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Educational Attainment in the U.S.*

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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 calibrated model of investment in human capital with heterogeneous learning ability. The inter-cohort variation in schooling is driven by changes in skill prices, tuition, and education quality over time, and average learning ability across cohorts. A version of the model with static expectations is successful in accounting for the main patterns in the data. Rising skill prices for college explain the rapid increase in college graduation till the 1948 cohort. The measured decline in average learning ability contributes to explain 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

We study the evolution of educational attainment of a large number of cohorts of U.S. white males.¹ Among the 1932–1972 birth cohorts, college graduation rates rose sharply until they peaked with the 1948 cohort. Strikingly, college attainment has basically not improved since this early expansion. Graduation rates actually declined between the 1948 and the 1960 cohorts, followed by only a slow recovery till the 1972 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, and education quality, and changes across cohorts in average learning ability measured at age fourteen. The inter-cohort variation in average learning ability is a novel and central feature of our analysis.

The model attributes almost two thirds of the increase in the college graduation rates of the early expansion (1932–1948) cohorts to a rising skill price for college graduates in the 1950s and 1960s. Skill prices, however, are inconsistent with the subsequent stagnation in college attainment. The observed variation in skill prices over time 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. Inter-cohort variation in average learning ability - calibrated using cohort-level data on standardized eight-grade test scores - helps address both of these issues. Standardized test scores show a steady decline starting with the 1948 cohort until the 1963 cohort. According to our model, this decline in average learning ability explains about 30 percent of the observed decline in college graduation rates of the 1948–1960 cohorts, and reduces the gain in college graduation rates of the slow recovery (1960–1972) cohorts by about 1 percentage point. Overall, the college graduation rate of the 1972 cohort would have been about 4 percentage points larger if average learning ability had remained constant.

¹Our 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 \(2010\)](#).

A second important ingredient of our analysis are static expectations, that is, expectations of future relative skill prices based on *current* skill premiums. The importance of static expectations for understanding educational attainment has also been emphasized, among others, by Keller (2013) 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.

Understanding the evolution of educational attainment is clearly important because of the tight link between investment in education, individual welfare, and wage inequality (see Autor, Katz and Kearney, 2008, for a summary of the evidence on college premiums).² We follow a standard theory of human capital accumulation in which skill prices are the single most important quantitative factor in explaining the evolution of educational attainment between the 1932 and the 1972 cohorts. The importance of skill prices in accounting for the increase in educational attainment has been emphasized in recent quantitative work by, among others, Heckman, Lochner and Taber (1998), Lee and Wolpin (2010), and Restuccia and Vandenbroucke (2013b).³ Our quantitative results are 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

²There is also an extensive and well-known literature following the seminal work of Katz and Murphy (1992) and including Topel (1997) and Goldin and Katz (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.

³Restuccia and Vandenbroucke (2013b) argue that most of the increase in educational attainment between 1940 and 2000 can be attributed to the rise in the relative skill price of college. Heckman, Lochner and Taber (1998, page 46) argue that skill prices alone can account for the dramatic rise in college enrollment in the 1960s. Lee and Wolpin (2010) state that “changes in the educational attainment of the workforce, as measured by the ratio of the number of employed college graduates to the number of employed high school graduates, was also mostly a demand-driven phenomenon.” Along similar lines, Topel (2005) writes that: “When increased demand raises the return to skills, basic economics tells us that investment in skills will rise, just as more houses will be built when the demand for them rises.”

increase in college attainment for the cohorts up to 1948. Differently from these papers, we focus on the *cohort-by-cohort* variation in attainment. This focus 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.

Regarding the tension between skill prices and the subsequent dynamics of educational attainment, a number of authors, such as Goldin and Katz (2008, page 347) and Carneiro and Heckman (2003, page 3), have also expressed concern about the lack of a stronger reaction of college attainment to the rise in the college premium of the 1980s. They have suggested that additional forces, other than skill prices, should be taken into account. While we consider some of these forces, like tuition, the novel feature of our analysis is the evolution of average learning ability across cohorts. Using a variety of standardized achievement tests, assembled and analyzed by the Congressional Budget Office (1986, 1987), we document a substantial decline in test scores for American elementary and secondary education students starting with the cohorts born in the late 1940s. The timing of this test score decline coincides with the beginning of the stagnation in college graduation rates in the U.S. We also show that the latter is in fact part of a broader educational phenomenon. There is, in particular, a striking parallel between the evolution of college attainment and the evolution of high school dropout rates, with stagnation in both series beginning with the 1948 cohort. We view this as indication that cohort-specific (rather than degree-specific) factors, like changes in average learning ability, are promising for understanding the data. While we are the first ones to emphasize and quantify the connection between stagnation in schooling and test scores, Bishop (1989) had previously quantified the effect of the “historically unprecedented” (in his words) test score decline on U.S. labor productivity growth.⁴

This paper is related to a growing literature, encompassing macro and micro studies, on the determinants of schooling over time in the U.S. In addition to the papers cited above, Goldin and Katz (2008) study the history of educational attainment and education earnings premiums during the entire 20th century. According to their analysis, the pre-WWII period was characterized by a rapid expansion of

⁴Bishop (1989, page 193) 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.

high school and college graduation rates accompanied by declines in high school and college wage premiums. We do not consider this period mainly for lack of comprehensive wage data.⁵ A number of papers have tried to explain the inter-cohort evolution of college attainment in the U.S. Some use reduced-form empirical models, while others adopt structural approaches. Among the former, [Topel \(1997, 2005\)](#) emphasizes the high correlation between the variation in college attainment and contemporaneous returns to college since the early 1960s to argue that returns drive attainment. [Card and Lemieux \(2001\)](#) estimate a number of reduced-form models of men's college graduation rates by cohort on returns to education, cohort size, and tuition. Relative to these contributions, we deal explicitly with the issue of selection across schooling levels and the related problem of measuring skill prices separately from average wages ([Heckman, Lochner and Taber, 1998](#), and [Hendricks and Schoellman, 2014](#)).⁶

In the structural literature, three papers ([Keller, 2013](#); [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 and comparison of our results with theirs 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.

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.

⁵[Goldin and Katz \(2008\)](#) use the Iowa Census and other sources. [Kaboski \(2004\)](#) formalizes some of their arguments to reconcile the rapid expansion in years of schooling in the first half of the century with the decline in returns to schooling observed during this period.

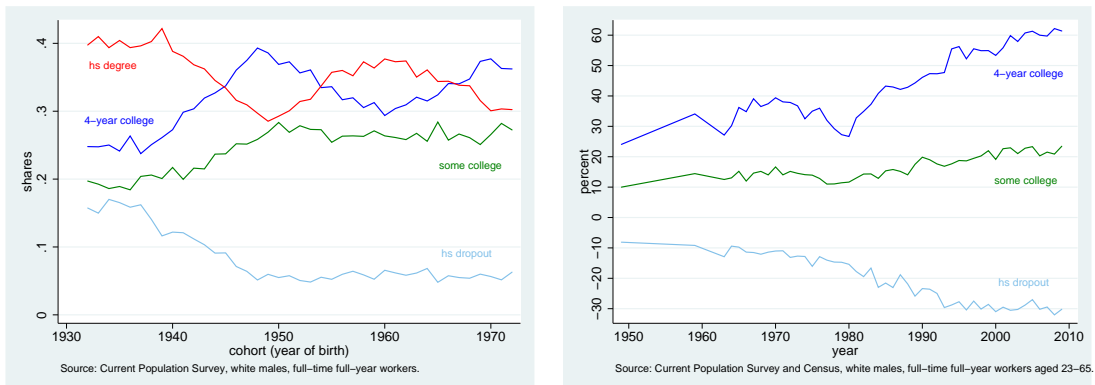
⁶[Bound and Turner \(2007\)](#), and [Lee \(2005\)](#) study the effect of cohort size on college attainment.

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. 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.⁷

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 presents the fraction of individuals in each cohort with a given level of schooling, for the 1932–1972 cohorts.



(a) Educational attainment by birth cohort.

(b) Wage premiums relative to high school degree.

Figure 1: Educational attainment and wage premiums

The data shows a rapid increase in achievement for the 1932–1948 birth co-

⁷See Appendix C.2 for details on the sample and the measures of educational attainment.

horts. 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.⁸ For the 1949–1960 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 \(2008, Figures 7.1, 7.2 and 9.2\)](#).

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](#).

⁸In [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.

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 age 23, the time of college entry in our model.⁹ 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.¹⁰

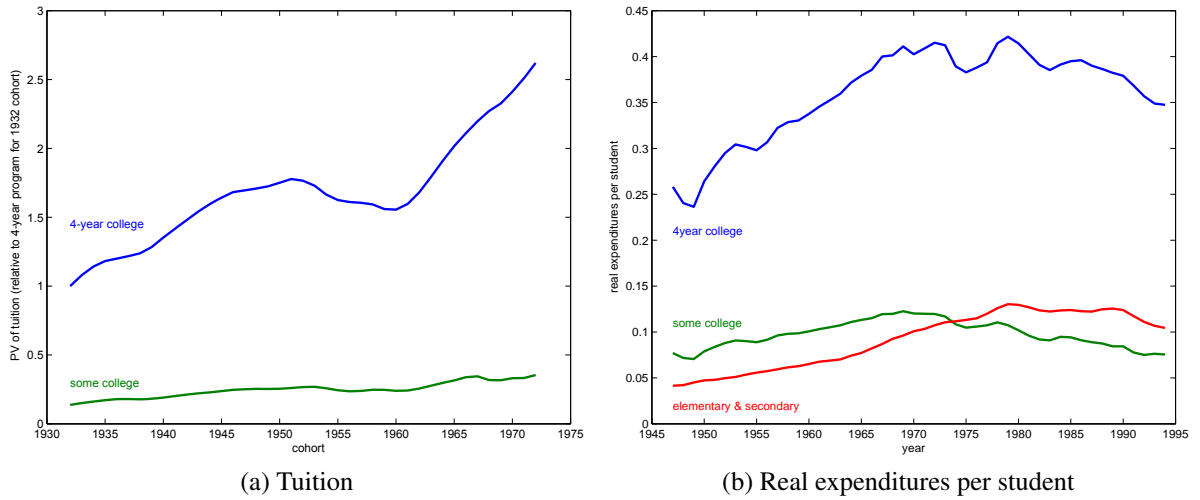


Figure 2: Tuition and education expenditures

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

⁹The 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.

¹⁰We 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.

elementary and secondary schools, and two and four-year college programs.¹¹ 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, 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 as measured at age 14. We rely on two related and lengthy studies published by the Congressional Budget Office (1986, 1987) to summarize the available evidence on the trends in educational achievement of elementary and high school students over time and across birth cohorts. Two trends emerge from the data analyzed by the Congressional Budget Office (CBO).¹² First, a variety of test scores show a progressive decline starting with the cohorts born in the late 1940s-early 1950s. Second, the decline stops for cohorts born in the early 1960s, and some test scores show a subsequent improvement for cohorts born since the mid-1960s.

Table 1 pertains to the decline phase. It reproduces Tables III-1 and III-2 from the 1986 report of the CBO. It presents the birth cohort for whom test scores started declining and the birth cohorts for whom test scores stopped declining, for different types of tests. In addition the table also reports the magnitude of the decline for each test between the onset and the end of the achievement decline.¹³

As the table suggests, and the Congressional Budget Office (1986, page 29) emphasizes, the decline was evident from a variety of tests, involving students in many grades, and in different subject areas. The average magnitude of the decline across different tests is about 0.3 standard deviations, so that the median student at the end of the decline would have scored at about the 38th percentile at the beginning

¹¹Nominal 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).

¹²These 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.

¹³See also Table C-1 of Congressional Budget Office (1986) for more comprehensive data on the extent of the decline in test scores for a larger number of tests by subject and grade.

of the decline. The larger decline associated with the ACT score would place the median student at the end of the decline at the 29th percentile of the distribution at the beginning of the decline. The test that best fits the timing of our model is the 8th grade Iowa Test of Basic Skills (ITBS), a standardized test that is now used in school districts throughout the U.S. The ITBS score data in Table 1, though, refer to Iowa students only, as that state was an early adopter of these tests.

Test	Onset (birth cohort)	End	Magnitude of decline (standard deviations)	
			Largest	Smallest
SAT	1946	1962	0.48 (verbal)	0.28 (math)
ACT composite	1949	1958	0.55 (social studies)	-0.06 (science)
Iowa grade 5 (ITBS)	1956	1964	0.38 (math)*	0.10 (vocabulary)*
Iowa grade 8 (ITBS)	1953	1963	0.47 (math)	0.26 (vocabulary)
Iowa grade 12 (ITED)	1951	1962	0.40 (reading)	0.27 (math)

Source: [Congressional Budget Office \(1986, Tables III-1 and III-2\)](#). SAT stands for scholastic aptitude test, ACT for American College Testing, ITBS for Iowa Tests of Basic Skills, ITED for Iowa Tests of Educational Development.

* Test scores are for grade 6 as the grade 5 scores are not reported in Table III-2 of the original report.

Table 1: Evidence on Test Score Decline

The data in Table 1 refer to populations that include both male and female students as well as whites and minority students alike. The [Congressional Budget Office \(1986, page 68\)](#) report contains a brief discussion of these trends for males and females separately, 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 [Congressional Budget Office \(1986, page 32 and Appendix B\)](#) 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 stagnation of 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 of the paper.

The [Congressional Budget Office \(1986, page 46\)](#) report also discusses an upturn phase in which test scores began to rise beginning with the cohorts born in the mid-1960s. The evidence on the upturn is however less extensive because of a smaller number of cohorts taking those tests by the time the report was written, in the mid-1980s. The evidence on the upturn is mixed if one considers the available data. The SAT verbal scores for the 1972 cohort of males are basically identical to the corresponding ones for the 1962 cohort, which marks the end of the decline according to the data in Table 1. The SAT math scores, instead, only show a slight improvement between these two cohorts.¹⁴ Since it can be argued that the SAT data suffer from a sample selection problem, it might be more informative to consider the nationally representative National Assessment of Educational Progress (NAEP) data. Consistent with the data in Table 1, the NAEP data (see [Hanushek, 2003, Figure 1](#)) show a consistent decline in science and math test scores for 17 years old students between 1969 (1952 cohort) and 1982 (1965 cohort). Both test scores then display a recovery but the extent of the recovery depends on the specific test. For example, by the 1972 cohort (the last cohort 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. Thus, while the evidence on the test score decline is consistent across tests and subjects, the evidence in support of the recovery for the 1965-1972 cohorts is less clear-cut.

Interestingly, the CBO reports also assess the evidence in favor of alternative explanations for the test score decline ([Congressional Budget Office, 1987, Table 1](#)). The CBO classifies possible explanations for the evolution of test scores into three broad categories. First, there are educational factors associated with measures

¹⁴The SAT data is from the Profile Report of [Total Group \(2013\)](#).

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). Several results of the CBO analysis are worth emphasizing. 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 factor is typically small. Among the factors that are potentially important according to the CBO, the rise in average family size associated with the baby boom stands out. Second, the CBO concludes that a number of factors probably did *not* contribute significantly to the trends. Among those are observed changes in teachers' quality (as measured by test scores or educational attainment of teachers), the rise in single-parent households, and the rise in female labor force participation. Third, some potentially important factors, like changes in coursework in K-12 education, cannot be quantified because of lack of data.

Based on this evidence, a distinctive feature of our model is that we let mean ability to learn, as measured at age 14, vary across cohorts. Section 4.1.3 describes the approach we follow in disciplining the evolution of this parameter.

3 Model

We focus on 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 τ . Calendar time is denoted by t and an individual's age by l . We assume that schooling choices are made at age 15, and take the convention that $l = 1$ denotes this age.¹⁵ An

¹⁵Calendar time is thus related to birth cohort and age by the following equation: $t = \tau + 14 + l$.

individual's economic life starts at age $l = 1$ and goes until age $l = L$, at which point the individual dies.¹⁶

Human Capital Accumulation Human capital is accumulated through schooling and experience. There are four mutually exclusive education choices, denoted by j . Each schooling level j 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 $S_1 = 8$ years of school (in addition to the eight years of middle school); some college ($j = 2$) involving $S_2 = 6$ years of school; high school degree ($j = 3$) for a total of $S_3 = 4$ years of school; and high school dropout ($j = 4$) involving $S_4 = 2$ years of school.¹⁷ During formal schooling leading up to terminal degree j , human capital of an individual born in year τ with learning ability θ accumulates according to the law of motion

$$h_{\tau+15+l} = \theta h_{\tau+14+l}^\gamma \left(x_{\tau+14+l}^{j'}\right)^\varphi + (1 - \mu) h_{\tau+14+l} \quad (3.1)$$

where j' denotes the level of schooling in which the agent is currently enrolled. Thus, for example, an agent whose terminal degree is $j = 1$ (four year college) will be enrolled in school level $j' = 4$ at ages $l = 1, 2$, in school level $j' = 3$ at ages $l = 3, 4$, and in school level $j' = 1$ at ages $l = 5 - 8$. Similarly for the other choices.

The rest of the notation is as follows: μ is the rate of depreciation and the first-term on the right-hand side of equation (3.1) is the investment at age l for an individual attending school level j' . The latter increases with an individual's ability to learn θ , with the previously accumulated human capital $h_{\tau+14+l}$ and with the quality of education $x_{\tau+14+l}^{j'}$ 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'

¹⁶We do not include a retirement period in the model. Given the fact that education choices are made at age 15 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.

¹⁷Notice that individuals in our model 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.

(e.g. it can differ in college relative to high school) and, for given schooling level, by cohort τ . The initial human capital, denoted by $h_1 \equiv h_{\tau+14+1}$, is a parameter and is assumed to be the same for all agents in all cohorts. An individual who completes S_j years of schooling obtains human capital $h_\tau^j(\theta)$, given by the left-hand side of equation (3.1) when $l = S_j$.

The learning ability parameter θ is distributed in the population according to a cumulative distribution function $G_\tau(\theta)$. We interpret θ 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 14. Motivated by the evidence discussed in Section 2.4, in the quantitative version of the model (Section 4.1.3) we allow average learning ability to vary across cohorts.

After the completion of formal education an individual's human capital evolves exogenously over time according to:

$$h_{\tau+14+l}^j(\theta) = h_\tau^j(\theta) \exp\left(\delta_1^j(l - S_j - 1) + \delta_2^j(l - S_j - 1)^2\right) \text{ for } l = S_j + 1, \dots, L \quad (3.2)$$

where δ_1^j and δ_2^j are the parameters governing the returns to experience, which are allowed to depend on the schooling level j (but not on calendar year), and $l = S_j + 1$ is the age at which the individual begins his working life.¹⁸

Preferences Individuals' preferences have two components. The first one reflects consumption over the life-cycle while the second one reflects preferences for specific education choices. Formally, an agent born in year τ with ability θ , 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 defined as follows:

$$\sum_{l=1}^L \beta^{l-1} \ln c_{\tau+14+l}^j + \sigma \left(\xi_i^j + \bar{\xi}^j \right), \quad (3.3)$$

¹⁸Notice that the returns to experience do not depend on the ability to learn parameter θ after conditioning on schooling. This specification is consistent with some of the previous papers in this literature, i.e. [You \(2014\)](#) and [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 (see Section 4.1.1).

where the parameter β is the constant discount factor. The random variable ξ_i^j represents individual i 's preferences for schooling-level j .¹⁹ These shocks are independent across degrees j for the same individual i . We also assume that each ξ_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 ξ_i at the beginning of his first period of life ($l = 1$) and 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. 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 ξ_i breaks the strict sorting of education choices on learning ability and allows for a degree of ability mixing within each schooling choice.²⁰ 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 will be to account for the attainment *dynamics* across cohorts, given the average attainment levels. As σ 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 $l = 1$, individuals in each cohort τ need to formulate expectations about the path of skill prices, $\{w_{\tau+14+l}^j\}_{l=S_j+1}^L$ for all j , they will face during their lifetime. We consider two alternative specifications for the formation of expectations.

The first one is perfect foresight: agents are assumed to know the future real-

¹⁹To save on notation, we omit the subscript i from consumption and human capital choices.

²⁰In other related models of education choice, such as Willis and Rosen (1979), Lee and Wolpin (2010), and Gemicci 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.

ization of the series of skill prices at the time they make their education choices. The assumption of perfect foresight is obviously strong, as it endows agents with the ability to predict shifts in trends of skill prices that are largely unexpected to researchers and policymakers. 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. It is, therefore, common in the literature to consider a version of the model in which expectations of future skill prices are based on the realizations of skill prices observed by the agent at the time education choices are made. These departures from perfect foresight are often shown to improve the fit of the attainment data, at least in some dimensions (e.g. Keller, 2013; Donovan and Herrington, 2013).

Based on these observations, we consider a second specification of expectations, which we label “static” . We postulate that agents in cohort τ make their schooling plans by assuming that skill prices will remain constant at the level they observe when they are about to make their schooling decisions. In practice, we suppose they rely upon skill prices at age seventeen, $w_{\tau+17}^j$.²¹ This is the age in the model when individuals have the opportunity to dropout of high-school. Given the way we measure skill prices in the data, based on cross-sectional information, our assumption is akin to supposing agents base their 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;²² and (ii) individuals are able to perfectly forecast the tuition

²¹We use prices at age 17 (rather than 15, which would correspond to $l = 1$) because the earliest observations on earnings are from the 1950 Census and refer to the calendar year 1949 (which equals 1932 plus 17). Using prices at age 17 therefore allows us to treat all cohorts symmetrically regarding their expectation formation.

²²Planned consumption decisions will instead differ from actual ones, depending on the skill price

and school quality levels that are relevant for their own education choices.

We denote by $\widehat{w}_{\tau+14+l}^j$ the skill price associated with education choice j expected at age l by an agent who is a member of cohort τ . Under perfect foresight, it is the case that $\widehat{w}_{\tau+14+l}^j = w_{\tau+14+l}^j$, while under static expectations $\widehat{w}_{\tau+14+l}^j = w_{\tau+17}^j$.

Budget Constraint An individual of cohort τ and learning ability θ that makes education choice j faces the following lifetime budget constraint:

$$\sum_{l=1}^L R^{-(l-1)} c_{\tau+14+l}^j = \sum_{l=S_j+1}^L R^{-(l-1)} (1 - \lambda) \widehat{w}_{\tau+14+l}^j h_{\tau+14+l}^j(\theta) - Z_{\tau}^j, \quad (3.4)$$

where R is the exogenous gross interest rate, λ is the labor income tax rate, which we assume to be constant, and Z_{τ}^j is the present value of tuition, as of age $l = 1$, for any individual in cohort τ who picks schooling option j . We assume that secondary schooling is publicly financed so that tuition is paid only by individuals attending college ($Z_{\tau}^4 = Z_{\tau}^3 = 0$). The present value of tuition Z_{τ}^j is defined as:

$$Z_{\tau}^j = \sum_{l=S_3+1}^{S_j} R^{-(l-1)} z_{\tau+14+l}^j, \text{ for } j = 1, 2$$

where $z_{\tau+14+l}^j$ represents the yearly tuition for an individual in cohort τ 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 are primarily motivated by the desire 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

realizations. Our ancillary assumption ensure this won't affect schooling decisions.

associated with parental background, rather than short-run parental liquidity, in determining college attendance.²³

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. It is 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.²⁴ Second, we postulate a simple environment in which individual earnings are 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 to track such evolution across the large number of cohorts we consider. We therefore opt for a simpler setting without idiosyncratic shocks.²⁵ Third, all agents begin their life with zero wealth and the present value of tuition Z_τ^j is assumed to be the same for all agents in the same cohort.²⁶ Cross-sectional heterogeneity along these dimensions would con-

²³However, 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. To the extent that a higher role for borrowing constraints may have coincided with the increase in tuition levels documented in Section 2.3, this feature could further improve the model's ability to explain the relative stagnation in college attainment for the post-1963 cohorts.

²⁴[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 explain the joint evolution of educational attainment and hours worked.

²⁵Relaxing 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.

²⁶Differences in effective tuition among individuals would emerge because of grants, scholarships, or inter-vivos transfers conditional on schooling choices. Notice that with frictionless financial markets, the only channel by which initial wealth affects schooling choices is by reducing the differences in lifetime consumption among alternative levels of schooling. Therefore, wealthier

tribute 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 σ) to preference shocks in schooling decisions. The more important question for our purposes 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 given choice of education, individuals solve for the optimal consumption profile. The first order condition for consumption is:

$$c_{\tau+14+l+1}^j = \beta R c_{\tau+14+l}^j \text{ for } l = 1, \dots, L - 1. \quad (3.5)$$

For simplicity, we assume that the discount factor is such that $\beta R = 1$, which implies constant consumption over the life-cycle. The planned consumption level of an individual of cohort τ and learning ability θ making school choice j is then:

$$c_{\tau}^j(\theta) = \frac{\sum_{l=S_j+1}^L R^{-(l-1)} (1 - \lambda) \widehat{w}_{\tau+14+l}^j h_l^j(\theta) - Z_{\tau}^j}{\sum_{l=1}^L R^{-(l-1)}}. \quad (3.6)$$

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

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.

(exclusive of ξ_i and $\bar{\xi}^j$):

$$V_\tau^j(\theta) = \ln(c_\tau^j(\theta)) \sum_{l=1}^L \beta^{l-1}.$$

An individual i of ability θ and preference vector ξ_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). 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. Hence, the model does not feature perfect sorting across schooling levels based on ability.

In order to determine the sorting pattern based on ability it is necessary to integrate out the school preference shocks. The well-known properties of the type-I extreme value distribution imply that the proportion of individuals of type θ in cohort τ who choose schooling level j is:

$$P_\tau^j(\theta) = \frac{\exp\left(V_\tau^j(\theta)/\sigma + \bar{\xi}^j\right)}{\sum_i \exp\left(V_\tau^i(\theta)/\sigma + \bar{\xi}^i\right)}. \quad (3.7)$$

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). As a consequence, earnings premiums associated with higher education levels reflect in part sorting by individuals with heterogeneous abilities instead of different skill prices (Taber, 2001).

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

In the first calibration step, we jointly estimate the period-by-period growth rates of skill prices for each schooling level together with the returns to experience parameters in equation (3.2). The essence of our approach is to exploit variation over time in the average earnings of individuals of a given schooling group and cohort to identify the evolution of skill prices. The challenge in trying to infer skill prices from earnings is the fact that variation in earnings over time might reflect either variation in skill prices or changes in the distribution of ability among individuals who choose a given education level. We solve this identification problem by tracking the evolution of average earnings of members of the *same* cohort and education group over time. While this approach allows us to compute the growth rates of skill prices over time, it does not pin down their initial levels (see Section 4.1.3 for a description of how these levels are determined).

Formally, let $w_t^j \bar{h}_{t\tau}^j$ represent the average earnings in period t of workers who belong to cohort τ and make schooling choice j . Average earnings for this group are the product of the skill price w_t^j and the average human capital of those workers,

denoted by $\bar{h}_{t\tau}^j$.²⁷ Simple manipulation of equation (3.2) shows how the growth rate of average earnings for individuals in cohort τ who choose schooling level j can be decomposed as follows:

$$\ln \frac{w_{t+1}^j \bar{h}_{t+1\tau}^j}{w_t^j \bar{h}_{t\tau}^j} = \ln \frac{w_{t+1}^j}{w_t^j} + \delta_1^j + \delta_2^j \left(2(t - \tau - 14 - S_j) - 1 \right), \quad (4.1)$$

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. Notice that the average human capital of a cohort τ measured at the time of graduation from school level j does not change over time and therefore drops out of the expression for the growth rate of earnings in equation (4.1). 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.

The growth rate of average earnings between periods t and $t + 1$ for a given cohort τ of agents is assumed to be measured with error:

$$e_{t+1\tau}^j = \ln \frac{w_{t+1}^j \bar{h}_{t+1\tau}^j}{w_t^j \bar{h}_{t\tau}^j} + u_{t+1\tau}^j, \quad (4.2)$$

where $e_{t+1\tau}^j$ denotes the observed growth rate and $u_{t+1\tau}^j$ is the classical measurement error. Replacing the cubic polynomial in time and equation (4.1) into equation (4.2) yields the regression equation we estimate:

$$e_{t+1\tau}^j = \delta_1^j + \alpha_0^j + \alpha_1^j t + \alpha_2^j t^2 + \alpha_3^j t^3 + \delta_2^j \left(2(t - \tau - 14 - S_j) - 1 \right) + u_{t+1\tau}^j, \quad (4.3)$$

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

Several remarks are in order. First, as can be noticed from equation (4.3), δ_1^j is not separately identified from the constant term α_0^j in the cubic polynomial. We identify δ_1^j in Section 4.1.3 by requiring the model to match a number of additional

²⁷See Appendix A for a formal definition of $\bar{h}_{t\tau}^j$.

moments. Second, the parameter δ_2^j and the coefficients α_k^j , for $k = 1 - 3$ can instead be identified and estimated using ordinary least squares. Differently from δ_1^j , the parameter δ_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.²⁸ Third, the structure of the data underlying equation (4.3) is an unbalanced panel of earnings growth by cohorts over time. The dependent variable $e_{i+1\tau}^j$ is constructed as the weighted (by weeks worked) average of weekly earnings of full-time full-year white male workers in a given cohort τ and schooling level j .²⁹ Thus, even if our goal is to explain the attainment data for the 1932–1972 cohorts, in order to estimate the parameters in equation (4.3), we include individuals who belong to the cohorts 1884–1986 as long as they satisfy the 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 (4.3) 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 under static expectations.³⁰

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

²⁸The point estimates of the curvature parameters δ_2^j are reported Appendix D together with the experience profiles by education group. The estimated δ_2^j are all negative, which is consistent with a hump-shaped profile of earnings over the life-cycle.

²⁹The 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.

³⁰As mentioned in the text, the skill price series cannot be estimated completely outside of the model because in the regression equation (4.3) 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.

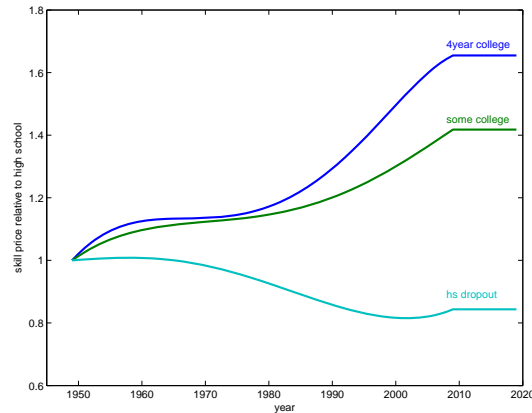


Figure 3: Skill Prices (relative to high school)

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.

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: $L = 50$. Since in the model individuals begin life at age 15 they are assumed to retire at age 65.
- Gross real interest rate: $R = 1.05$. A standard value, and the one used by Heckman, Lochner and Taber (1998).
- Discount factor: $\beta = 1/R$.
- Labor income tax-rate: $\lambda = 0.15$, the same as in Heckman, Lochner and Taber (1998).
- Curvature of human capital accumulation technology during schooling period: $\gamma = 0.85$. This is consistent with the values estimated by Heckman,

Lochner and Taber (1998) and employed by You (2014).³¹

- Depreciation rate of human capital accumulation technology: $\mu = 0$, consistent with Heckman, Lochner and Taber (1998) and You (2014).
- The parameter φ , which captures the elasticity of human capital formation to school quality, is set to 0.06, as estimated by You (2014). Recall that our proxy for school quality are education expenditures per student at different levels of schooling shown in Figure 2b.
- Psychic cost of high-school dropouts is normalized to zero without loss of generality: $\bar{\xi}^4 = 0$.
- Initial human capital is normalized without loss of generality: $h_1 = 1$.
- The distribution of ability, conditional on cohort τ , is lognormal: $\theta \sim LN(\mu_{\theta\tau}, \sigma_\theta)$ with mean $\mu_{\theta\tau}$ and standard deviation σ_θ . 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 of our calibration procedure we calibrate the remaining fourteen parameters. These are $(\sigma_\theta, \sigma, \{\bar{\xi}^j\}_{j=1}^3, \{w_0^j\}_{j=1}^4, \{\delta_1^j\}_{j=1}^4)$, plus an additional parameter, $\mu_{\theta 1963}$, that represents average learning ability of individuals in the 1963 cohort (more on this below). To calibrate these fourteen parameters we focus on the following sixteen moments (their empirical counterparts are listed in Table 4):

- 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.

³¹Computations we have performed and that are not shown, suggest that our results are not sensitive to a specific choice of γ in the range $[0.5, 1]$.

- 7.-8. High school dropout earnings premium (relative to high school) among 27 year old workers in the 1932 and 1972 cohorts.³²
- 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 1972.³³
14. Standard deviation of log weekly earnings among 37 year old workers in the 1932 cohort.³⁴
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 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. Specifically, the main feature of the empirical evidence reviewed by the **Congressional Budget Office (1986)** is a steady decline in median test scores between the 1948 and the 1963 cohorts. We take the peak-to-trough magnitude

³²We 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.

³³The 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.

³⁴Our model abstracts from labor earnings uncertainty, among full-time full-year workers. We follow **Guvnen 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. **Guvnen and Kuruscu (2010)** report an estimate of the variance of such shocks to be 0.135, based on **Guvnen (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 **Guvnen's (2009)** sample.

of the decline to be equal to 0.37 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 1948 cohort. The decline by 0.37 standard deviations equals the average decline on the math and vocabulary Iowa Test of Basic Skills administered to 8th grade students (Table 1). We focus on 8th grade students because they are about to begin high school, as the agents in our model. 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) learning ability θ in the model. Moreover, since the empirical distribution of test scores in the data is typically normal, it is natural to interpret $\log \theta$, which is normally distributed by assumption, to represent the model counterpart of a test score. Let $E_\tau [\log \theta]$ and $V_\tau [\log \theta]$ denote the mean and variance of $\log \theta$ among agents in the τ cohort. Thus, the evidence that the average test scores in the 1963 cohort are 0.37 standard deviations below the average test scores in the 1948 cohort can be formalized as follows:

$$\frac{E_{1963} [\log \theta] - E_{1948} [\log \theta]}{\sqrt{V_{1948} [\log \theta]}} = -0.37. \quad (4.4)$$

This moment identifies the average learning ability, denoted by $\mu_{\theta 1963}$, of individuals in the 1963 cohort.³⁵ 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

$$\mu_{\theta \tau} = \begin{cases} 1, & \tau \leq 1948; \\ 1 - (1 - \mu_{\theta 1963}) \frac{\tau - 1948}{1963 - 1948}, & 1948 < \tau \leq 1963; \\ \mu_{\theta 1963}, & \tau > 1963. \end{cases} \quad (4.5)$$

Thus, average learning ability is constant between $\tau = 1932$ and $\tau = 1948$, declines at a constant pace between $\tau = 1948$ and $\tau = 1963$, and is again constant for later cohorts.

³⁵Since θ is lognormally distributed, $\log \theta$ is distributed as a normal, and therefore there is a one-to-one mapping between $E_\tau [\log \theta]$ and $V_\tau [\log \theta]$ and the structural parameters $\mu_{\theta \tau}$ and σ_θ^2 .

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 σ . 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 σ_θ , 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 data moments 1–15 and that matches moment 16 exactly.³⁶

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 we consider, static and perfect foresight.³⁷ The parameters set a-priori are listed in Table 2 and the remaining ones in Table 3.

L	β	R	γ	μ	h_1	λ	$\bar{\xi}^4$	μ_θ	φ
50	0.95	1.05	0.85	0.00	1.00	0.15	0.00	1.00	0.06

Table 2: Parameters Set A-Priori

Table 4 summarizes the moments used to calibrate the parameters and their predicted values. Overall, the model fits the moments very well. Notice that according to the calibration, average learning ability drops by four–five percent, depending on the version of the model, between the 1948 and the 1963 cohorts.

³⁶We impose that the model match moment 16 exactly because the decline in average learning ability is the novel feature of our analysis.

³⁷Under 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
σ	3.9707	1.6428
σ_θ	0.1088	0.1332
$\bar{\xi}^1$	-1.2806	-3.2635
$\bar{\xi}^2$	-1.2323	-2.2837
$\bar{\xi}^3$	-0.9460	-1.3424
w_0^1	0.0167	0.0138
w_0^2	0.0429	0.0415
w_0^3	0.1339	0.1374
w_0^4	0.3813	0.4053
δ_1^1	0.0637	0.0632
δ_1^2	0.0567	0.0554
δ_1^3	0.0499	0.0476
δ_1^4	0.0482	0.0462
$\mu_{\theta 1963}$	0.9611	0.9529

Table 3: Calibrated Parameters

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 do so for the case of static expectations, as in the next section we show that it provides a better account of the evolution of educational attainment than the perfect foresight version of the model. Figure 4 illustrates the basic mechanisms underlying the selection of heterogeneous individuals across 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 θ 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

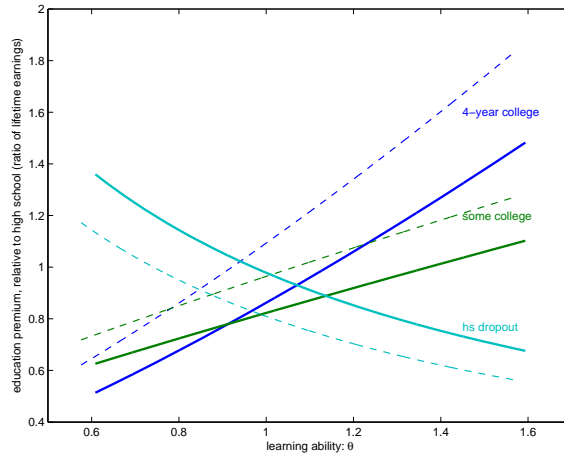
Moments	Data	Static	P. Foresight
<i>Educational attainment, 1932 cohort</i>			
1. High school	0.3976	0.3971	0.3947
2. Some college	0.1971	0.1986	0.1956
3. Four-year college	0.2479	0.2455	0.2724
<i>Educational attainment, 1972 cohort</i>			
4. High school	0.3024	0.3030	0.3082
5. Some college	0.2724	0.2708	0.2793
6. Four-year college	0.3623	0.3663	0.3762
<i>Education premiums (relative to high school), 1932 cohort</i>			
7. High school dropout	0.9261	0.9281	0.9288
8. Some college	1.0650	1.0213	1.0508
9. Four-year college	1.1546	1.1945	1.2110
<i>Education premiums (relative to high school), 1972 cohort</i>			
10. High school dropout	0.7485	0.7495	0.7616
11. Some college	1.1084	1.1510	1.1159
12. Four-year college	1.5741	1.5067	1.4462
13. Earnings in 2009 relative to 1959, all cohorts	1.7022	1.6955	1.6849
14. Std deviation log weekly earnings, 1932 cohort	0.2513	0.2524	0.2582
15. Present value of 4 year college tuition relative to earnings of high school dropout in 1949	0.8772	0.8789	0.8859
16. Decline in median test scores, from 1948 to 1963 cohort (ITBS avg, grade 8, in standard deviations)	0.37	0.37	0.37

Table 4: Targeted Moments

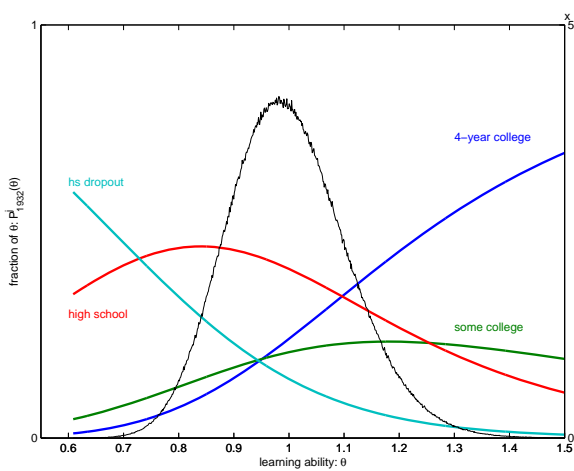
individuals in the 1932 and 1972 cohorts who choose a schooling level j as a function of ability, i.e. $P_{1932}^j(\theta)$ and $P_{1972}^j(\theta)$, together with the population densities of abilities. Notice that, consistent with our calibration, the ability distribution of the 1972 cohort is shifted to left compared to the 1932 cohort.

From Figure 4a we gather, for example, that low ability individuals at age 17 expect to earn more as high school dropouts than as high school graduates. 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

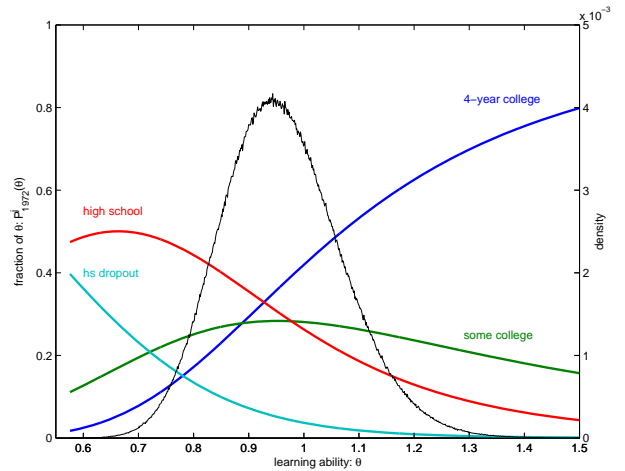
fraction of individuals choosing the highest one increases with ability (Propositions 1 and 2 in Appendix B). As a corollary, ability selection is stronger for the lowest and the highest degrees, with a relatively high (low) propensity of low (high) ability types to drop out of high-school, and the reverse for college graduation.



(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

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.³⁸ 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 went 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 ability of a college graduate in 1972. This selection effect is, however, relatively small: the ratio of average ability among four-year college graduates relative to average ability among high-school graduates increases from 1.06 to 1.07 between the 1932 and the 1972 cohorts.

5 Results

We start by presenting the model's main results. In Section 5.1 we then evaluate the impact of each driving force on the evolution of educational attainment. Section 5.2 considers an alternative approach to identifying the decline in mean learning ability and presents the related results. 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

³⁸College 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.

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 expectation scenarios (Figures 5b and 5d). The key factor behind the evolution of education premiums is the dynamics of skill prices (Figure 3).³⁹

However, the two versions of the model - perfect foresight and static expectations - give rise to very different predictions regarding the evolution of educational attainment across cohorts. In what follows we argue that the static expectations version provides a better fit of the data. We reach this conclusion by focusing first on four-year college and then on the other schooling levels.

Consider four-year college graduation rates first. 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 5 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).⁴⁰

The model under perfect foresight predicts a pattern of college graduation across cohorts that is almost the opposite of the data. College graduation rates predicted by this version of the model display the slowest growth for the 1932–1948 cohorts, at a pace of 0.23 percentage points per cohort, and the fastest for the 1948–1972 cohorts, at a pace of 0.40 percentage points per cohort (Figure 5a). Moreover, according to this version of 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.

³⁹Recall that Figure 3 displays skill prices for the calibration under static expectations, however the corresponding figure for perfect foresight is similar.

⁴⁰The recovery is slow relative to the pace of expansion experienced by the 1932–1948 cohorts.

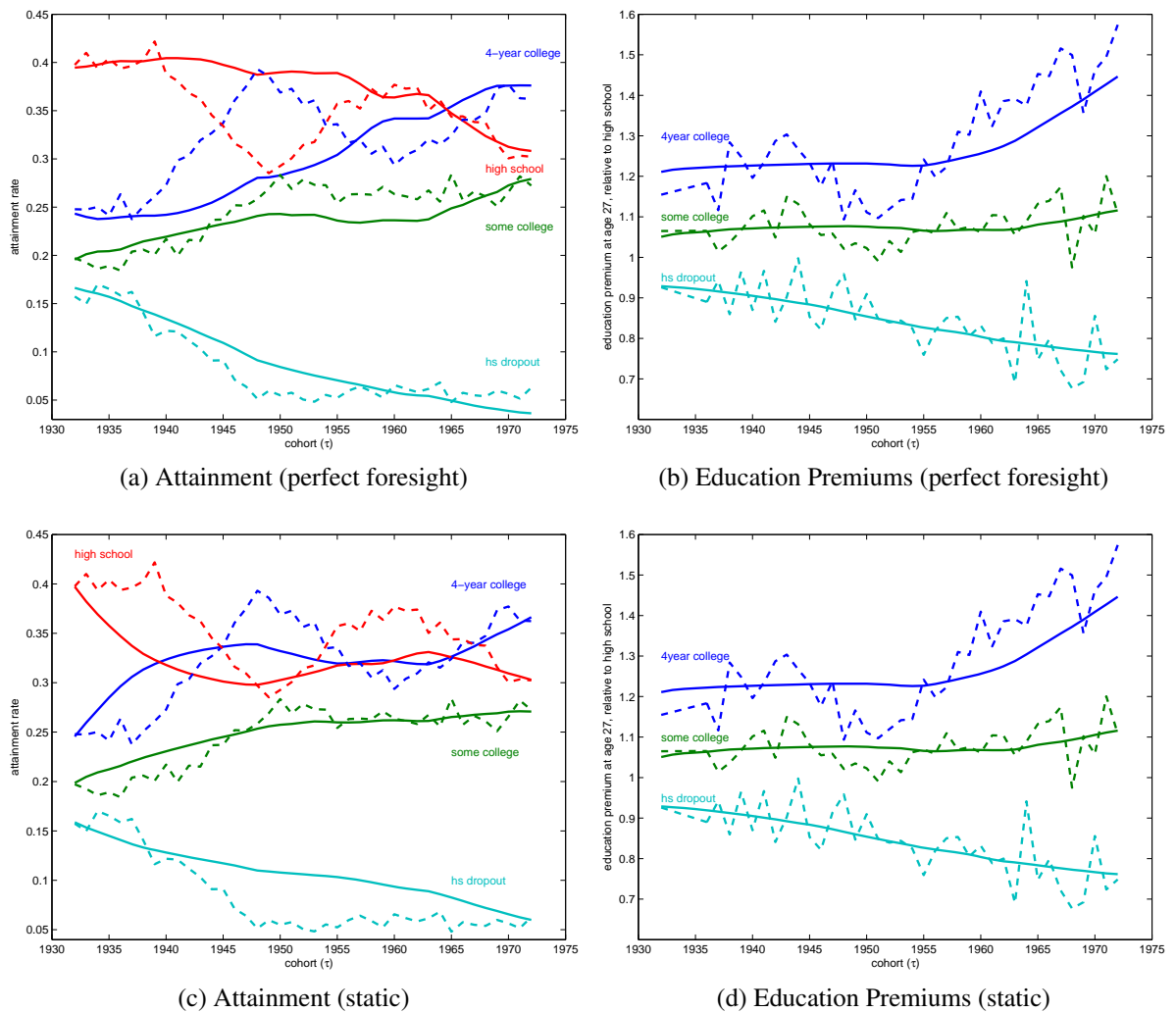


Figure 5: Predictions of the model with static expectations and the model with perfect foresight; model (solid) vs data (dashed).

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 the fastest among the 1932–1948 cohorts while it stagnates for the 1948–1972 ones. The model is also successful in generating a loss 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 64 percent of the observed increase in college graduation rates for the 1932–

	Cohorts			
	1932–48	1948–1972	1948–1960	1960–1972
<i>Model version</i>				
Perfect foresight	0.23	0.40	0.51	0.29
Static expectations	0.58	0.12	-0.14	0.37
<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 5: Accounting for the change in four-year college attainment across cohorts.

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 0.12 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 18 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.

Even with static expectations, however, skill prices alone, cannot entirely account for the decline in college graduation observed for the 1948–60 cohorts and

the weak gains displayed by the 1960–1972 ones. The model is still successful in generating an overall stagnation for the 1948–1972 cohorts because of the key role played by the remaining driving forces, namely increasing tuition, declining expenditures, and declining average learning ability. The next section illustrates in more detail the role played by these effects.

The second dimension along which we evaluate the two versions of 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, instead, tend to be stagnant between the 1948 and the 1972 cohorts. The model with static expectations accounts for these patterns. The only dimension in which the model with perfect foresight seems to provide a somewhat better fit of the data concerns the evolution of high school dropout rates. The reason is that, under perfect foresight, agents in the 1932–1948 cohort are able to react early on to the decline in the skill price associated with dropping out of high school that occurs starting in about 1970. This anticipated decline induces them not to drop out of high school at the same rate as agents making choices under static expectations.

We conclude that the model under static expectations provides an overall better fit of the educational attainment compared to perfect foresight. In what follows we restrict attention to 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 6 present the results.⁴¹ In what follows we discuss the contribution of each mechanism.

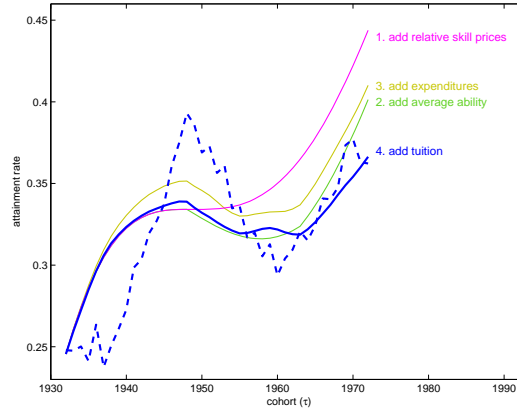


Figure 6: Contribution of the model’s driving forces to four-year college attainment; experiments (solid) and data (dashed).

Experiment	Cohorts			
	1932-48	1948-1972	1948-1960	1960-1972
1. Add relative skill prices	0.55	0.46	0.13	0.78
2. Add mean ability	0.00	-0.18	-0.27	-0.08
3. Add education quality	0.11	-0.04	-0.02	-0.05
4. Add tuition	-0.08	-0.13	0.01	-0.27

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 6: Contribution of the model’s driving forces to the change in four-year college attainment.

Relative Skill Prices Figure 6 and Table 6 illustrate two points regarding the contribution of skill prices to the evolution of college attainment. First, the rise in the college skill price almost fully accounts for the expansion in college graduation rates predicted by the model for the 1932–1948 cohorts. Second, changes in skill

⁴¹Notice that these counterfactual exercises are performed in partial equilibrium, so each time we activate a new driving force the previous ones are unaffected.

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-1948 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 0.27 percentage points per cohort for a cumulative decline of more than three 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 0.08 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, reducing their college graduation rates by about four percentage points.

Changes in Education Quality The increase in the quality of high school and college education over time (Figure 2b) contributes to an overall increase in four-year college graduation. This effect is, however, unevenly distributed across cohorts. The observed rise in school quality ends in the early 1970s, contributing to increase college graduation rates between the 1932 and the 1948 cohorts by about 0.11 percentage point per cohort, or a cumulative effect of 1.75 percentage points. The slight decline in school quality beginning in the mid-1970s, instead, contributes

to the slow recovery of college attainment for the later cohorts, for a cumulative negative effect of about 0.70 percentage points for the 1960–1972 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 higher tuition faced by the 1932–1948 cohorts nearly cancels out the effect of higher school quality on college attainment discussed previously. The declining tuition faced by the 1948–1960 cohorts, instead, mitigates, but does not offset, the drop in college graduation attributed to lower average ability. Finally, the sharp rise in tuition faced by the 1960–1972 cohorts 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 0.27 percentage points per cohort, for a cumulative effect of about 3 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 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.⁴² Second, our

⁴²Student 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

model abstracts from credit constraints. Binding credit constraints would increase the elasticity of attainment to tuition.⁴³ 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 (see Figure 1a). The stagnation in college attainment for subsequent cohorts has its counterpart in the stagnation of high school dropout rates.⁴⁴

In order to translate these ideas into a calibration strategy, we maintain the same specification for $\mu_{\theta\tau}$ as in equation (4.5) and recalibrate the static expectations version of the model. The calibration procedure and the targeted moments are the same as specified in Section 4.1.3, with the exception of moment 16 (the measured decline in test scores). This moment is, instead, replaced by the high school dropout rate for the 1963 cohort in our data sample (6.2 percent). This alternative approach thus identifies the decline in $\mu_{\theta\tau}$ from the pattern of high school dropout rates of the 1932, 1963 and 1972 cohorts. Skill prices alone would suggest a larger decline in high school dropout rates between the 1932 and 1963 cohort than what observed in the data. The decline in average learning ability therefore reconciles the model with the data in this dimension. The new set of parameters is reported in Table 8 in Appendix E, and the fit of the model in matching the targeted moments is in Table 9. Figure 7 plots the evolution of educational attainment predicted by this version of the model and compares it with the benchmark and the data.

This version of the model produces the same qualitative pattern of college at-

in the number of recipients.

⁴³The 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

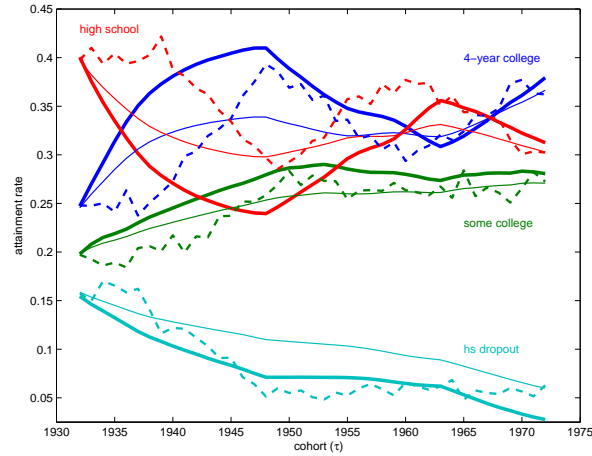


Figure 7: Educational attainment: benchmark (thin), alternative calibration (thick), and data (dashed).

tainment as the benchmark in Figure 5c, but fits the data better according to the measures considered in Table 5. The better fit is achieved by a larger reduction in average learning ability ($\mu_{\theta 1963} = 0.9126$) compared to the one disciplined by the decline in test scores ($\mu_{\theta 1963} = 0.9611$ in Section 4.1.3). The predicted change in college graduation rates for the 1932–1948, 1948–1960, 1960–1972 cohorts is now 1.02, -0.67 , 0.42, respectively.

5.3 Relationship with the Literature

In this section we compare our mechanisms and results with those in 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 college graduation rates in the U.S. between the cohorts born in the early 1930s and those born in the early 1970s. A few of them also attempt to explain the stagnation in male college attainment starting from the cohorts born in the late 1940s. We organize our reading of the literature around these two approaches.

Consider, first, the long-run perspective. Most papers in this literature assign a prominent role to skill prices, namely (Lee and Wolpin, 2010; Restuccia and Van-

of investment in education in which the cost of college evolves endogenously over time.

⁴⁴Notice that there is no mechanical way in which these two series are related.

denbroucke, 2013b; You, 2014; Gemici and Wiswall, 2014). Our paper shares the same view. From the analysis of Section 5.1, skill prices are the main force generating incentives for higher schooling achievement in our model. By contrast, Keller (2013) and Donovan and Herrington (2013) rely on alternative mechanisms. Keller (2013) 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 skill prices rise, the return to higher college quality increases too. Higher college quality, in turn, increases the incentives to attend college in the first place.⁴⁵ In our model, we focus on real education expenditures per student as a measurable proxy for the quality of college at a point in time. We find that the latter plays a positive but minor role in generating the long-run rise in attainment (see our Table 6).

Donovan and Herrington (2013, page 3) attribute the dramatic rise in college attainment between the 1930 and 1950 cohorts to “changes in college costs” and the post-1950 cohort rise in attainment to a rising college premium. However, according to Figure 2a (and Donovan and Herrington’s (2013) Figure 8) tuition *increased* across successive cohorts starting with the 1932 one (about the year 1950) and until the 1950 cohort (the late 1960s).

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 (2013) has emphasized the decline in skill price growth that occurred starting in the early 1970s.⁴⁶ 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

⁴⁵Figure 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 lifecycle. We attribute this gap in average attainment between the two cohorts to the effect of endogenous education quality described in the text, although Keller (2013) does not explicitly quantify this mechanism.

⁴⁶The effect of expected skill price *growth* on schooling decisions was first discussed by Bilal and Klenow (2000).

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 under static expectations. We may, however, assess its quantitative importance in our framework 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 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. This is a relatively large number. Notice, however, that under perfect foresight the decline in expected skill price growth does not occur unexpectedly. For example, the slowdown of the 1970s should also affect the cohorts born in the 1940s. As Keller (2013) points out, this timing issue can be partially addressed by assuming agents are myopic instead of forward looking. The farther agents are from being fully forward-looking, however, the less important this mechanism becomes.

The second mechanism, also present in Keller's (2013) 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 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 (φ) of human capital formation to measures of spending per student, as estimated in the literature (You, 2014). Differently from us, in Keller's (2013) 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 (2013) 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 \(2014, Table B-4\)](#) 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 according to the literature ([Keller, 2013](#); [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 (2013). She assumes that agents are myopic relative to the expected growth rate of skill prices, rather than the level of the college premium. According to her benchmark model, in fact, college attainment should slowdown starting with the cohorts born in the early 1940s, while in the data the slowdown occurs almost a decade later. Myopia allows her model to better match the timing of the slowdown in college attainment as myopic agents in her model fail to realize the slowdown in skill price growth starting in the early 1970s and continue investing in college education.

6 Conclusions

We study the evolution of educational attainment for the cohorts of U.S. males born between 1932 and 1972. We introduce a novel mechanism - variation across cohorts in average learning ability - and quantify its contribution to the observed stagnation in college attainment between the 1948 and the 1972 cohorts. The decline in learning ability for the post-1948 cohorts is calibrated to match the observed decline in test scores of eight-grade students. According to our calibrated model, the decline in average learning ability contributed to reduce college graduation rates between the 1948 and 1960 cohorts by about three percentage points. It also reduced the subsequent increase in college graduation rates for the post-1960 cohorts by about one percentage point. More generally, our paper suggests that the reasons for the slowdown in college attainment in the last forty years are likely to have the same fundamental cause that led to a stagnation in high school graduation rates since the late 1960s.

We conclude with some comments on our modeling choices and paths for future research. In terms of modeling choices, 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.⁴⁷

In addition to these specific extensions, we think there are at least three promising general areas for future research on this topic. First, the causes of the variation in average learning ability across cohorts are not well understood. Making progress on this question is difficult but the payoff, from the policy perspective, is potentially large. Second, our empirical analysis has focused on males. Four-year college graduation rates for females also peak around the 1950 cohort, and decline relative to this peak for the 1950–1960 cohorts, but they 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 τ 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 τ in year t (when they reach age $l = t - \tau - 14$) is defined as follows:

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

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

$$\bar{h}_{t\tau}^j \equiv \frac{\int_\theta h_{t-\tau-14}^j(\theta) P_\tau^j(\theta) dG_\tau(\theta)}{AR_\tau^j}. \quad (\text{A.3})$$

B Propositions

B.1 Proposition 1

Proposition 1. *If an individual i of cohort τ , with ability θ and preference vector ξ_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 θ' , 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

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

where

$$\widehat{\sigma} = \frac{\sigma}{\sum_{l=1}^L \beta^{l-1}}.$$

This further simplifies to:

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

Replace equation (3.6) so that the inequality becomes:

$$\sum_{l=S_{j'}+1}^L R^{-(l-1)} (1 - \lambda_{\tau+14+l}) w_{\tau+14+l}^{j'} h_l^{j'}(\theta') \leq \exp \left[\widehat{\sigma} \left(\bar{\xi}^{j'} - \bar{\xi}^j \right) \right] \times \sum_{l=S_j+1}^L R^{-(l-1)} (1 - \lambda_{\tau+14+l}) w_{\tau+14+l}^j h_l^j(\theta').$$

Replace the expression (3.2) for human capital and rewrite the inequality as:

$$\frac{h^{j'}(\theta')}{h^j(\theta')} \leq \frac{\exp \left[\widehat{\sigma} \left(\bar{\xi}^{j'} - \bar{\xi}^j \right) \right] \sum_{l=S_j+1}^L R^{-(l-1)} \widehat{w}_{\tau+14+l}^j}{\sum_{l=S_{j'}+1}^L R^{-(l-1)} \widehat{w}_{\tau+14+l}^{j'}} \quad (\text{B.1})$$

where the variable $\widehat{w}_{\tau+14+l}^j$ collects taxes, skill prices and experience profiles:

$$\widehat{w}_{\tau+14+l}^j \equiv (1 - \lambda_{\tau+14+l}) w_{\tau+14+l}^j \exp \left(\delta_1 (l - S_j - 1) + \delta_2 (l - S_j - 1)^2 \right).$$

Notice that since the agent with ability θ is indifferent between j and j' it must

be the case that:

$$\frac{h^{j'}(\theta)}{h^j(\theta)} = \frac{\exp\left[\widehat{\sigma}\left(\bar{\xi}^{j'} - \bar{\xi}^j\right)\right] \sum_{l=S_{j'}+1}^L R^{-(l-1)} \widehat{w}_{\tau+14+l}^j}{\sum_{l=S_j+1}^L R^{-(l-1)} \widehat{w}_{\tau+14+l}^{j'}}. \quad (\text{B.2})$$

Together, equations (B.1) and (B.2) imply that:

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

for $\theta' > \theta$ and $j' < j$. This leads to a contradiction if the ratio $h^{j'}(\theta)/h^j(\theta)$ is strictly increasing in θ . 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 θ , it is then enough to show that each ratio on the right-hand side is increasing in θ . Thus, we simply need to show that

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

is increasing in θ where $h_{l+1}(\theta)$ is given by equation (3.1). We do so by induction. First, we show this is the case for $l = 2$ 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 $l = 2$. Since

$$h_2(\theta) = \theta h_1^\gamma + (1 - \mu)h_1,$$

it is straightforward to show that $h_2(\theta)/h_1$ is increasing in θ given that h_1 is the same for all agents. Now consider the inductive argument. Suppose that $h_{l+1}(\theta)/h_l(\theta)$

is increasing in θ , where:

$$\frac{h_{l+1}(\theta)}{h_l(\theta)} = \theta h_l(\theta)^{\gamma-1} + 1 - \mu.$$

The ratio on the left-hand-side is increasing in θ if and only if $x(\theta) \equiv \theta h_l(\theta)^{\gamma-1}$ is increasing in θ . Now consider

$$\begin{aligned} \frac{h_{l+2}(\theta)}{h_{l+1}(\theta)} &= \theta h_{l+1}(\theta)^{\gamma-1} + 1 - \mu \\ &= \theta (\theta h_l(\theta)^\gamma + (1 - \mu) h_l(\theta))^{\gamma-1} + 1 - \mu \\ &= x(\theta) (x(\theta) + 1 - \mu)^{\gamma-1} + 1 - \mu. \end{aligned}$$

To show that $h_{l+2}(\theta)/h_{l+1}(\theta)$ increases with θ , take the derivative with respect to θ , and collect terms to obtain:

$$\frac{\partial [h_{l+2}(\theta)/h_{l+1}(\theta)]}{\partial \theta} = x'(\theta) (x(\theta) + 1 - \mu)^{\gamma-2} [1 - \mu + x(\theta) \gamma] > 0$$

where the inequality follows because $x'(\theta) > 0$ by assumption. Q.E.D.

B.2 Proposition 2

Proposition 2. *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:

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

Notice also that:

$$V_\tau^{j'}(\theta) - V_\tau^j(\theta) = \ln\left(\frac{c_\tau^{j'}(\theta)}{c_\tau^j(\theta)}\right) \sum_{l=1}^L \beta^{l-1}$$

and that the ratio of consumptions $c_\tau^{j'}(\theta)/c_\tau^j(\theta)$ is increasing in θ if and only if the ratio of human capitals $h^{j'}(\theta)/h^j(\theta)$ also is. We have already shown in the proof of Proposition 1 that $h^{j'}(\theta)/h^j(\theta)$ is indeed increasing in θ .

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

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

This ratio is strictly decreasing in θ 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 θ grows the ratio is decreasing even further, so that:

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

for all values of θ with at least a strict inequality for some θ . 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.⁴⁸

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

⁴⁸Notice 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.

data. [Card and Lemieux \(2001, Table 1B\)](#) estimate the excess college graduation rate due 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.⁴⁹ [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.⁵⁰

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

⁴⁹The corresponding figures for some college attendance (as opposed to completion of a four-year degree) are 1.80, 4.01 and 0.90.

⁵⁰[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.

middle-school degree.⁵¹

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.

⁵¹The restriction to individuals with at least a middle-school degree is made in order to limit the 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 ($x_t^{2\text{yr}}$) remained constant prior to 1970 at the 1970 level, $x_t^{4\text{yr}}/x_t^{2\text{yr}} = x_{1970}^{4\text{yr}}/x_{1970}^{2\text{yr}}$ for $t < 1970$, and then use the following identity to infer $x_t^{2\text{yr}}$ from the aggregate per student spending in higher education (x_t^{he}): $x_t^{2\text{yr}} = x_t^{\text{he}} / (e_t^{2\text{yr}} + e_t^{4\text{yr}} x_{1970}^{4\text{yr}}/x_{1970}^{2\text{yr}})$, for $t < 1970$, where $e_t^{2\text{yr}}$ and $e_t^{4\text{yr}}$ 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 δ_2^j are reported in Table 7. Our calibrated values for the profile parameters δ_1^j are in Table 3. 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 7: Estimates of the experience parameters δ_2^j .

Figure 8 plots the estimated experience-earnings profiles by education group, for individuals with average learning ability $\theta = 1$, born in cohort $\tau = 1947$. Consistent with our static expectations assumption, we keep skill prices constant at the level observed by these individuals at age 17.

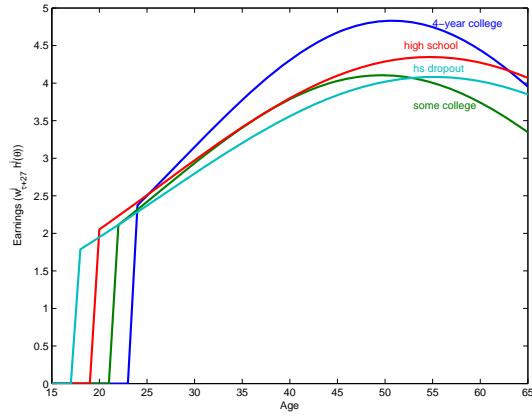


Figure 8: Lifetime earnings profile for an individual of type $(\theta, \tau) = (1, 1947)$.

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 type of individual under consideration. This is either due to differences in skill prices, or due to differences in human capital when finishing school $h_\tau^j(\theta)$. Given the lifetime earnings profiles displayed in the figure, a large fraction of the individuals of type $(\theta, \tau) = (1, 1972)$ 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 8 and 9.

Parameter	Value
σ	2.0337
σ_θ	0.1252
$\bar{\xi}^1$	-4.6919
$\bar{\xi}^2$	-3.2866
$\bar{\xi}^3$	-1.8411
w_0^1	0.0142
w_0^2	0.0427
w_0^3	0.1372
w_0^4	0.4027
δ_1^1	0.0603
δ_1^2	0.0541
δ_1^3	0.0471
δ_1^4	0.0471
$\mu_{\theta 1963}$	0.9126

Table 8: Alternative Calibration

Moments	Data	Model
<i>Educational attainment, 1932 cohort</i>		
1. High school	0.3976	0.4005
2. Some college	0.1971	0.1980
3. Four-year college	0.2479	0.2472
<i>Educational attainment, 1972 cohort</i>		
4. High school	0.3024	0.3124
5. Some college	0.2724	0.2806
6. Four-year college	0.3623	0.3793
<i>Education premiums (relative to high school), 1932 cohort</i>		
7. High school dropout	0.9261	0.9327
8. Some college	1.0650	1.0575
9. Four-year college	1.1546	1.1844
<i>Education premiums (relative to high school), 1972 cohort</i>		
10. High school dropout	0.7485	0.7406
11. Some college	1.1084	1.1410
12. Four-year college	1.5741	1.4976
13. Earnings in 2009 relative to 1959, all cohorts	1.7022	1.7001
14. Std deviation log weekly earnings, 1932 cohort	0.2513	0.2542
15. Present value of 4 year college tuition relative to earnings of high school dropout in 1949	0.8772	0.8747
16. High school dropout rate, 1963 cohort	0.0616	0.0620

Table 9: Targeted Moments, Alternative Calibration

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