) assumes (i) a cohort-dependent distribution of initial human capital ( $h_1$  in our notation), with trends in both its cross-sectional mean and variance, and (ii) endogenous changes in education quality. Regarding the latter, agents in her model choose not only whether to attend college, but also the quality of college education. As the *level* of skill prices rises, the return to higher college quality increases too. Higher college quality, in turn, increases the incentives to attend college in the first place.<sup>54</sup> In our model, we focus on real education expenditures per student as a measurable proxy for the quality of college

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<sup>53</sup>For comparison with Table 4, the predicted change in college graduation rates for the 1932–1948, 1948–1960, 1960–1972 cohorts is now 1.37, −0.92, 0.22, respectively.

<sup>54</sup>Figure 7 (a) in her paper shows how in her model the educational attainment of an agent in the 1940 cohort is much higher than that of an agent in the 1930 cohort, despite the fact that the 1940 cohort agent faces a slower growth in skill prices over her life-cycle. We attribute this gap in average attainment between the two cohorts to the effect of endogenous education quality described in the text, although Keller (2014) does not explicitly quantify this mechanism.

at a point in time. We find that the latter plays a minor role in generating the long-run rise in attainment (Table 5).

Donovan and Herrington (2013, page 3) consider a model in which agents choose whether to attend college or work subject to uncertainty about their ability to complete college, and borrowing constraints. They attribute the dramatic growth in college attainment between the 1930 and 1950 cohorts to a reduction in tuition relative to disposable income, and the post-1950 cohort increase in attainment to a rising college premium.

Consider now the slowdown in male educational attainment of the post-1948 cohorts. The literature has interpreted this evidence through the lens of four distinct mechanisms. First, Keller (2014) has emphasized the decline in skill price growth that occurred starting in the early 1970s.<sup>55</sup> Specifically, higher expected skill price growth leads to higher educational attainment by reducing the opportunity cost of schooling investment relative to its final payoff. The logic of this effect is, then, that a decline in the *growth rate* of skill prices leads to a reduction in the *level* of educational attainment. It follows that, if the post-1948 cohorts expected a smaller growth rate than the pre-1948 cohorts, they should have been less likely to attend college. This level effect, per se, might therefore help explain the observed decline in college attainment for the 1948-1960 cohorts. This mechanism is obviously not operative in our model under static expectations. We may, however, assess its quantitative importance under perfect foresight. According to our estimated skill price series, there has been a decline of about 2 percentage points in the average yearly growth rate of high school skill prices between the 1949-69 and the 1969-89 sub-periods. Under perfect foresight, our model predicts that such a decline - given the *relative* skill prices of other education levels - would give rise to a drop in the college graduation rate of about 4 percentage points, a relatively large number.

The second mechanism, also present in Keller's (2014) analysis, is a stagnation in the quality of higher education starting around the year 1970. As mentioned above, the obvious challenge is how to measure college quality and its effect on human capital. We proxy college quality by education expenditures per student (see Section

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<sup>55</sup>The effect of expected skill price *growth* on schooling decisions was first discussed by Bils and Klenow (2000).

2.3). College quality, thus measured, increases over our sample period till the early 1970s, after which it stagnates and then declines slightly. Although this pattern is qualitatively consistent with the slowdown in college attainment, we find it plays a minor quantitative role (Section 5.1). The key is that our exercise is disciplined by a relatively small elasticity ( $\varphi$ ) of human capital formation to measures of spending per student, as estimated in the literature (You, 2014). Differently from us, in Keller's (2014) model agents choose the quality of higher education. As skill prices stagnate after the year 1970, so does the incentive to invest in college quality. In turn, stagnation in college quality translates into stagnation in college attainment in her model. Unfortunately, Keller (2014) does not isolate the quantitative contribution of this mechanism in generating stagnation in college attainment. We conjecture, however, that the magnitude of this effect is much larger in her paper than in ours as she postulates a much higher elasticity of human capital to college quality than we do (0.5, according to her Table 2, compared to our 0.06).

The third mechanism discussed in the literature is the rise in college tuition, which plays a quantitatively important role in Gemici and Wiswall (2014). They compare the college graduation rates of men born in 1940 and 1960. Unfortunately they do not report the magnitude of the rise in tuition faced by these two cohorts, making the comparison difficult. According to our data, the present value of four-year college tuition faced by the 1960 cohort was about 13 percent higher than for the 1940 cohort. Based on our model and the elasticity we computed in Section 5.1, this increase should have reduced college attainment of the 1960 cohort by about half of a percentage point compared to the 1940 cohort. Gemici and Wiswall (2014, Table 4) report, instead, a reduction of 21 percentage points, all else constant, based on their tuition data. The magnitude of this effect appears very large, indeed much larger than the available empirical estimates based on a tuition increase similar to ours. A further observation is that the large increases in college tuition in the U.S. started only around 1980 (Snyder, 1993). Thus, rising tuition should have played a key role in dampening college attendance of the *post*-1960 cohorts, as in our model (see Section 5.1), rather than the earlier ones.

Finally, the fourth mechanism contributing to the slowdown in educational attainment (Keller, 2014; Donovan and Herrington, 2013), is a deviation from the

assumption of perfect foresight. Myopia is, however, better thought of as an ingredient of the analysis, as opposed to an independent mechanism because all cohorts are assumed to be myopic in the same way. Myopic expectations help improve these models' fit by interacting with other driving forces that are time-varying. For example, according to [Donovan and Herrington's \(2013\)](#) benchmark model, college attainment should not have slowed down after the 1948 cohort, as returns to college increased in the 1980s and 1990s. The role of myopia in their setting is to effectively *mute* the counterfactual implications of rising returns to college for the post 1948 cohorts, and thus to generate a significant slowdown in the growth of college attainment. In fact, differently from us, [Donovan and Herrington \(2013, Section 4.3.1\)](#) assume that individuals in one cohort expect their college premium to equal an average of the premiums earned by college graduates in the previous 25 years. By contrast, agents in our model expect the observed college premium at age 17 to persist over time, and thus incorporate new information at a much faster rate. Myopia plays a somewhat different role in [Keller \(2014\)](#). She assumes that agents are myopic relative to the expected growth rate of skill prices, rather than the level of the college premium. Myopia allows her model to better match the timing of the slowdown in college attainment as myopic agents in the cohorts born in the late 1940s fail to realize the slowdown in skill price growth starting in the early 1970s and continue to invest in college education at high rates.

## 6 Conclusions

We study the evolution of educational attainment for the 1932–1972 cohorts of U.S. males. We quantify the contribution of time-varying skill prices, tuition, education quality, and changes in average learning ability across cohorts to the early rise (1932–48 cohorts) and subsequent stagnation (1948–72 cohorts) in college attainment. The novel force in our analysis - the decline in learning ability for the post-1953 cohorts - is calibrated to match the observed decline in test scores of eighth-grade students. According to the quantitative model, rising relative skill prices for college graduates in the 1950s and 1960s account for most of the increase in college graduation rates of the 1932–1948 cohorts. Skill prices, however, cannot

explain the subsequent stagnation in college attainment. The latter is due to rising tuition and declining or lower average learning ability, in approximately equal parts. Specifically, the college graduation rate of the 1972 cohort would have been 2.5 percentage points higher if average learning ability had remained constant at the level of the 1953 cohort. Moreover, the learning ability channel is the single-most important factor in accounting for the observed *decline* in college graduation rates of the 1948–1960 cohorts. More generally, our paper suggests that the same fundamental cause might be responsible for the slowdown in college attainment in the last forty years and for the lack of improvements in high school graduation rates since the late 1960s.

We conclude with some comments on our modeling choices and paths for future research. We have worked under the relatively strong assumption of perfect capital markets, so that schooling choices are based on present values of earnings across different alternatives, rather than, for example, parental resources. In doing so, we do not intend to deny the potential importance of incomplete markets for higher education. The presence of borrowing constraints and uninsurable risks associated with dropping out of college and with the labor market environment might help accounting for the slow growth in college attainment of the post-1960 cohorts (Lochner and Monge-Naranjo, 2012; Athreya and Eberly, 2013). A second modeling choice that may be relaxed in future work is to allow skill prices to evolve over time in a cohort-specific way, even if this generalization comes with the practical difficulty of empirically disentangling age, time and cohort effects. A third interesting extension, would be to consider more explicitly the extensive margin of government provision of higher education. The share of college enrollment accounted for by the public sector peaks in the early 1970s. Thereafter, it either stagnates or even declines slightly (Snyder, 1993, Figure 15). Here we have considered the role played by expenditures per student enrolled on attainment, but have not incorporated the effect of the number of college slots made available by U.S. states' budget allocations.<sup>56</sup>

There are also a number of promising areas for future research on this topic. First, the causes of the variation in average learning ability across cohorts are not

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<sup>56</sup>This supply-side dimension is considered by Bound and Turner (2007) in their empirical analysis of the effects of cohort size on college enrollment.

well understood. Although this is a difficult question, the payoff is potentially large from the policy perspective. Second, our empirical analysis has focused on males. Four-year college graduation rates for females also peak around the 1950 cohort, and then decline for the 1950–1960 cohorts, but later rebound faster and more strongly than for males (Goldin, Katz and Kuziemko, 2006, Figure 1). Understanding the evolution of female educational attainment in the last few decades is likely to help clarify the experience of its male counterpart. Third, our analysis is limited to U.S. data. Determining whether other countries are also characterized by a stagnation in male college attainment will help shed further light on this important question.

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## Note: Appendix not intended for publication.

### A Aggregation

In this section we formally define some of the variables to which we refer in the calibration sections of the main text. The proportion of individuals in each cohort  $\tau$  choosing schooling-level  $j$  (educational attainment rate for education level  $j$ ) is defined as:

$$AR_\tau^j \equiv \int_\theta P_\tau^j(\theta) dG_\tau(\theta). \quad (\text{A.1})$$

The education earnings premium between schooling levels  $j$  and  $j'$  among working members of cohort  $\tau$  in year  $t$  (when they reach age  $a = t - \tau$ ) is defined as follows:

$$\frac{w_t^j \bar{h}_{\tau t}^j}{w_t^{j'} \bar{h}_{\tau t}^{j'}}, \quad (\text{A.2})$$

where  $\bar{h}_{\tau t}^j$  denotes the average human capital of cohort  $\tau$  agents in year  $t$  conditional on schooling choice  $j$ :

$$\bar{h}_{\tau t}^j \equiv \frac{\int_\theta h_{\tau t-\tau}^j(\theta) P_\tau^j(\theta) dG_\tau(\theta)}{AR_\tau^j}. \quad (\text{A.3})$$

### B Propositions

#### B.1 Proposition 1

**Proposition 1.** *Suppose no tuition,  $Z_\tau^j = 0$  for all  $j$ . If an individual  $i$  of cohort  $\tau$ , with ability  $\theta$  and preference vector  $\xi_i$ , is indifferent between education levels  $j$  and  $j'$ , with  $j'$  denoting higher attainment ( $j' < j$ ), then an individual  $i'$  in the same cohort with higher ability  $\theta'$ , with  $\theta' > \theta$  and the same preference vector  $\xi_{i'} = \xi_i$ , will find it strictly optimal to choose  $j'$ .*

The proof requires showing that  $V_\tau^{j'}(\theta') / \sigma + \bar{\xi}^j > V_\tau^j(\theta') / \sigma + \bar{\xi}^{j'}$  for  $j' \leq j$  whenever  $V_\tau^{j'}(\theta) / \sigma + \bar{\xi}^j = V_\tau^j(\theta) / \sigma + \bar{\xi}^{j'}$ . Suppose instead that  $V_\tau^{j'}(\theta') / \sigma + \bar{\xi}^j \leq$

$V_{\tau}^j(\theta') / \sigma + \bar{\xi}^{j'}$ . This implies that

$$V_{\tau}^{j'}(\theta') - V_{\tau}^j(\theta') \leq \sigma \left( \bar{\xi}^{j'} - \bar{\xi}^j \right).$$

Given the expression for the indirect utility function the inequality above becomes

$$\ln \left( c_{\tau}^{j'}(\theta') \right) - \ln \left( c_{\tau}^j(\theta') \right) \leq \hat{\sigma} \left( \bar{\xi}^{j'} - \bar{\xi}^j \right)$$

where

$$\hat{\sigma} = \frac{\sigma}{\sum_{a=17}^A \beta^a}.$$

This further simplifies to:

$$c_{\tau}^{j'}(\theta') \leq c_{\tau}^j(\theta') \exp \left[ \hat{\sigma} \left( \bar{\xi}^{j'} - \bar{\xi}^j \right) \right]. \quad (\text{B.1})$$

For agent  $\theta$  we have:

$$c_{\tau}^{j'}(\theta) = c_{\tau}^j(\theta) \exp \left[ \hat{\sigma} \left( \bar{\xi}^{j'} - \bar{\xi}^j \right) \right]. \quad (\text{B.2})$$

Notice that consumption can be written as:

$$c_{\tau}^j(\theta') = \frac{h^j(\theta') \sum_{a=7+S_j}^A R^{-a} \tilde{w}_{\tau+a}^j}{\sum_{a=17}^A R^{-a}},$$

where the variable  $\tilde{w}_{\tau+a}^j$  collects taxes, skill prices and experience profiles:

$$\tilde{w}_{\tau+a}^j \equiv (1 - \lambda) \tilde{w}_{\tau+a}^{j'} \exp \left( \delta_1^j (a - S_j - 7) + \delta_2^j (a - S_j - 7)^2 \right),$$

and  $h^{j'}(\theta')$  denotes human capital at the end of schooling level  $j'$ . Thus:

$$\begin{aligned} c_{\tau}^j(\theta') &= \left[ h^j(\theta') / h^j(\theta) \right] \frac{\sum_{a=7+S_j}^A R^{-a} \tilde{w}_{\tau+a}^j h^j(\theta)}{\sum_{a=17}^A R^{-a}} \\ &= \frac{h^j(\theta')}{h^j(\theta)} c_{\tau}^j(\theta). \end{aligned}$$

Thus, equation (B.1) holds if

$$\frac{h^{j'}(\theta')}{h^{j'}(\theta)} c_{\tau}^{j'}(\theta) \leq \frac{h^j(\theta')}{h^j(\theta)} c_{\tau}^j(\theta) \exp \left[ \widehat{\sigma} \left( \bar{\xi}^{j'} - \bar{\xi}^j \right) \right].$$

Use (B.2) to re-write as:

$$\frac{h^{j'}(\theta')}{h^{j'}(\theta)} \leq \frac{h^j(\theta')}{h^j(\theta)}.$$

This leads to a contradiction if the ratio  $h^{j'}(\theta)/h^j(\theta)$  is strictly increasing in  $\theta$ . We now show that this is the case. Notice that:

$$\frac{h^{j'}(\theta)}{h^j(\theta)} = \frac{h_{S_{j'}}(\theta)}{h_{S_j}(\theta)}$$

where  $S_{j'} > S_j$  is the length of schooling in years associated with  $j'$  and  $j$ . Notice that we can write the ratio as the following product:

$$\frac{h_{S_{j'}}(\theta)}{h_{S_j}(\theta)} = \frac{h_{S_{j'}}(\theta)}{h_{S_{j'}-1}(\theta)} \frac{h_{S_{j'}-1}(\theta)}{h_{S_{j'}-2}(\theta)} \cdots \frac{h_{S_{j'}+1}(\theta)}{h_{S_j}(\theta)}.$$

To show that the left-hand is increasing in  $\theta$ , it is then enough to show that each ratio on the right-hand side is increasing in  $\theta$ . Thus, we simply need to show that

$$\frac{h_{l+1}(\theta)}{h_l(\theta)}$$

is increasing in  $\theta$  where  $h_{l+1}(\theta)$  is given by equation (3.1). We do so by induction. First, we show this is the case for  $l = 1$  and then that it holds for  $h_{l+2}(\theta)/h_{l+1}(\theta)$  given that it holds for  $h_{l+1}(\theta)/h_l(\theta)$ . Consider first the case  $l = 1$ . Since

$$h_2(\theta) = \theta x_1^{\varphi} h_1^{\gamma} + (1 - \mu)h_1,$$

it is straightforward to show that  $h_2(\theta)/h_1$  is increasing in  $\theta$  given that  $h_1$  is the

same for all agents. Now consider the inductive argument. Notice that

$$\frac{h_{l+1}(\theta)}{h_l(\theta)} = \theta x_l^\varphi h_l(\theta)^{\gamma-1} + 1 - \mu. \quad (\text{B.3})$$

Use the analogous expression for  $h_l(\theta) / h_{l-1}(\theta)$  to write:

$$\theta x_l^\varphi h_l(\theta)^{\gamma-1} = \left( \frac{x_l}{x_{l-1}} \right)^\varphi \frac{\frac{h_l(\theta)}{h_{l-1}(\theta)} - (1 - \mu)}{\left( \frac{h_{l-1}(\theta)}{h_l(\theta)} \right)^{\gamma-1}}.$$

Replace it in (B.3) to obtain:

$$\frac{h_{l+1}(\theta)}{h_l(\theta)} = \left( \frac{x_l}{x_{l-1}} \right)^\varphi \left\{ \left( \frac{h_l(\theta)}{h_{l-1}(\theta)} \right)^\gamma - (1 - \mu) \left( \frac{h_l(\theta)}{h_{l-1}(\theta)} \right)^{\gamma-1} \right\} + 1 - \mu.$$

Notice that, if  $h_l(\theta) / h_{l-1}(\theta)$  is increasing in  $\theta$ , so is  $h_{l+1}(\theta) / h_l(\theta)$  because  $\gamma < 1$ . Thus, the ratio  $h_{l+1}(\theta) / h_l(\theta)$  is increasing in  $\theta$  for all  $l \geq 1$ . Q.E.D.

## B.2 Proposition 2

**Proposition 2.** *Suppose no tuition,  $Z_\tau^j = 0$  for all  $j$ . Consider two education levels  $j'$  and  $j$ , with  $j'$  denoting higher attainment ( $j' < j$ ). Then, the relative proportion of individuals choosing education level  $j'$  rather than  $j$  increases with ability:*

$$\frac{\partial [P_\tau^{j'}(\theta) / P_\tau^j(\theta)]}{\partial \theta} > 0.$$

*Moreover, the distribution of ability among agents who choose  $j'$  first-order stochastically dominates the distribution of ability among agents who choose  $j$ .*

By definition:

$$\begin{aligned} \frac{P_\tau^{j'}(\theta)}{P_\tau^j(\theta)} &= \frac{\exp(V_\tau^{j'}(\theta) / \sigma + \bar{\xi}^{j'})}{\exp(V_\tau^j(\theta) / \sigma + \bar{\xi}^j)} \\ &= \exp\left(\left(V_\tau^{j'}(\theta) - V_\tau^j(\theta)\right) / \sigma + \bar{\xi}^{j'} - \bar{\xi}^j\right). \end{aligned}$$



Notice also that:

$$V_{\tau}^{j'}(\theta) - V_{\tau}^j(\theta) = \ln\left(\frac{c_{\tau}^{j'}(\theta)}{c_{\tau}^j(\theta)}\right) \sum_{a=17}^A \beta^a$$

and that the ratio of consumptions  $c_{\tau}^{j'}(\theta) / c_{\tau}^j(\theta)$  is given by:

$$\frac{c_{\tau}^{j'}(\theta)}{c_{\tau}^j(\theta)} = \frac{h^{j'}(\theta)}{h^j(\theta)} \frac{\sum_{a=7+S_{j'}}^A R^{-a} \tilde{w}_{\tau+a}^{j'}}{\sum_{a=7+S_j}^A R^{-a} \tilde{w}_{\tau+a}^j}. \quad (\text{B.4})$$

The latter is increasing in  $\theta$  if the ratio of human capitals  $h^{j'}(\theta) / h^j(\theta)$  is increasing in  $\theta$ . We have already shown in the proof of Proposition 1 that  $h^{j'}(\theta) / h^j(\theta)$  is indeed increasing in  $\theta$ .

The density of ability among education levels is, by definition:

$$p_{\tau}(\theta|j) = \frac{P_{\tau}^j(\theta)g_{\tau}(\theta)}{\int_0^{\infty} P_{\tau}^j(\theta)dG_{\tau}(\theta)},$$

where  $g_{\tau}(\theta)$  is the density of ability. To prove that  $p_{\tau}(\theta|j')$  first-order stochastically dominates  $p_{\tau}(\theta|j)$  it is sufficient to show that there is a cut-off  $\bar{\theta}_{\tau}^{jj'}$ :

$$\begin{aligned} \frac{p_{\tau}(\theta|j)}{p_{\tau}(\theta|j')} &\geq 1 \text{ for } \theta \leq \bar{\theta}_{\tau}^{jj'} \\ \frac{p_{\tau}(\theta|j)}{p_{\tau}(\theta|j')} &< 1 \text{ for } \theta > \bar{\theta}_{\tau}^{jj'}. \end{aligned}$$

Notice that

$$\frac{p_{\tau}(\theta|j)}{p_{\tau}(\theta|j')} = \frac{P_{\tau}^j(\theta)}{P_{\tau}^{j'}(\theta)} \frac{\int_0^{\infty} P_{\tau}^{j'}(\theta)dG_{\tau}(\theta)}{\int_0^{\infty} P_{\tau}^j(\theta)dG_{\tau}(\theta)}.$$

This ratio is strictly decreasing in  $\theta$  by the first part of this proposition. It remains to be shown that for  $\theta \rightarrow 0$  the ratio is larger than 1. If that's the case, the fact that the ratio is decreasing implies that there exists a  $\bar{\theta}_{\tau}^{jj'}$  with the desired property. Suppose then that for  $\theta \rightarrow 0$  the ratio is weakly smaller than 1. This implies that as

$\theta$  grows the ratio is decreasing even further, so that:

$$p_{\tau}(\theta|j) \leq p_{\tau}(\theta|j')$$

for all values of  $\theta$  with at least a strict inequality for some  $\theta$ . This cannot be the case since both  $p_{\tau}(\theta|j)$  and  $p_{\tau}(\theta|j')$  are densities and have to integrate to one. Q.E.D.

## C Data

### C.1 Attainment Effects of War Conflicts and GI Bills

In our modelling analysis of Section 3, we restrict attention to the cohorts born between 1932 and 1972. Notice that individuals in these cohorts were not affected by the 1944 GI Bill, as they were too young to have served during World War II. However, individuals in the 1932–1935 cohorts might have served in the Korea War (1950–53) and hence been affected by the Korea GI Bill of 1952 (Stanley, 2003). Moreover, the opportunity to defer the Vietnam War draft (whose open combat period spans the years 1965–73) afforded by the pursuit of a college degree might have motivated individuals born between 1940 and 1954 to enroll in college (Card and Lemieux, 2001). It is therefore natural to assess the contribution of these events to the educational achievement of the relevant cohorts displayed in Figure 1a.<sup>57</sup>

Stanley (2003, page 673) finds that the increase in post-secondary educational attainment attributable to the Korea GI Bill was largest for the 1921–1933 cohorts. According to his estimates, eligibility for the Korea GI Bill benefits increased college graduation rates by 5 to 6 percentage points among veterans of the Korea War. Notice that if we were to net out from the attainment data the increase in four-year college graduation attributable to the Korea GI Bill, we would have to explain an even larger increase in attainment for the 1928–1948 cohorts than is observed in the data. Card and Lemieux (2001, Table 1B) estimate the excess college graduation rate due

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<sup>57</sup>Notice that the mechanisms by which these two wars might have affected educational attainment are similar. The Korea GI Bill operated on the direct cost of attending college by subsidizing college tuition and living expenses for veterans. The possibility of deferring (and eventually avoiding) the Vietnam draft reduced the opportunity cost of attending college.

to draft avoidance behavior by cohort. According to their results, draft avoidance led to an increase in four-year college graduation rates by 1 percentage point for individuals in the 1941 cohort, 2.22 percentage points for individuals in the 1947 cohort (the peak effect), and 0.50 percentage points for individuals in the 1951 cohort.<sup>58</sup> Card and Lemieux (2001, page 101) conclude their paper arguing that “these effects are modest relative to the overall slowdown in the rate of growth in educational attainment that occurred between cohorts born in the 1940s and those born in the 1950s.” Angrist and Chen (2011) attempt to measure the effect of the Vietnam GI bill on education attainment exploiting randomization induced by the draft-lottery. They estimate that veteran status increase (in a causal sense) college completion by about 5 percentage points for whites (see their Table 3) in the 1948–1952 cohorts. Given that about 24 percent of white males in those cohorts served in Vietnam, the Vietnam war GI bill might have increased educational attainment of those cohorts by about one percentage point, a relatively small number.

In light of these numbers, we conclude that neither the Korea GI Bill nor the Vietnam War had a significant effect on the basic facts we are set of explain. We therefore chose not to further adjust the data when calibrating the model or when interpreting the results.

## C.2 Sample Selection

Our sample is drawn from the March Current Population Survey (CPS) 1964–2010 and the U.S. 1950 and 1960 Censuses.

We include white males, ages 23–65. Since the Current Population Survey does not provide information on an individual’s birthplace before 1994, we do not condition on U.S. born individuals.<sup>59</sup>

We focus on individuals who have attended at least one year of high school, since the population we study in the model refers to individuals with more than a middle-school degree.<sup>60</sup>

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<sup>58</sup>The corresponding figures for some college attendance (as opposed to completion of a four-year degree) are 1.80, 4.01 and 0.90.

<sup>59</sup>Carneiro and Heckman (2003) and Goldin and Katz (2008) show that the slowdown in U.S. educational attainment since 1970 is not due to immigration.

<sup>60</sup>The restriction to individuals with at least a middle-school degree is made in order to limit the

We also restrict attention to the cohorts born between 1932 and 1972. This choice is dictated by the availability of wage data. We would like to focus on the post-WWII period. The earliest representative wage data after WWII were collected in the 1950 U.S. Census and refer to the calendar year 1949. Assuming that an individual drops out of high school at age 16 and begins working at age 17 (as our model assumes), and taking into account that the earliest wage data refer to 1949, this person must be part of the 1932 cohort. We stop with the 1972 cohort to be able to have 15 years of wage data for this cohort starting in 1995 (the year when this cohort's college graduates are assumed to start working).

The sample further restricts attention to individuals who work full-time and full-year, i.e. working at least 35 hours per week at the time of the survey, and who worked at least 40 weeks and had positive earnings in the previous calendar year. By focusing attention on workers with a strong attachment to the labor force we are able to minimize the influence of composition effects in the measurement of earnings over time.

Real weekly earnings are obtained by dividing annual earnings by weeks worked last year and by deflating them using the consumer price index. In doing so for each year and skill group we eliminate from the sample workers in the top and bottom one percent of the weekly earnings distribution.

Regarding educational attainment, one issue is that the age of college graduation and attendance has changed over time, with individuals in later cohorts more likely to graduate in their late 20s than earlier cohorts. We therefore consider the highest degree that individuals report sufficiently late in life. In practice, for a given cohort and degree, we compute the average graduation rate reported between ages 30 and 40. We consider the 30-40 age average in order to obtain reliable estimates, since the number of observations from the CPS is very small once we condition on age, cohort, and degree. We stop at age 40 to prevent death rates, which are systematically associated with education, from affecting our attainment figures.

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set of education choices and keep the structure simple.

### C.3 Tuition

The tuition data series we use is from the *Digest of Education Statistics* (2010, Table 345) for data after 1976 and the book *120 Years of American Education: A Statistical Portrait* (Table 33) for data prior to 1976. Both sets of data include only tuition and required student fees, and are net of room and board (since room and board is not a net cost of education). The data aggregates information from public and private institutions and tuition is in-state for public institutions. Separate data for two and four-year college programs are available only after 1976. We construct the four and two year tuition data prior to 1976 by assuming that the growth rate of each of these two series is the same as the growth rate for aggregate college tuition per student (i.e. the series that does not distinguish between two and four-year programs). Using these growth rates we extrapolate both series backward all the way to the academic year 1950-51. In order to calibrate the level of tuition we construct the present value of four-year tuition for academic year 1950-51 and divide it by the average yearly earnings of high school dropouts in 1949. The resulting ratio is approximately equal to 0.82. We target this moment in the calibration of the version of the model with tuition.

### C.4 Schooling Expenditures

We concentrate on nominal current-fund expenditures per student in fall enrollment, from 1947 until 1994. This allows us to generate comparable series across time and degrees. For elementary and secondary schooling, the data comes from Table 190 of the *2010 Digest of Education Statistics* and Table 170 of the *2000 Digest of Education Statistics*. For higher education, the data on expenditures comes from Table 338 of the *2000 Digest of Education Statistics*, and the data on fall enrollment comes from Table 198 of the *2010 Digest of Education Statistics*. Separate series for two-year and four-year programs are available only starting in 1970 (aggregated between public and private institutions). Notice that for the purpose of allocating expenditures, we identify the “some college” category in the model with a two-year program. The observations prior to 1970 were imputed by the following method. We assume per student expenditures in four-year programs ( $x_t^{4\text{yr}}$ ) relative to two-year

( $x_t^{2yr}$ ) remained constant prior to 1970 at the 1970 level,  $x_t^{4yr}/x_t^{2yr} = x_{1970}^{4yr}/x_{1970}^{2yr}$  for  $t < 1970$ , and then use the following identity to infer  $x_t^{2yr}$  from the aggregate per student spending in higher education ( $x_t^{he}$ ):  $x_t^{2yr} = x_t^{he}/(e_t^{2yr} + e_t^{4yr} x_{1970}^{4yr}/x_{1970}^{2yr})$ , for  $t < 1970$ , where  $e_t^{2yr}$  and  $e_t^{4yr}$  are, respectively, the share of two-year and four-year fall enrollment in the higher education aggregate. This imputation method factors in the possibility that aggregate per student expenditures might vary over time due changes in the composition of higher education enrollment, but not necessarily changes in per student expenditures in each type of program. For a small number of years, observations are missing for all variables. To generate a complete panel for nominal expenditures, we imputed them by linear interpolation. Nominal per student expenditures were then deflated by the Personal Consumption Expenditure aggregate price index for education services, which is available from Table 2.4.4. of the NIPA.

## D Estimates of Experience Profile Parameters

The OLS estimates of the experience profile parameters  $\delta_2^j$  are reported in Table 6. Our calibrated values for the profile parameters  $\delta_1^j$  are in Table 2. We concentrate here on the case of static expectations.

Education Level	Estimate	Standard Error
$j = 1$	-0.0009908**	0.0000937
$j = 2$	-0.0008688**	0.0001047
$j = 3$	-0.0006231**	0.0000762
$j = 4$	-0.0006000**	0.0001317

Note: \*\* denotes statistical significance at the 1 percent level.

Table 6: Estimates of the experience parameters  $\delta_2^j$ .

Figure 8 plots the estimated experience-earnings profiles by education, for an individual with learning ability  $\theta = 1$  and born in cohort  $\tau = 1948$ . Consistent with our static expectations assumption, we keep skill prices constant at the level observed by individuals of this type at age 17.

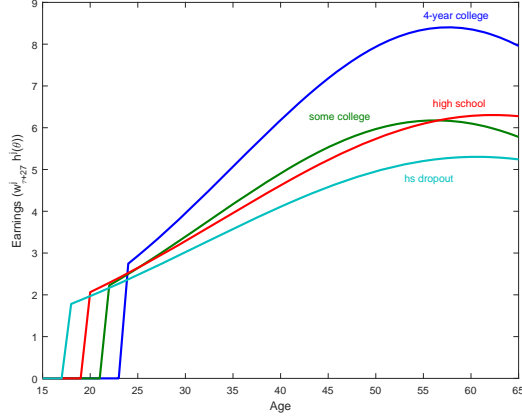


Figure 8: Lifetime earnings profile for an individual of type  $(\theta, \tau) = (1, 1948)$ .

Our estimates of the experience profile parameters  $\{\delta_1^j\}$  and  $\{\delta_2^j\}$  imply that age-earnings profiles have the typical hump-shape, independently of schooling level, and that they are steeper for higher schooling levels. The profiles for different degrees are shifted proportionally depending on the type of individual under consideration. This is either due to differences in skill prices, or due to differences in human capital when finishing school  $h_{\tau+5_j}^j(\theta)$ . Given the lifetime earnings profiles displayed in the figure, a large fraction of the individuals of type  $(\theta, \tau) = (1, 1948)$  end up choosing to graduate from a four-year college program.

## E Alternative Calibration

The calibrated parameters and the moment matching of the alternative calibration of our model are displayed in Tables 7 and 8.

Parameter	Value
$\sigma$	4.2938
$\sigma_\theta$	0.0618
$\bar{\xi}^1$	2.9841
$\bar{\xi}^2$	2.2633
$\bar{\xi}^3$	1.8017
$w_0^1$	0.0006
$w_0^2$	0.0012
$w_0^3$	0.0026
$w_0^4$	0.0053
$\delta_1^1$	0.0340
$\delta_1^2$	0.0308
$\delta_1^3$	0.0264
$\delta_1^4$	0.0333
$\mu_{\theta 1963}$	0.6651

Table 7: Alternative Calibration

## Appendix References

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Moments	Data	Model
<i>Educational attainment, 1932 cohort</i>		
1. High school	0.3976	0.3759
2. Some college	0.1971	0.1940
3. Four-year college	0.2479	0.2407
<i>Educational attainment, 1972 cohort</i>		
4. High school	0.3024	0.3150
5. Some college	0.2724	0.2796
6. Four-year college	0.3623	0.3765
<i>Education premiums (relative to high school), 1932 cohort</i>		
7. High school dropout	0.9261	1.0286
8. Some college	1.0650	0.9960
9. Four-year college	1.1546	1.1150
<i>Education premiums (relative to high school), 1972 cohort</i>		
10. High school dropout	0.7485	0.6468
11. Some college	1.1084	1.1615
12. Four-year college	1.5741	1.6585
13. Earnings in 2009 relative to 1959, all cohorts	1.7022	1.6780
14. Std deviation log weekly earnings, 1932 cohort	0.2513	0.2474
15. Present value of 4 year college tuition relative to earnings of high school dropout in 1949	0.8772	0.8899
<i>High-school dropout rates</i>		
16. 1935 cohort	0.1654	0.1520
17. 1940 cohort	0.1219	0.1070
18. 1945 cohort	0.0913	0.0773
19. 1950 cohort	0.0550	0.0622
20. 1955 cohort	0.0524	0.0620
21. 1960 cohort	0.0657	0.0621
22. 1965 cohort	0.0480	0.0564
23. 1970 cohort	0.0565	0.0351
Fit (avg Euclidean percentage deviation from data)		0.1180

Table 8: Targeted Moments, Alternative Calibration