Best Time for College? A tale of two endowments

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Abstract

Rather than completing all school education consecutively before entering the labor force, people often delay college start and engage in labor market activities between periods of college enrollment. To examine the welfare consequence of college with such intermittence, I incorporate an endogenous college enrollment choice at each age in a life-cycle model in an incomplete market general equilibrium framework. College serves as an investment device for the younger and a risk reduction for the older. Having access to college at a later age matters more for the initially less advantageous. Removing college access after age 22 reduces the total welfare value of college by two-thirds. Wealthier background and better human capital preparedness at age 18 raise college value, incentivizing enrollment and younger age completion. Boosting college readiness for high schoolers may alleviate some initial human capital disadvantage, and need-based financial aid helps the less wealthy students. Both policies promote college attendance, but policies targeting the initial wealth inequality can have more considerable long-term welfare improvement.

JEL classification: E2, I24, J24, J31.

Keywords: Lifecycle inequality, college enrollment, college stopout, school interruption, returns to college, college value, human capital accumulation, investment, risk, insurance, general equilibrium, heterogeneous agent

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1 Introduction

Most studies examining the college decisions focus on a one-time enrollment or dropout in students' early twenties. However, people commonly experience intermittence in college education: delaying initial entry, stopping from school temporarily and return back to enrollment at a later age.[1] Using the National Longitudinal Survey of Youth 1979, I find that people access college flexibly throughout lifetime and repeat school-work transitions on average 1.7 times. Over 16% of all with a bachelor's degree complete college after age 30. Previous research finds that college education at the first stage of lifecycle before engaging in the labor force shifts up the earnings profile and raises earnings risk (e.g. Kim, 2021; Schweri, Hartog, and Wolter, 2011). Yet, a later age college enrollment interrupts labor market engagement and interacts with lifecycle uncertainties. What role does college education at a *later* age play in the lifecycle?

In this paper, I connect a person's pre-college age family background to college enrollment and completion patterns and examine the welfare consequence of having *flexible* access to college through one's lifecycle. Empirical evidence shows that college intermittence is strongly associated with family wealth and human capital preparedness at age 18, the two initial endowments. Better prepared individuals from wealthier families are more likely to follow a "traditional" path, finishing college at a younger age with a lower likelihood for interruptions. To uncover the transmission channels from the age 18 human capital and wealth endowments to lifetime welfare, I construct an incomplete market life-cycle model in general equilibrium, adapting from Huggett, Ventura, and Yaron (2011). Similar to Huggett et al. (2011), the primary source of life-cycle risk comes from the idiosyncratic human capital productivity shock to working individuals. One main difference, however, is human capital acquisition: individuals can accumulate human capital through learning on the job

[1] Literature refers to a temporary exit from college as stopout, implying a returning to college some periods later. This is in comparison to dropout, describing a permanent exit from college before completing the degree (e.g. Light, 1995a,b; Monks, 1997; Dynarski, 1999; Seftor and Turner, 2002; Jepsen and Montgomery, 2012; Johnson, 2013; Arcidiacono, Aucejo, Maurel, and Ransom, 2016; Gurantz, 2019).

and through college schooling at any working age. I feed the model with the empirical distribution of individuals on wealth and human capital at age 18 and calibrate it to lifecycle schooling profiles. The model successfully replicates the intermittent college patterns across individuals and generates empirically relevant heterogeneous income processes.

I measure the welfare of having access to college as the consumption equivalence when removing college access, a method Mukoyama (2010) outlined.[2] The welfare value of college at each age extends beyond its financial return. When there is a relative psychic cost between schooling and working, the utility return of college does not align with its financial return (Yang and Casner, 2021; Belley and Lochner, 2007). Moreover, completing each year of college in a life-cycle setting embeds sequential consequences, opening doors to a new career or further educational opportunities, adjusting the rest of the earnings profile (e.g. Bhuller, Mogstad, and Salvanes, 2017; Kunz and Staub, 2020). To the best of my knowledge, this is the first paper that evaluates the welfare value of having access to college at each age.

The primary message of this paper is that allowing for flexible access to college over the life-cycle has significant welfare gain, especially to the initially less advantageous people. Consumer welfare drops by nearly 24% for an economy without college. About two-thirds of it is attributed to allowing for flexible college enrollment at any age. While better prepared young people with wealthier backgrounds value college more, individuals with the lowest wealth endowment at age 18 value flexible college access twice as much as those from the highest wealth families. Over the life-cycle, accessing college before age 29 translates to the highest lifetime welfare gain. Yet, later college access presents a more minor but positive value.

I explain the heterogeneous welfare value of college through three channels: price, investment, and risk propagation channels. The price channel comes from an adjustment of interest and wage rates in general equilibrium if there is a restriction on access to college.

[2] Similarly, I measure the welfare of flexible access to college as the consumption equivalence when restricting initial access to college only at age 18 and removing subsequent access to college once a person interrupts from consecutive enrollment.

Rather than paying for tuition-related costs, individuals can accumulate more assets, raising the supply for capital. Meanwhile, restricted access to college also lowers the supply of more productive college-educated labor. As a result, interest rate decreases and wage rate increases when markets clear, and individuals substitute between human capital and physical capital. Although the idiosyncratic impact depends on each person's wealth and human capital position, it accounts for about one-third of the total welfare loss when removing college, and nearly half of the total loss from restricting flexible access to college.

I define the investment value of college as its role in increasing human capital that can be realized in the labor market, following Mincer (1974). In the model, the idiosyncratic productivity shock perturbs a person's human capital. To isolate the shock, I measure the investment value as the consumption equivalence of having access to each additional year of college without the exogenous uncertainty. Overall, the investment value is the highest among individuals with the highest human capital and wealth endowments. It is worth near 45% of lifetime consumption among individuals with the largest initial wealth and over 35% for the individuals with the highest human capital at age 18. However, the investment value diminishes quickly and disappears by age 24. This explains why most college enrollment concentrates on the early twenties and favors the initially more advantageous individuals. All else equal, a larger human capital endowment creates a higher overall investment value of college because of the self reproductive nature of human capital (Cunha, Heckman, Lochner, and Masterov, 2006). Interestingly, among individuals with similar human capital endowments, the investment value is higher for those with higher wealth endowment.

The risk propagation of college considers the role that college plays in transmitting the exogenous productivity shock in a risk averse person's lifetime welfare. College education can augment the impact of risk when the productivity shock multiplies a higher level of human capital. It may also reduce the welfare cost from risk if a person attends college in response to current and expected future human capital shock.[3] I approximate the risk propagation

[3]Meghir and Pistaferri (2011) discuss two directions of college as risk reduction: *Ex-ante*, a person may store current wealth in human capital through education, raising the future human capital stock that

of college by comparing the welfare cost of risk between models with and without access to college at each age, a method resembling Castex (2017). All else equal, a larger welfare loss due to risk from a model with access to college indicates a risk augmentation of college, otherwise a risk reduction. Overall, I find that accessing college before age 22 augments the welfare loss of risk, while going to college afterward reduces it. This is because younger individuals have lower wealth and higher risk aversion. As one ages, resources accumulate and risk aversion reduces. Individuals are more likely to take advantage of college in the event of an adverse shock. The peak of the risk reduction from attending college happens at around age 24, mitigating nearly 30% of the welfare loss from risk. The less advantageous individuals experience a larger risk augmentation from college at the younger age. But the risk reduction value of college in later life is more prominent among those with lower wealth endowment at age 18, even controlling for the initial human capital endowment.

The three channels indicate the heterogeneity of initial wealth and human capital endowments, translating to unequal college valuation and attendance. A one-standard-deviation increase of wealth endowment at age 18 raises the investment value of college by 0.42 standard deviations and the risk reduction value of college by 0.21 standard deviations. Similarly, a one-standard-deviation increase of human capital endowment raises the investment value by 0.76 standard deviations and the risk reduction value of college by 0.11 standard deviations. The investment value of college is especially effective in encouraging college enrollment and early age completion. The risk reduction value has a comparable impact in promoting the completion of college. This result suggests that raising initial wealth or human capital endowments can encourage college enrollment and completion.

Lastly, I explore the welfare consequence of removing the initial endowment inequalities[4].

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dampens the fluctuation of marginal utility. *Ex-post*, one may attend school retooling after negative labor market shock and skill depreciation.

[4]Huggett et al. (2011) and Griffy (2021) study the cost of inequality by comparing a counterfactual economy with a smaller spread of an initial distribution. Contrarily, I compose a counterfactually equal economy through having uniformly distributed individuals on the original support. An economy with uniform human capital distribution at age 18 promotes college enrollment and completion through investment and insurance channels. It leads to higher tuition spending and lower asset supplied for physical capital, and a higher supply of college-educated workers.

Data show that more individuals concentrate on the lower end of the wealth and the human capital values. Policies boosting college preparedness for high school students can move up the less prepared individuals reducing the initial human capital inequality. Alternatively, need-based financial aid can alleviate the unequal initial wealth distribution. I find that a society with uniformly distributed age 18 conditions amplifies the investment and risk reduction values of college, raising college attendance and welfare in the short run. But the associated adjustment in general equilibrium from the price channel may counter some of the welfare gains in the long run. Specifically, a society with uniformly distributed initial human capital endowment has the price channel dominating the welfare gain from the college value channels, leading to an overall welfare loss from the unequal baseline economy. But having a uniformly distributed initial wealth endowment generates net welfare gain, even after the general equilibrium price adjustment. This exercise further stresses the role wealth inequality plays in college attendance and welfare. It also suggests that an aggressive financial aid policy alleviating the monetary burden for less wealthy high school students may induce significant positive college responses and have persistent overall welfare gain.

This paper situates in the studies examining the causes and consequences of college over the lifecycle. The recent macro-education literature examines the college values through finding the post-college career trajectories (Kim, 2021; Athreya and Eberly, 2021; Hendricks and Leukhina, 2018; Vardishvili and Wang, 2019; Belley and Lochner, 2007; Arcidiacono, Bayer, and Hizmo, 2010; Stange, 2012). This paper breaks down college enrollment through the lifecycle and investigates the sequential decisions on each year of college and the option values it creates. Rather than estimating the financial returns, this paper assesses the welfare valuation of college at each age.

College is a risky investment.[5] It is important to consider the risk and risk attitude in college decisions (Levhari and Weiss, 1974; Hartog and Diaz-Serrano, 2015; Yang and Casner,

[5]The returns can be unpredictable (Storesletten, Telmer, and Yaron, 2004; Schweri et al., 2011; Lee, Shin, and Lee, 2015; Mazza and van Ophem, 2018), and the time-to-completion can be uncertain (Hungerford and Solon, 1987; Bowen, Chingos, and McPherson, 2009; Hendricks and Leukhina, 2017).

2021). Recent studies construct measurement for risk preference and show that higher risk tolerance leads to more college education (Belzil and Leonardi, 2013; Brodaty, Gary-Bobo, and Prieto, 2014; Heckman and Montalto, 2018; Kunz and Staub, 2020). This paper focuses on understanding the coexistence of human capital investment and risk avoidance of college education. By endogenizing college enrollment and exit decisions, I can investigate the interaction of college education and labor market risk in a lifecycle model. My approach assesses the impact of college on risk perception while bypassing the implicit bias and the difficulty in separating various factors constituting the risk attitude (Hartog and Diaz-Serrano, 2015).

Germane to my paper, Castex (2017) investigates the risk and returns of college in a partial equilibrium framework with exogenous college completion risk. Inspired by Abbott, Gallipoli, Meghir, and Violante (2019), I find the importance of the price channel in altering the welfare value in general equilibrium. Matsuda (2020) examines the impact of financial aid on endogenous college completion in a general equilibrium setting. Their models do not allow returning to school after the second stage of the lifecycle. My model finds three channels that lead to endogenous schooling decisions and uncovers important welfare values for later-age college access.

Much of the literature discusses the importance of ability and early age human capital preparedness that generates life-cycle inequality (e.g. Keane and Wolpin, 1997; Huggett et al., 2011). Studies argue that college readiness due to ability and existing human capital drives college attendance and completion (Hendricks, Herrington, and Schoellman, 2021; Belzil and Hansen, 2020; Abbott et al., 2019). Once controlling for the readiness, wealth background matters less in college decisions. Nevertheless, financial constraint is still a barrier for college (Ozdagli and Trachter, 2011; Johnson, 2013; Hai and Heckman, 2017). This paper adds to the discussion by showing that wealth matters to human capital acquisition and life-cycle welfare, given its influence on risk attitude. The unequal wealth endowment at age 18 can translate to significant lifetime welfare inequality through college enrollment and completion.

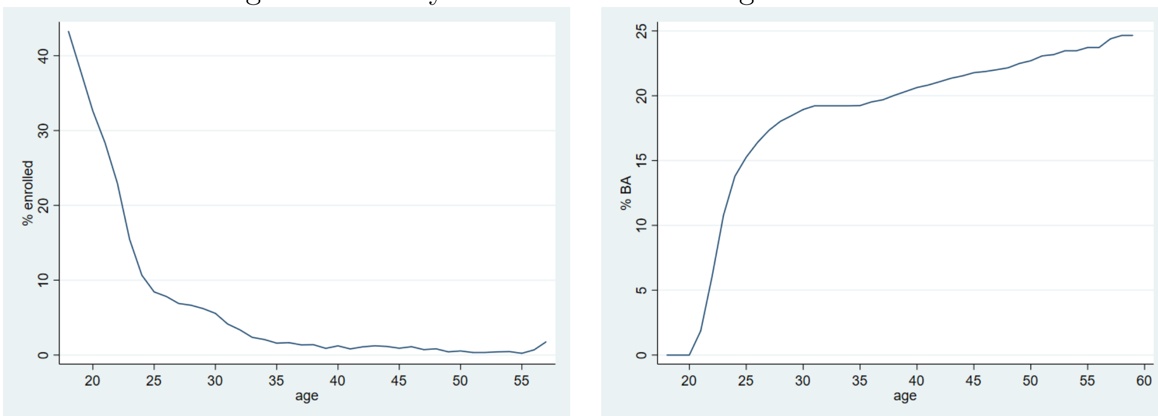
To a broader audience, this paper adds to the literature discussing means of self-insurance against lifecycle uncertainties and the sources of lifetime inequalities, facilitated by Meghir and Pistaferri (2011) and Huggett et al. (2011). Recently, Jang (2020) and Jung, Tran, et al. (2019) examine the role of health insurance and default choices against health shock. Kunz and Staub (2020) and Griffy (2021) study the role of job moving against labor market risk. Traditionally, the lifecycle framework implies that one attends school in the first phase of life, after which one supplies labor and largely learns on the job (Ben-Porath, 1967; Mincer, 1974; Rubinstein and Weiss, 2006). This paper models repeated cycles of intermittent college enrollment, orienting college education as a means for self-insurance through the lifecycle. My result relates to the general conclusion from Cocco, Gomes, and Maenhout (2005): college at a younger age serves as an investment strategy, and at a later age serves as an insurance strategy.

The paper proceeds as follows. Section 2 provides empirical evidence on the intermittent college education profile and the unequal initial distributions from data. Section 3 lays out the theoretical framework. Section 4 discusses the calibration procedure. Section 5 presents the main results. Section 6 explores the mechanism for the main results. Section 7 extends an experiment on the welfare consequence of initial inequality. Section 8 concludes.

2 Empirical facts

In this section, I document an intermittent college education profile in the U.S. I define intermittent college education as an education profile interrupted by gaps of non-enrollment before obtaining the degree. This includes delays to college start after high school and stopouts after starting college. About two-thirds of all with a college degree in the U.S. experience some intermittence in college education. Over 10% of them complete their college after age 35. I link the timing and completion of college to a person's wealth and human capital endowments at age 18. Individuals from wealthier families or with higher human capital are more likely to complete college at a younger age.

Figure 1: Life-cycle enrollment and degree attainment



(a) Percent enrolled in school by age (b) Percent completed degree BA by age

Notes: This figure uses data from NLSY79 to plot college enrollment and completion profiles age by age. Panel (a) plots the average enrollment for each age starting at age 18. Panel (b) plots average bachelor level degree completion for each age. The data is smoothed with locally weighted regression with bandwidth of 0.15. I replace the older age value for average degree attainment by the previous age value if the older age attainment is lower than the previous age value.

2.1 Intermittent college education profile

I use data from the National Longitudinal Survey of Youth 1979 (NLSY79) to summarize the life-cycle education profile. Respondents in NLSY79 have been continuously surveyed from 1979, covering an age range from 14 to 59.[6] For college enrollment, I define it as attending formal credited degree-granting college education for at least five months of a year, and college completion as completing 16 years of education, following the literature (Light, 1995a,b; Monks, 1997; Dynarski, 1999; Seftor and Turner, 2002; Johnson, 2013; Arcidiacono et al., 2016).

Figure 1 plots the life-cycle college enrollment and completion patterns. Panel (a) shows that the majority of students enroll in college before age 23. However, a decreasing but still significant number of individuals enroll in school after age 35. Panel (b) plots the sample share obtaining a bachelor's degree at a given age. The sharp increase starts from age 22 and lasts until age 26. However, steady addition of individuals moves to get a bachelor's degree throughout the life-cycle.

[6]See Appendix A for detailed sample construction.

Table 1: College completion and timing

Full sample			
No college	BA by 22	interrupted without BA	interrupted with BA
38.91%	9.29%	34.77%	17.03%
Of all with BA			
≤25	25-30	30-35	>35
72.77%	10.82%	6%	10.41%

Notes: The top panel reports the unweighted percent of the full sample under each category. The bottom panel reports the unweighted percent of the sub sample with bachelor's degree under each category. The result is similar if weighted by person weight.

Table 1 describes the college completion and timing of completion. About 39% of the sample report to have never enrolled in college. Only 9.3% of the sample complete college by age 22. These are the individuals described by the "traditional" consensus in lifecycle human capital acquisition literature, where one completes formal school training exclusively at the first stage of life.17% of the sample obtain a college degree after some interruptions, accounting for 2/3 of all with a bachelor's degree. About 35% have college experience but do not complete a degree. Examining all with a college degree, 73% obtain it at an age younger than 25. Still, over 10% receive it after age 35.

2.2 Age 18 background conditions

Studies have found the importance of early age background leading to lifetime decision-making and inequalities. For example, Huggett et al. (2011), Hai and Heckman (2017), Abbott et al. (2019), Griffy (2021), Athreya, Ionescu, Neelakantan, and Vidangos (2019) explore the impact of wealth background, human capital, and learning ability differentials across individuals in early adulthood. However, it is difficult to pinpoint the exact accessibility of wealth for a young adult before the early twenties, especially if one cohabits with parents. Human capital and learning ability are theoretical concepts in labor studies that are difficult to measure separately. Literature on life-cycle models often conjectures the distribution of each dimension through a calibration exercise. I follow the spirit of the literature but focus on the ordinal property of each dimension to gauge the most out of empirical evidence.

For wealth, I use the average of a respondent's net family income across ages 17, 18, 19 to approximate one's relative position in the wealth distribution since NLSY79 does not provide early age net wealth measurement. Though with a difference, studies have shown a strong positive correlation between income and family wealth (e.g. Kuhn, Schularick, and Steins, 2020). In addition, averaging cross net income over three years further smooths out inaccuracies of temporary income fluctuations.

For the dimension of human capital and learning ability, I use AFQT (Army Forces Qualification Test) score as an approximation[7]. Literature has long recognized the difficulty in separating innate ability, skill, and human capital (e.g. Schultz, 1961; Lang and Kropp, 1986; Woodhall, 1987; Altonji, Blom, and Meghir, 2012). I take an agnostic stand and consider human capital as anything that makes an individual more productive in the labor market. Therefore, it is a broader set of definitions, including innate ability, learned knowledge and skills, and other factors contributing to school preparedness and labor productivity from an individual's perspective. AFQT has been widely used as a measurement for human capital, though criticized with its accuracy (e.g. Schofield, 2014; Rodgers III and Spriggs, 1996; Lang and Manove, 2011; Griliches and Mason, 1972). Nevertheless, it provides a useful approximation of one's relative position in the distribution of human capital that impacts learning in school and labor market earnings (Arcidiacono et al., 2010).

I split each dimension into five equal-valued bins. Table 2 shows the distribution of individuals along the two dimensions. Three patterns emerge. First, both family wealth and human capital conditions at age 18 are unequally distributed. Fewer individuals are at the higher value bins than ones at the lower value bins for both conditions. Second, the wealth dimension is more skewed than the human capital endowment. Third, both conditions are positively correlated, with a correlation coefficient of 0.29. For the top wealth condition bins (top two bins), individuals are more likely to have a high human capital endowment (bin four

[7] AFQT is administered in 1980 to the majority of respondents in NLSY79 and has been widely adopted as a standard test for cognitive aptitude.

Table 2: Age 18 family wealth and AFQT

		Human capital condition				
		23.16	25.18	21.41	16.85	13.41
Wealth condition		1st	2nd	3rd	4th	5th
52.08	1st	15.82	14.46	10.21	7.06	4.54
32.06	2nd	5.70	7.82	7.54	6.05	4.95
11.55	3rd	1.25	2.30	2.80	2.80	2.39
3.62	4th	0.33	0.50	0.59	0.85	1.34
0.7	5th	0.07	0.09	0.26	0.09	0.20

Notes: The rows describe the percent of sample in each human capital bins, measured by AFQT scores. The values on the first row reports unconditional distribution on the human capital dimension. The columns describe the percent of the sample in each wealth bins, measured by average of age 17, 18, 19 net family wealth. The first column reports the unconditional distribution on the family wealth dimension. The inner five by five matrix describes the joint distribution on human capital and wealth. The 1st bin has the lowest value and the 5th bin has the highest value.

and bin five). For those at the lower financial conditions (bin one and bin two), individuals are more likely to have lower human capital conditions (bin one and bin two).

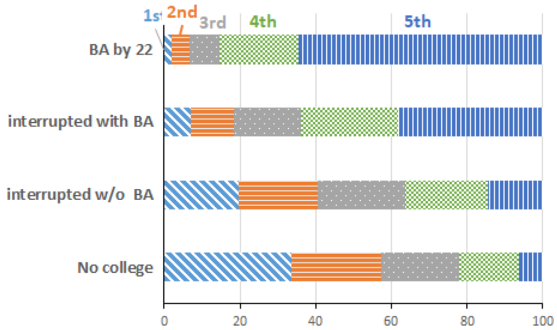
2.3 Age 18 conditions and intermittent college education

In this subsection, I provide descriptive statistics connecting age 18 endowments to the timing and completion of college. In Figure 2, I split individuals into five human capital and wealth quintiles, rather than equal-valued bins as in Table 2.[8] Panel (a) and Panel (b) describe the various patterns of college completion in relationship to age 18 human capital endowment and wealth conditions. Individuals at the top 20% of the human capital and wealth endowment are more likely to complete college by age 22. Conversely, individuals at the bottom 20% of the human capital and wealth conditions are more likely to never enroll in college. Those from higher human capital and wealth quintiles are more likely to complete a bachelor's degree than those from lower quintiles.

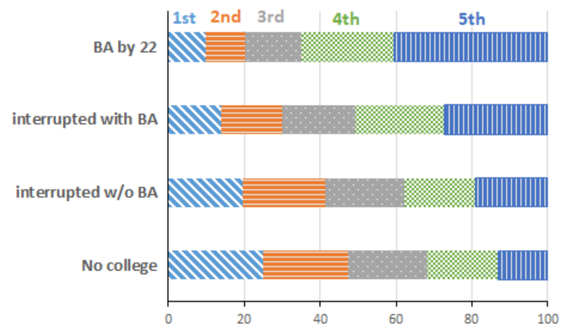
Further examining all with a college degree, in Panel (c) and Panel (d) of Figure 2, ones with the top human capital and wealth endowments are more likely to obtain the degree at

[8]Spliting individuals in equal-value bins shows similar results, but each bin has a different number of individuals becacuse of unequal distribution in the initial conditions.

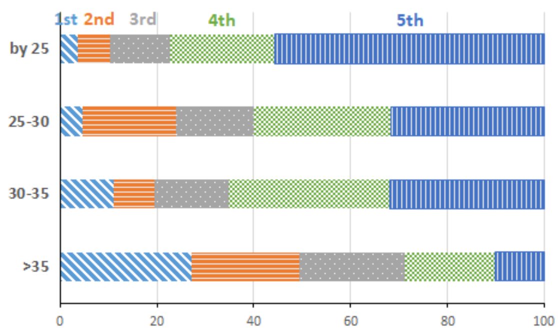
Figure 2: Initial conditions and patterns of intermittent schooling



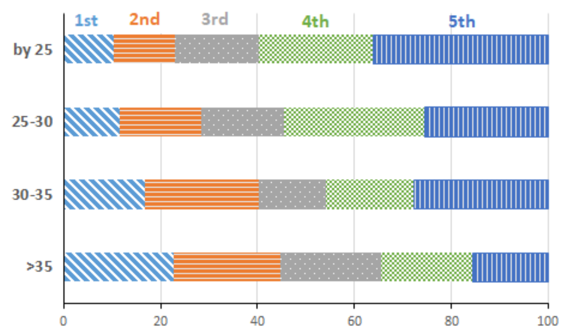
(a) Age 18 human capital and college completion



(b) Age 18 family financial and college completion



(c) Age 18 human capital and BA timing



(d) Age 18 family financial and BA timing

Notes: Panel (a) and Panel (b) show the percent of the sample in each education interruption pattern category come from each quintile. The categories are: with bachelor's degree by age 22 (BA by 22), complete a bachelor's degree with some interruptions (interrupted with BA), have some college experience but never complete the degree (interrupted w/o BA), and never attend college (no college). Panel (c) and Panel (d) show the percent of the sample in each college degree completion category from each quintile The categories are: complete college degree by age 25 (by 25), between age 25 and 30 (25-30), between age 30 and 35 (30-35), and after age 35 (>35). Quintile 1 is the lowest 20% and Quintile 5 is the highest 20%

a younger age and before 25. By contrast, among all who received the college degree after age 35, most are from the bottom 20% of the age 18 human capital and wealth endowments.

These patterns describe the intermittent college education. Notably, such intermittence correlates to the age 18 wealth and human capital positions. In the next section, I construct a life-cycle model in general equilibrium to examine the theoretical connection of how age 18 conditions translate to college education choices.

3 Model

In this section, I construct a life-cycle overlapping generation model in an incomplete market general equilibrium setting. Each model period is one year. Individuals enter the model at age 19, retire at age 65, and live up to age 85 with a total of 67 years. One representative firm hires effective units of labor and rents capital from individuals to produce a single output. It extends beyond the standard model as follows.

First, individuals can endogenously choose to attend college for each year at any period between the age of 19 and 65. Second, I introduce the human capital productivity shock to capture the life-cycle risks, following Huggett et al. (2011). Third, individuals are allowed to borrow a non-defaultable debt up to a borrowing limit. The debt limit is set as the maximum of either the economy-wide borrowing limit or the person's natural debt limit. The natural debt limit is set as the most lenient limit to ensure repayment by the end of the life-cycle given the age, human capital, years of schooling, and current labor market status. Forth, individuals are *ex-ante* heterogeneous on initial human capital and wealth, based on empirical evidence. Age provides an additional layer of *ex-ante* difference. *Ex-post*, education level, wealth, human capital, and labor market status differ after endogenous choices.

3.1 Individuals' problem

Every period, ω of new individuals enter the model, and ω exit. I normalize the total population to be one. Therefore, ω assigns value 1/67. Individuals maximize expected lifetime utility, given initial financial wealth s and initial human capital h.

Table 3 describes the timeline for individuals' lifecycle labor status decisions. From the age of 19 to 65, each individual chooses one of the four discrete decisions e: working full time w, working part-time and schooling part-time pt, schooling full time sch, and leisure full time $nonemp$. After age 65, one retires and enjoys full leisure activities.

Individuals are also differentiated on how many years of post-secondary schooling one has completed yrs. The maximum number of full time education years after high school is set to be four. Together, individuals are heterogeneous in the idiosyncratic states: $\phi \equiv \{h, s, yrs, e, age\}$.

Based on their decisions, individuals evolve on each dimension of the idiosyncratic states every period. We have an endogenous aggregate state μ, a probability measure of individuals on each idiosyncratic state, generated by the open subset of the product space: Φ=$\{\mathbb{R}_+ \times \mathbb{R} \times \mathbb{Z}_+ \times \mathbb{Z}_+ \times \mathbb{Z}_+\}$. As one retires, labor status and years of education cease to matter. For ease of computation, the distribution of individuals after retirement evolves to μ_{re}, only on $\{age, h, s\}$.

Table 3: Life-cycle time-line

Real age:	19 – 65	66 – 85
Model age:	1 – 47	48 – 67
Discrete choices:	Work full time, part time and school part time, school full time, leisure full time	Retired

The source of uncertainty over the lifecycle comes from the human capital production shock, ϵ. It is realized if one is working (full time or part time). All shocks are *iid* across individuals and time. Equation 1 describes the extensive margin labor supply and human capital investment decisions before retirement ($age \leq 47$). Individuals maximize lifetime value V by choosing e given the beginning of the period location. $V^{work}, V^{pt}, V^{sch}$, and V^{nonemp} describe the values for one's choice of $e = [work, pt, sch, nonemp]$.

$$V_{\{age\leq 47\}}(\phi; \mu, \mu_{re}) = \max\{V^w(\phi; \mu, \mu_{re}), V^{pt}(\phi; \mu, \mu_{re}), V^{sch}(\phi; \mu, \mu_{re}), V^{nonemp}(\phi; \mu, \mu_{re})\} \tag{1}$$

In addition to the discrete e choice, each individual chooses consumption and saving to maximize the lifetime value. For working individuals, as in Equation 2, human capital accumulates through learning on the job by a fixed parameter A with learning curvature a. Human capital shocks ϵ perturb the learning efficiency. ϵ abstracts from various individual-related factors impacting one's productivity. ϵ is *iid* across individuals and time. But given its nature on h, a stock variable for human capital, the impact of ϵ is persistent.

The labor supply takes from the indivisible labor framework (Hansen, 1985; Rogerson, 1988). The individuals supply a full unit of time to work and receive the disutility of working $disu_w(ft)$. One receives wage paid to the efficient units of labor h and interest income rs. Every period, employed individuals pay social security tax at rate τ and lump sum income tax Υ. One may borrow a non-defaultable debt with borrowing limit $max(\underline{S}, \underline{s}(\phi, \mu, \mu_{re}))$. $\underline{S}$ is the economy-wide common debt limit. Depending on where the current status of the individual is, one has natural debt limit $\underline{s}(\phi, \mu, \mu_{re})$ set to enforce full repayment by the end of the lifecycle. If a person's natural debt limit is more strict than the economy-wide limit, the borrowing follows her natural debt limit. Regardless of working status or age, everyone receives an equal lump-sum profit rebate from firm Π.

$$\begin{aligned} V^{work}(\phi; \mu, \mu_{re}) = \max_{c,s'} \{u(c) - disu_w(ft) \\ +\beta(V(\phi'; \mu', \mu'_{re})\} \\ \text{s.t.} \\ c + s' = (1 + r_{\mu,\mu_{re}})s + w_{\mu,\mu_{re}} h(1-\tau) + \Upsilon + \Pi \\ h' = \epsilon A h \\ s' \geq max(\underline{S}, \underline{s}(\phi, \mu, \mu_{re})) \end{aligned} \tag{2}$$

If an individual decides to go to school full time, the person has to pay a fixed tuition cost, psychic cost, and opportunity cost from giving up current earnings and learning on the job to enroll in school. As in Equation 3, the person incurs disutility $disu_{sch}$ from going to school. The disutility depends on a person's existing human capital, age, current schooling status, years of school completed, and full time/part time schooling status. The individual's income only comes from previous savings (or debt) and tax transfer, which must be allocated among consumption, savings (or borrowing) for the future, and tuition payment κ. Human capital moves up by a scaling factor $\Delta(yrs)$, a function based on years of education.

$$
\begin{aligned}
V^{sch}(\phi;\mu,\mu_{re}) = \max_{c,s'}\{u(c) - disu_{sch}(h, age, e, yrs, ft) \\
+\beta V(\phi';\mu',\mu'_{re})\} \\
\text{s.t.} \\
c + s' + \kappa\epsilon_s = (1 + r_{\mu,\mu_{re}})s + \Upsilon + \Pi \\
h' = \Delta(yrs)h \\
s' \geq max(\underline{S}, \underline{s}(\phi,\mu,\mu_{re}))
\end{aligned}
\tag{3}
$$

If one chooses part-time working and part-time schooling, as in Equation 4, one receives disutility from working and from schooling. The human capital accumulates as an average of learning on the job and school education. Human capital shock ϵ still perturbs the efficiency of learning on the job. One receives half of the wage w paid to the efficient units of labor h and spends half of the full-time tuition κ.

$$
\begin{aligned}
V^{pt}(\phi;\mu,\mu_{re}) = \max_{c,s'}\{u(c) - disu_w(pt) - disu_{sch}(h, age, e, yrs, pt) \\
+\beta V(\phi';\mu',\mu'_{re})\} \\
\text{s.t.} \\
c + s' + \kappa\epsilon_s/2 = (1 + r_{\mu,\mu_{re}})s + hw_{\mu,\mu_{re}}(1-\tau)/2 + \Upsilon + \Pi \\
h' = (\epsilon h A + \Delta(yr)h)/2 \\
s' \geq max(\underline{S}, \underline{s}(\phi,\mu,\mu_{re}))
\end{aligned}
\tag{4}
$$

Suppose an individual decides to stay at home, as in Equation 5. In that case, one faces a simple consumption-saving problem with full time to leisure (normalized to zero compared to disutility from school and working). However, the human capital depreciates deterministically by the δ_h portion every period.

$$
\begin{aligned}
V^{nonemp}(\phi;\mu,\mu_{re}) = \max_{c,s'}\{u(c)+\beta(V(\phi';\mu',\mu'_{re})\} \\
\text{s.t.} \\
c+s' = (1+r_{\mu,\mu_{re}})s+\Upsilon+\Pi \\
h' = (1-\delta_h)h \\
s' \geq max(\underline{S},\underline{s}(\phi,\mu,\mu_{re}))
\end{aligned}
\tag{5}
$$

After age 65, one retires from the labor market, as in Equation 6, and no longer chooses to attend school. The aggregate state variable μ retrieves to μ_{re}, where individuals are located on age, human capital h, and current level of asset s. One receives social security benefit $B(h)$ and pays income tax Υ. Even though human capital stops evolving after retirement, I set the retirement benefit $B(h)$ as a function of the human capital (representing earnings) by the last age before retirement. At the final age, $age = 67$, $V^R_{age+1} = 0$, and individuals cannot leave the model with debt. It is a Huggett (1993) problem.

$$
\begin{aligned}
V^R(age,s,h;\mu,\mu_{re}) = \max_{c,s'}\{u(c)+\beta V^R(age+1,s';\mu',\mu'_{re})\} \\
\text{s.t.} \\
c+s' = (1+r_{\mu,\mu_{re}})s+B(h)+\Upsilon+\Pi \\
s' \geq max(\underline{S},\underline{s}(\phi,\mu,\mu_{re}))
\end{aligned}
\tag{6}
$$

Standard concave utility qualities apply. In particular, $V^w, V^{pt}, V^{sch}, V^{nonemp}$ are concave in consumption c, hence $\frac{\partial V^e}{\partial y} > 0$, and $\frac{\partial V^e}{\partial y \partial y} < 0$, where $y \in \{s,h\}$.

3.2 Firm's problem

One homogeneous firm employs efficient units of labor and rents capital for final goods production as in Equation 7. Capital k comes from individuals' savings s'. Capital depreciates at a rate of δ.

$$\Pi = zF(K, L) - wL - (r + \delta)K \tag{7}$$

The markets operate competitively. Given the constant returns to scale production technology, firms pay price at competitive market rate: $w = MPL$, and $r + \delta = MPK$.

3.3 Stationary Equilibrium

Let H be the space for human capital, S be the space for asset, E be the space for employment-schooling status, and G_s be the support for tuition shock ϵ_s. Let ϕ_{age} be the idiosyncratic state variables for individuals $\{h, s, yrs, e\}$ at a given age, and μ and μ_{re} be the distribution of all individuals before retirement and after retirement on idiosyncratic states. A stationary recursive competitive equilibrium is a collection of factor prices $w(\mu, \mu_{re})$, $r(\mu, \mu_{re})$, individuals' decision rules $s_{age+1}(\phi_{age}, \mu, \mu_{re})$, $h_{age+1}(\phi_{age}, \mu, \mu_{re})$, $e_{age}(\phi_{age}, \mu, \mu_{re})$, $c_{age}(\phi_{age}, \mu, \mu_{re})$, $yrs_{age}(\phi_{age}, \mu, \mu_{re})$, and value functions $V_{age}(\phi_{age}, \mu, \mu_{re})$ such that

1. Given w and r, individuals optimize individuals' problem.

2. All prices are paid competitively where $w = F_2(K, L)$, and $(r + \delta) = F_1(K, L)$.

3. Aggregate efficient units of labor supply has:

$$\begin{aligned} L^s = \sum_{age=1}^{47} \sum_{yrs=0}^{4} \int_H \int_S &(h_{age,e,yrs,s,h} I_{\{e=work\}}) \\ &+ \frac{1}{2}(h_{age,e,yrs,s,h} I_{\{e=pt\}}))\mu(age, e, yrs, h, s)dsdh \end{aligned}$$

4. Aggregate savings has:

$$K^s = \sum_{age=1}^{47} \sum_{yrs=0}^{4} \sum_{e}^{E} \int_H \int_S s\mu(age, e, yrs, h, s)dsdh + \sum_{age=48}^{67} \int_H \int_S s\mu_{re}(age, h, s)dsdh$$

5. Aggregate consumption has:

$$C = \sum_{age=1}^{47} \sum_{yrs=0}^{4} \sum_{e}^{E} \int_H \int_S c\mu(age, e, yrs, h, s) ds dh + \sum_{age=48}^{67} \int_H \int_S c\mu_{re}(age, h, s) ds dh$$

6. Aggregate tuition cost has:

$$\begin{aligned} Tuition = \sum_{age=1}^{47} \sum_{yrs=0}^{4} \int_H \int_S \int_{G_s} (&\epsilon_s \kappa I_{\{e_{age,e,yrs,s,h}=sch\}} \\ &+ \frac{1}{2}\epsilon_s \kappa I_{\{e_{age,e,yrs,s,h}=pt\}}) \mu(age, e, yrs, h, s) d\epsilon_s ds dh \end{aligned}$$

7. Market clearing requires:

$$L^s = L^d$$

$$K^s = K^d$$

$$Y^s = zF(K, L) = Y^d = Tuition + C + \delta K$$

8. Government balance budget: $\sum_{age=48}^{67} \int_H \int_S B(h)\mu_{re}(age, h, s) ds dh = w\tau L^s - \Upsilon$

9. Individual decision rules are consistent with the aggregate law of motion, Γ, where $\mu' = \Gamma\mu$ and $\mu'_{re} = \Gamma_{re}\mu_{re}$

4 Calibration

I calibrate two categories of parameters for the baseline model to match the U.S. economy. One set of parameters describe the initial distribution of individuals on age 18 human capital and wealth dimensions. The other set of parameters are either externally chosen, listed by the end of Table 5 or jointly determined by minimizing the distance between model-generated moments and targeted statistics, as listed in the top panel of Table 5 and Table 4. All model-generated moments are calculated by simulating the baseline model 50,000 times.

4.1 Initial distribution and grid setup

Table 2 in Section 2.2 describe the empirical initial distribution of individuals on human capital and wealth margins. Literature following Huggett et al. (2011) often construct a multivariate normal distribution with the dimensions describing wealth, human capital, and learning ability. The mean, variance, and covariance of the distribution are calibrated to generate lifecycle earnings profiles that target their empirical counterparts. Comparing to the normal distribution, Table 2 shows that individuals are right skewed on the support. Given the importance of initial conditions in generating lifecycle profiles, smoothing the patterns from the empirical distribution may lead to large consequences in the simulation results. Therefore, I directly feed a more refined distribution from Table 2 into the model.

For the support of the human capital dimension, I create 20 equal-valued consecutive bins for the AFQT scores. Each bin is mapped into a grid point from the 21st to the 40th position on the human capital grid. Then, the number of individuals from each bin is assigned to the corresponding grid position.[9]

For the initial wealth dimension, I first split the proxy for family wealth described in Section 2.2 into equal-valued 20 consecutive bins. The first bin holds 8% of the sample, and the second bin holds 18%. According to the Survey of Consumer Finance, 17% of people between the age of 17 and 19 have negative net wealth. To locate zero wealth, I split the first two bins into equally spaced four sub-groups. The first three sub-groups account for 17.57% of the sample. When fitting the initial wealth support into the model on the asset grid, I set the last of the four subgroups at zero and the first three sub-groups on three equally spaced grid points below zero. The remaining 18 bins are mapped one-to-one on grid points valued above zero equally spaced with distance doubling that among the first four. In total, the support for initial wealth spans 22 grid points on the asset grid.[10] Same as the fitting

[9] To complete the human capital grid, I reserve 20 grid positions before the lowest initial human capital value to allow for human capital depreciation below it. I assign 60 more grid positions after the highest initial human capital level to allow for human capital accumulation above the highest initial level.

[10] To complete the asset grid, I reserve 20 grid positions before the lowest initial wealth value and 43 additional grid points after the highest initial wealth level for further wealth accumulation.

of initial distribution on the human capital grid, I assign the number of individuals in each wealth bin from the data to the initial distribution along each of the 22 grid points for initial value.

Altogether, the support for the initial distribution is a 20 by 22 matrix. Table B.1 reports the distribution of individuals along the human capital and wealth dimensions following the criteria as above. The vertical dimension represents the human capital margin, and the horizontal dimension represents the wealth margin. I directly import the matrix in the optimization and simulation of the model as the starting age conditions.

4.2 Other parameters

The remaining parameters of the model come from an externally chosen set and a calibrated set that minimizes the distance between model generated and data moments. The lower portion of Table 5 lists five parameters chosen externally. The first two relate to the tax system. Government imposes social security tax on all working individuals before the retirement age of 65 and transfers annual retirement income to retirees post-65. I follow Huggett et al. (2011) and Huggett and Parra (2010) for the tax system. Social security tax (τ) imposes at a rate of 0.106. Different from Huggett et al. (2011) for setting a common social security benefit in retirement, I allow social security benefit (ω) a transfer of 40% of an individual's end of working-age income, allowing the heterogeneity of income persisting into retirement. The third one, α governs the labor share of income, set as 0.64.

I parameterize the utility function a summation of three portions: consumption portion, labor-leisure portion, and school psychic cost portion. The consumption portion is set as $u(c) = \frac{c^{1-\rho}}{1-\rho}$. I select the risk aversion ratio ρ to be 2, a standard value used in macro literature, for example Huggett et al. (2011) and Browning, Hansen, and Heckman (1999). In the labor-leisure portion, $disu_w = \psi \frac{n^{1-1/\gamma}}{(1-1/\gamma)}$. I assign γ, the Frisch elasticity, to be 0.75, which lies in the range of estimations in literature as reviewed by Chetty, Guren, Manoli, and Weber (2013).

Table 4: Disutility of schooling by age

Age	*19*	*20*	*21*	*22*	*23*	*24*	*25*
pre BA							
continuous schooling	4.00	2.42	1.36	2.20	16.74	-4.11	3.82
new enrollment		8.47	6.90	7.08	25.45	79.36	14.56
completing BA				-3.15	2.94	6.09	6.93
Age	*26*	*27*	*28*	*29*	*30*	*31*	*32*
pre BA							
continuous schooling	3.56	1.92	5.01	5.99	6.62	6.87	7.58
new enrollment	12.86	9.16	9.24	9.10	9.29	9.89	10.16
completing BA	7.38	7.68	8.08	8.46	8.84	9.12	9.65
Age	*33*	*34*	*35*	*36*	*37*	*38*	*39*
pre BA							
continuous schooling	7.96	9.37	10.35	22.49	29.84	20.93	18.85
new enrollment	9.96	10.46	10.70	11.19	11.79	12.28	12.59
completing BA	25.63	38.45	85.54	43.38	11.80	12.39	12.54
Age	*40*	*41*	*42*	*43*	*44*	*45*	*46*
pre BA							
continuous schooling	19.74	23.63	28.33	31.44	19.80	14.39	22.89
new enrollment	13.39	13.36	13.89	14.11	14.21	15.06	15.87
completing BA	13.00	13.38	14.04	14.17	15.64	14.81	15.62
Age	*47*	*48*	*49*	*50*	*51*	*52*	*53*
pre BA							
continuous schooling	27.98	32.73	32.69	39.78	49.27	61.72	65.48
new enrollment	15.41	16.31	16.37	19.53	18.08	31.81	18.71
completing BA	16.60	16.65	17.07	17.01	17.76	17.75	18.79
Age	*54*	*55*	*56*	*57*	*58*	*59*	*60*
pre BA							
continuous schooling	66.40	55.93	36.45	15.53	19.67	21.74	18.08
new enrollment	34.04	19.19	55.90	19.74	19.91	106.04	67.75
completing BA	18.65	24.19	19.47	26.11	19.63	20.84	26.49
Age	*61*	*62*	*63*	*64*	*65*		
pre BA							
continuous schooling	18.74	22.69	29.25	28.00	21.68		
new enrollment	71.58	78.35	71.30	73.66	132.39		
completing BA	28.46	31.67	36.65	41.25	93.07		

Notes: This table reports the calibrated parameter values for $dis(e, age, yrs)$. For each age, I differentiate the utility cost (gain) from the current enrollment status and whether one is in the final year completing the degree. *pre BA continuous schooling* reports the disutility of schooling for each age if one is currently enrolled in school, and is at least 1.5 years away from completing a bachelor's degree. *pre BA new enrollment* reports the disutility of schooling for each age if one is currently not enrolled in school, and is at least 1.5 years away from completing a bachelor's degree. *completing BA* reports the disutility of schooling for each age if one is at most one year before completing a bachelor's degree, regardless of the current enrollment status.

The rest of the parameters are jointly calibrated to minimize the distance between empirical moments and model simulated moments. Motivated by Johnson (2013), Hai and Heckman (2017), Guo (2018) and Abbott et al. (2019), I parameterize the school psychic cost portion of the utility function as $disu_{sch}(h, age, e, yrs, ft) = n_{sch}(dis(e, age, yrs) - h)$.[11] $n_{sch} = 1$ is for full time schooling and $n_{sch} = 0.5$ for part time schooling. The psychic cost is relative to the size of human capital, h, that the person already has, following the self-productive nature of learning[12].

Human capital investment is time-sensitive. Whether it is through learning on the job or schooling, the rate of accumulation for each mode and the associated psychic cost may differ by age (Cunha et al., 2006). A current student may be more likely to continue enrolling in school than one currently away from school.[13] Lastly, if one is near completing a degree, the student may find a different psychological challenge than the beginning stage of college. Therefore, I model $dis(e, age, yrs)$ to represent a set of parameters describing the relative disutility of schooling by age, years of schooling completed, and continuing enrollment status. The three sets of dis parameters for each age are reported in Table 4. These parameters are calibrated to target the new and continuing enrollment and BA attainment statistics in Figure 3.[14].

The rest of the calibrated parameters and their most relevant moments are reported in

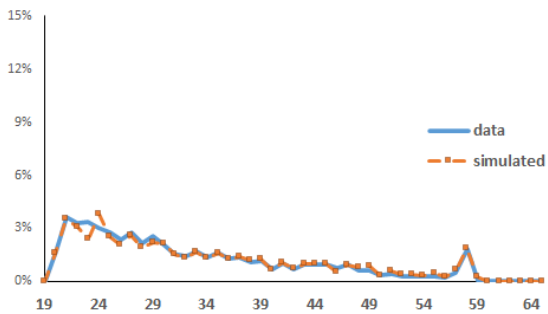
[11] Much macro literature with human capital acquisition only allows for the opportunity cost of learning and does not model a direct cost associated with it (e.g. Huggett et al., 2011; Griffy, 2021). Hsieh, Hurst, Jones, and Klenow (2019) argue that a direct cost is essential in generating asymmetric human capital investment behaviors. Most of the general equilibrium models with human capital acquisition introduce direct financial cost to accommodate the argument (e.g. Athreya and Eberly, 2021; Krebs, Kuhn, and Wright, 2015; Lee and Seshadri, 2019; Kim, 2021). Belley and Lochner (2007) demonstrate that additional utility cost allows a model to generate important empirical schooling patterns that are difficult to reproduce. Yang and Casner (2021) provide further theoretical account showing that utility cost to school creates a critical channel linking wealth, precautionary savings, and risk aversion to schooling decisions. Missing such components may create omitted variable bias in the simulation.

[12] See for example Macdonald (1981), Card (1994), Card (2001), Johnson (2013), Hai and Heckman (2017), Guo (2018), Abbott et al. (2019), and Cunha et al. (2006). The higher the human capital, the easier it is to gain more via education.

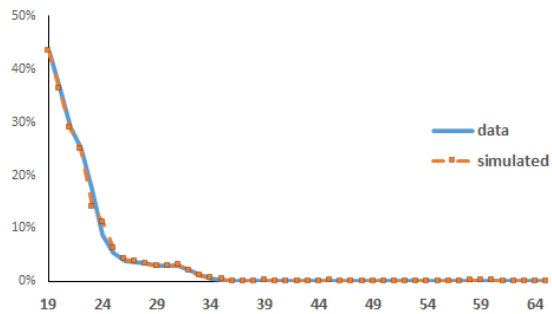
[13] For example, Stinebrickner and Stinebrickner (2012) discuss the signaling one receives while in school and at work could propel one making school-work decisions differently.

[14] The data from NLSY79 is only available for the age up to 59, but the model extends to age 65. I impose the enrollment and the additional degree completion rates to be zero after age 59, given the small number in college enrollments at ages near 59.

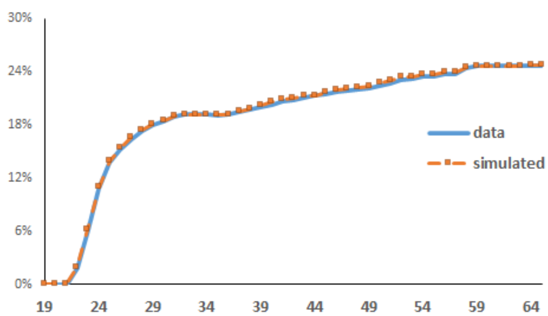
Figure 3: Life-cycle enrollment and degree attainment: data and model moments



(a) new enrollment by age



(b) continuous enrollment by age



(c) completed BA by age

Notes: This figure compares the model simulated lifecycle enrollment and college degree completion to data moments. The blue hard line reports data values, and the red dotted line reports model simulated moments. Panel (a) reports the percent of the sample at each age newly enrolling in college. Panel (b) reports the percent of the sample at each age continuously enrolling in college (including full time and part time enrollments). Panel (c) reports the percent of the sample at each age with a bachelor's degree.

Table 5. In the labor-leisure portion of the utility function, ψ governs the scale of disutility from working. For simplicity, working time is discrete, where $n = 1$ is for full-time working, and $n = 0.5$ is for part-time working. I calibrate $\psi = 0.7741$ to match the employment to population ratio calculated using the average CPS data from 1979 to 2016.

Table 5: Calibration and targeted statistics

Parameter	Value	Description	Target statistics	data	model
Chosen internally					
ψ	0.7741	disutility of working	emp-pop ratio	0.61	0.61
a	0.93	curvature of wage growth	wage spread expansion	0.01	0.01
A	1.1179	learning on the job	lifetime wage growth	1.95	2.41
Δ_1	1.1071	school learning pre BA	some college premium	1.03	1.03
Δ_2	1.4305	school learning by BA	college premium	1.06	1.04
δ_i	0.0375	human capital depreciation	mean unemp wage loss	0.04	0.05
κ	1.0944	schooling cost	college spending share	0.14	0.14
δ	0.0715	capital depreciation	K/Y	3.23	3.23
β	0.9503	discount factor	risk free rate	0.04	0.04
ϵ	(0.7878, 1.2122)	human capital shock	wage variance	0.56	0.56
Chosen externally					
τ	0.106	social security tax			
ω	0.40	social security income			
α	0.64	labor share of income			
γ	0.75	Frisch elasticity			
ρ	2.00	risk aversion			

Notes: This table reports the parameters, their values, and the descriptions. The top panel presents the parameters chosen internally through minimizing the distance between model generated moments and data. The last two columns of the top panel compare the targeted moments between data and model simulated values. The bottom panel reports the five parameters chosen externally of the model, their values and descriptions.

Human capital can move along three trajectories: accumulating on the job (or, loosely speaking, "learning" on the job), learning in school, and depreciating while enjoying full-time leisure. Parameter a determines the curvature of all human capital accumulation. Browning et al. (1999) and Huggett et al. (2011) describe the importance of a in generating the rise of dispersion of income over the lifetime. I set a to match the wage dispersion over a lifetime in my calibration, measured as the slope of variance of log wage from 18 to 65. All wage-related moments are calculated using detrended CPS data from 1992 to 2016[15]. Models

[15] I follow Huggett et al. (2011) by removing time and cohort effect from the data and deflating all price variables to 2009 level.

following Huggett et al. (2011) use a separate continuous-time choice devoted in learning (e.g. Griffy, 2021). The core of human capital production in this model is deterministic, depending on the employment status. A governs the rate of return to learning on the job; Δ's govern the efficiency of schooling learning, and δ_i governs the loss of human capital from non-employment. To build in the "sheepskin" effect of education (Hungerford and Solon, 1987), I let Δ_1 describe the human capital return from each year of college enrollment before graduation and Δ_2 for it when one receives the college degree. Δ_1 calibrates to the age 65 mean earnings ratio between people with some college experience but without the degree to those without college experience. Similarly, Δ_2 calibrates to college degree premium, calculated as the ratio of age 65 mean earnings between all with a college degree and all without college experience. A helps match the lifetime wage growth, defined as the ratio of mean earnings at age 65 to mean earnings at age 19. Parameter δ_i is used to identify the average depreciation rate of the human capital of 4.3% during the first year of non-employment, a value estimated by Dinerstein, Megalokonomou, and Yannelis (2020). The direct tuition-related financial cost of schooling κ is calibrated to match the average post-secondary education cost as a share of output, as estimated by Yum (2020).

Lastly, β calibrates to the annual risk-free interest rate of 0.04, and δ calibrates to the capital-output ratio of 3.23 estimated by Fernandez-Villaverde, Krueger, et al. (2011). The earnings shock, ϵ, serves as the primary source of lifecycle uncertainty. Similar to Huggett et al. (2011), ϵ follows an *iid* process across time and individuals, and it describes the risk that affects human capital production on the job. Huggett (1993) calibrates ϵ to be mean negative to generate the depreciation of human capital. I take an agnostic stand and let it be mean zero. To reduce computation burden, I allow only two values of ϵ to target the overall cross-sectional variations in earnings, calculated using the detrended CPS data.

4.3 Model fit

Figure 4 compares a set of untargeted moments between data and model simulation. Panel (a) compares the college interruption patterns, and Panel (b) compares the age of individuals completing a bachelor's degree. The model generates similar patterns comparing to data. Panel (c) and Panel (d) further compare the relationship between age 18 human capital and wealth conditions to the college interruption patterns. I split the initial conditions into four equal-valued bins. The patterns to compare are individuals who obtain BA after some interruptions, individuals with some college experience but not completing the degree, and those without college experience at all. Both data and model show that those with higher age 18 human capital are more likely to complete a BA, less likely not to have college experience. Similarly, ones with higher initial family wealth are more likely to complete the degree.

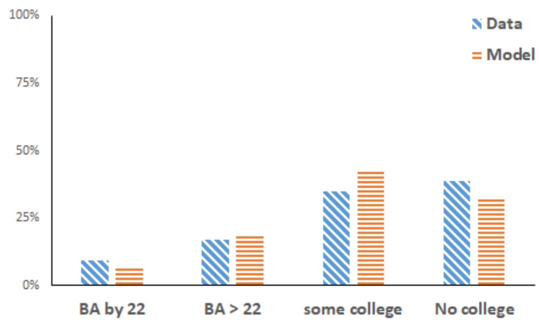
This paper intends to examine the risk and consumer welfare value associated with empirically relevant intermittent access to college. From the model setup, college education transforms to welfare through direct utility value and its interactions with earnings profile. The earnings profile contains information relevant to schooling: human capital realizable to earnings, level of risk and risk perception, and relative value of human capital to physical assets. Hence, it is important to validate the heterogeneous lifecycle earnings dynamics between the baseline model and data. Guvenen (2007), Guvenen (2009) and Guvenen and Smith Jr (2014) categorize two patterns of earnings dynamics from the literature, restricted income process (RIP) and heterogeneous income process (HIP). The following process describes the lifecycle earnings:

$$y^i_{h,t} = g(\theta_t, X^i_{h,t}) + f(\alpha^i, \beta^i, X^i_{h,t}) + z^i_{h,t} + \epsilon^i_{h,t}$$

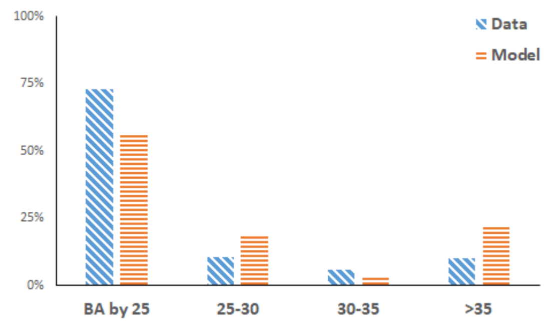
$$z^i_{h,t} = \rho z^i_{h-1,t-1} + \eta^i_{h,t},\ z^i_{0,t} = 0$$

where $\{i, h, t\}$ describes individual, age, and time; $\{\rho, \sigma^2_\alpha, \sigma^2_\beta, \sigma^2_\eta, \sigma^2_\epsilon, corr_{\alpha\beta}\}$ describe persistence, variances and co-variances of the earnings process. $g(\theta_t, X^i_{h,t})$ describes the common

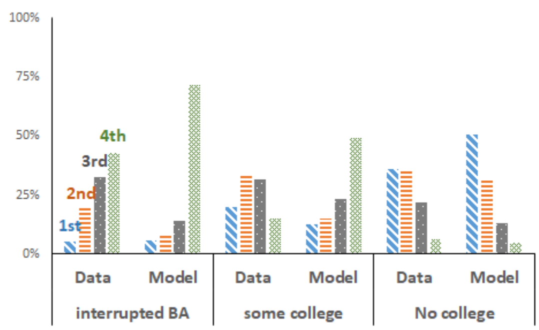
Figure 4: Education and initial conditions: data and model moments



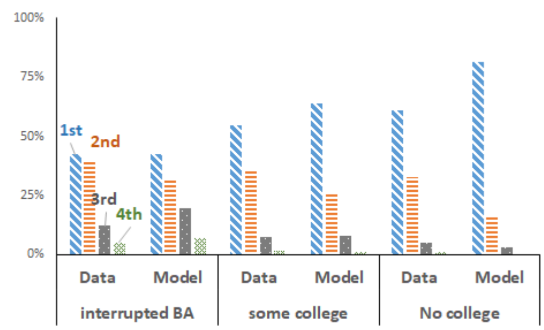
(a) interruption pattern



(b) BA completion pattern



(c) human capital bins



(d) wealth bins

Notes: This figure compares the data moments to simulated moments from the baseline model. Panel (a) plots the percentage of the sample under each college interruption pattern. Panel (b) plots the percentage of all with bachelor's degree who completes the degree within each age range. Panel (c) plots the percentage of sample in each interruption pattern that comes from each of the initial human capital bin. Panel (d) plots the percentage of each interruption pattern that comes from each initial wealth bin.

variances across individuals. $f(\alpha^i, \beta^i, X^i_{h,t})$ describes individual variations, in which α_i is drawn from a distribution governing initial intercept heterogeneity across individuals; β_i describes slope heterogeneity. $z^i_{h,t}$ models the AR(1) process of earnings shocks with persistence ρ and innovation η; $\epsilon^i_{h,t}$ models the transient *iid* shocks across time and individuals.

Following Guvenen (2009), I remove the common variations $g(\theta_t, X^i_{h,t})$ through fitting a cubed polynomial of age to earnings equation and examine the residual process. I use minimum distance estimation to find parameters of the income process. Compared to HIP, RIP removes individual slope differences β. Table 6 compares the benchmark model simulated processes to the estimation from Guvenen (2009). Across all parameters of the statistical earnings process, the baseline model shows a strong quality of reflecting the empirical earnings process.

Table 6: Statistical models of earnings

	ρ	σ^2_α	σ^2_β	$corr_{\alpha\beta}$	σ^2_η	σ^2_ϵ
RIP model						
Baseline	0.981	0.038	-	-	0.011	0.051
Guvenen (2009)	0.988	0.058	-	-	0.015	0.061
HIP model						
Baseline	0.827	0.125	0.00028	-0.005	0.028	0.025
Guvenen (2009)	0.821	0.022	0.00038	-0.230	0.029	0.047

Notes: This table reports the parameter values from estimating RIP and HIP processes. The baseline is reported by simulated the baseline model 50,000 times and fit the RIP and HIP process to the simulated heterogeneous earnings profile.

5 Main findings

In this section, I present the main findings of this paper: the aggregate and distributional welfare consequences of having flexible access to college. First, I examine the role of college by comparing the aggregate variables between the baseline economy and the counterfactuals restricting college access in the general equilibrium. Then, I inspect the heterogeneous impact of having access to college on people with different age 18 conditions. I measure the welfare value through consumption equivalence using the average of individual's welfare measure outlined by Mukoyama (2010). A positive consumption equivalence means households prefer the original model, while a negative value means households prefer the counterfactual model. A negative value is interpreted as the percentage of original consumption that the households are willing to give up to keep the counterfactual environment. A positive value is interpreted as the percentage of original consumption that the households need to be compensated to maintain the counterfactual environment.

5.1 Aggregate effect of having flexible access to college

In the baseline model, a person can flexibly choose to enroll in college at any age before retirement and leave without completing the degree. I examine the aggregate impact of having such flexible access to college and having college at all in Table 7. The first column reports the baseline values. The second column reports the change of values compared to the baseline model when I shut down flexible access to college. The last column reports the change of values when I remove college completely from the baseline model.

Table 7: Aggregate effect of college

	Baseline	No flexible access	No college
	(1)	(2)	(3)
enrollment/population	0.05	11.83%	
BA attainment/population	0.25	-28.48%	
employment/population	0.61	4.02%	-1.06%
K/Y	3.23	0.02%	0.41%
Y	6.00	0.41%	5.64%
C/Y	0.76	0.20%	1.56%
w	1.24	0.24%	0.27%
r	0.04	-1.25%	-1.41%
consumption equivalence		-15.68%	-23.92%

Notes: The first column reports the baseline values. The second column reports the change of values compared to baseline model, from a model where I shut down flexible access to college. Individuals do not have access to college if they do not enroll at age 19, or leave college at any point. The last column reports the change of values from the baseline model, when I remove college completely.

When I remove the flexible access to college, individuals can only have college access right after high school by age 19 and cannot return to college once they leave school. This means that the 19% of individuals who complete college after age 22 in Panel (a), Figure 4 have to either advance their degree attainment age, choose non-stopping but part-time schooling, or give up college after age 22. As a result, such restriction reduces total BA attainment by 28% but increases enrollment by 12%. More people are working, and more asset saves to physical capital, leading to a modicum increase of output, capital share, consumption share, and employment. In the general equilibrium, additional capital supply reduces the interest rate by 1%, while the wage rate increases by 0.2%. Although with higher output and consumption share, individuals still lose on welfare. The consumption equivalence reduces by 16%, indicating that flexible college access creates important consumer welfare, a dimension additional to output and consumption.

In the last column, I remove college completely. Individuals can only choose to work or stay at home. As a result, more assets can be accumulated in savings without tuition-related costs, subsequently converting to production capital. In general equilibrium, the interest rate decreases (by -1.4%), and the wage rate increases (by 0.3%). As a result, output, capital, and consumption increase more. However, consumer welfare drop by nearly 24%. Compared to the welfare change in column (2), flexible college access accounts for 66% of the value of college measured by consumption equivalence.

Overall, Table 7 shows that college has a significant impact on consumer welfare to the aggregate economy. About 2/3 of the consumer valuation of college comes from having flexible access. The difference in enrollment and degree attainment responses suggests the importance of separating an intensive margin college enrollment and an extensive margin college degree completion.

5.2 Heterogeneous impact of access to college

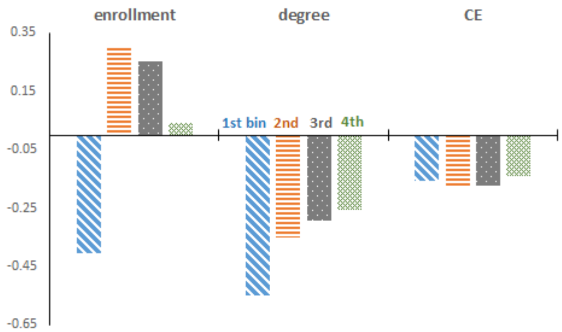
Empirical evidence suggests a link of initial conditions to college patterns. In this subsection, I examine the heterogeneous value of flexible access to college on individuals with different initial conditions and the alternative behavior in a counterfactual without such flexibility. Specifically, I split individuals into four equal valued bins along the initial human capital dimension and four along the initial wealth dimension. I explore the change in enrollment, degree attainment, and welfare for each bin.

The first row in Figure 5 compares the baseline values to the counterfactual model of removing flexible access to college. Panel (a) examines the changes in enrollment, degree attainment, and consumption equivalence along the initial human capital margins, and Panel (b) examines the changes along the initial wealth margin. Connecting to Table 7, the near 12% increase in enrollment after removing flexible access to college comes primarily from individuals on the second and the third initial human capital and wealth bins. Individuals on the highest initial human capital bin have only a slight increase in enrollment response. The highest family wealth bin does not react to the change of access. However, individuals on the lowest initial human capital bin show an over 40% reduction in enrollment. Ones on the lowest initial wealth bin present a minor increase.

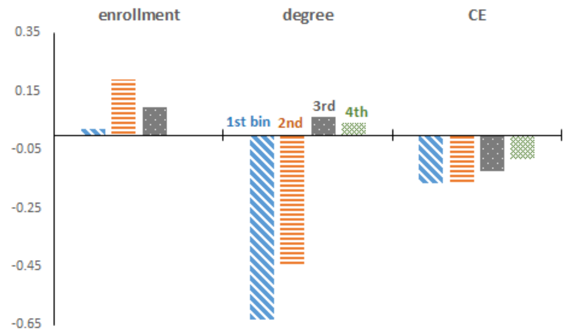
This shows that individuals with the highest wealth or human capital are less affected by flexible access to college in terms of enrollment. People in the middle human capital or wealth bins can adjust their enrollment timing when losing flexible college access. Those with the lowest initial human capital values rely on later and flexible access to college.

In terms of degree completion after restricting flexible access, people with higher human capital have a minor reduction in degree completion shown in Panel (a). In Panel (b), individuals in the top two wealth bins have a small increase in degree completion, whereas those from the lower two bins incur a significant loss in the completion. About 60% of the people from the lowest bin can no longer complete their degree without flexible access to college.

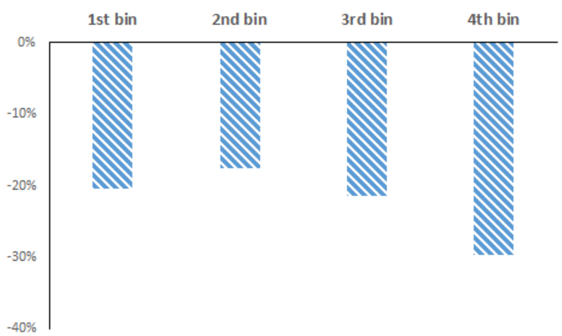
Figure 5: Heterogeneous impact of college and stopout



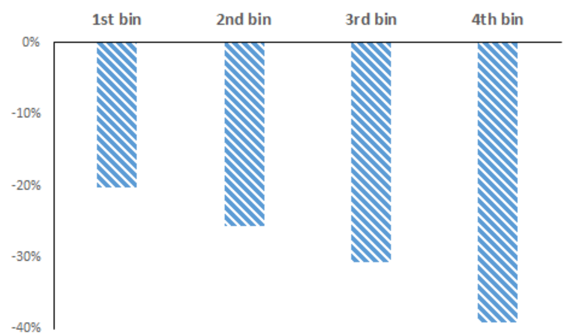
(a) impact of stopout - initial human capital



(b) impact of stopout - initial family wealth



(c) CE of college - initial human capital



(d) CE of college - initial family wealth

Notes: The first row reports the change of values compared to baseline model, from a model where I shut down flexible access to college. Individuals do not have access to college if they do not enroll at age 19, or leave college at any point. Panel (a) examines the changes along the initial human capital margin. The initial human capital is split into four equal-valued bins. The first bin has the lowest value and the forth bin has the highest value. The changes examined are enrollment, bachelor's degree attainment, and consumption equivalence of not having flexible access to college. Panel (b) examines the changes along the initial wealth margin. The initial wealth is split into four equal-valued bins with 1st bin the lowest and the 4th bin the highest. The bottom row reports the change of values compared to the baseline model, from a model when I remove college completely. Panel (c) reports the consumption equivalence by initial human capital conditions, and Panel (d) reports the consumption equivalence by initial wealth conditions. Both conditions are split into four equal-valued bins as in Panel (a) and (b).

Everyone suffers from reduced welfare in terms of consumption equivalence when removing the flexible access to college. The ones from lower wealth bins pay a higher welfare cost, similar to those from the middle human capital bins. People from the highest wealth bin have the most negligible welfare reduction.

The bottom row of Figure 5 illustrates the heterogeneous welfare cost when removing college completely from the baseline model. Individuals from the top wealth or human capital bins have the most considerable welfare loss. Ones from lower wealth or human capital bins generally suffer from less severe welfare loss, except those from the lowest human capital bin encounter a comparable loss from the third human capital bin.

The nearly reverse welfare effect between the top and bottom rows of Figure 5 suggests that people with higher initial wealth and human capital conditions value college more, but having flexible access to college matters more to people with lower initial conditions.

6 Mechanism

This section examines the mechanisms of transforming college value to lifetime welfare through three channels: price, investment, and risk propagation channels. I first explore the price channel by comparing the aggregate results between partial and general equilibrium exercises. Next, I distinguish the college investment and risk propagation channels by identifying human capital accumulation and risk perception change from attending college. Finally, I focus on the heterogeneity of initial conditions while studying investment and risk propagation channels.

6.1 General equilibrium price channel

Table 7 shows that having different levels of access to college changes aggregate asset holding and efficient units of labor supply. In general equilibrium, it results in a shift in market-clearing wage and interest rates. To isolate the price channel that impacts college enrollment, degree attainment, and welfare, I show in Table 8 the difference of aggregate variables by restricting price change.

Column (1) - (3) in Table 8 present the change of aggregate variables after removing flexible access to college. Overall, the majority of the increase in enrollment and decrease in degree completion in Table 7, Column (2) comes from Column (1) in Table 8. However, the general equilibrium price channel accounts for about half of the welfare reduction when removing flexible access to college.

Column (1) fixes the interest and wage rates at the baseline level and compares the aggregate variables to the baseline values. This leads to a near 8% increase in enrollment and a 32% reduction in degree completion. In Column (2), I relax only the wage rate to the general equilibrium level when there is no flexible access to college. The wage rate is about 0.24% higher than the baseline level. The interest rate remains at the baseline level. All values in Column (2) compare to the levels in Column (1). A higher wage rate leads to a higher return to human capital investment, inducing a slight increase in college activities compared to Column (1) (0.16% increase in enrollment and 0.42% increase in degree attainment). However, the feedback to output and consumer welfare is small (0.01% reduction in consumption equivalence).

Column (3) allows both prices to adjust to the general equilibrium level. The reported values in Column (3) compares to the levels in Column (2) experiment. The interest rate is about 1.25% lower than the baseline level. A lower interest rate creates a lower return to asset, incentivizing individuals to substitute capital savings for human capital investment. As a result, enrollment and degree completion continue to increase (by near 4% and 5% respectively) compared to Column (2). The lower interest rate also reduces capital costs to firms. In general equilibrium, output and capital to output ratio both increase by 1%. Nevertheless, a lower interest rate slows the asset accumulation and leads to a reduction of consumer welfare by 7.6% from Column (2). Together with the 8.9% reduction in welfare in Column (1), they constitute the total welfare reduction of 15.7% in Table 7 when restricting flexible access to college.

Table 8: Aggregate effect of college from partial to general equilibrium

	No flexible access			No college		
	fixed r & w	fixed r	GE	fixed r & w	fixed r	GE
	(1)	(2)	(3)	(4)	(5)	(6)
enrollment/pop.	7.68%	0.16%	3.69%			
BA attainment/pop.	-31.87%	0.42%	4.54%			
employment/pop.	4.15%	-0.07%	-0.05%	-0.23%	-0.07%	-0.76%
K/Y	-1.14%	-0.24%	1.42%	-1.98%	-0.37%	2.81%
Y	-0.84%	0.06%	1.20%	3.09%	0.03%	2.45%
C/Y	0.00%	0.06%	0.14%	0.76%	0.03%	0.76%
consump. equivalence	-8.78%	-0.01%	-7.55%	-16.32%	2.13%	-10.98%

Notes: Column (1) - (3) present the change of aggregate variables after shutting down flexible access to college. Individuals do not have access to college if they do not enroll at age 19, or leave college at any point. Column (1) keeps the interest and wage rates at the baseline level. It reports the change of values compared to baseline model. Column (2) keeps the interest value at the baseline level, and the wage rate at the new general equilibrium level when shutting down flexible access to college. It compares the values to Column (1) level. Column (3) allows interest and wage rates to adjust to the new general equilibrium level. The general equilibrium interest rate at Column (3) is 1.25% lower than baseline level, and the wage rate is 0.24% higher than the baseline level. The reported values in Column (3) compares to the levels in Column (2) experiment. Similarly, Column (4) - (6) present the change of aggregate variables after removing college completely. The rest of the reporting follows Column (1)-(3). The general equilibrium interest rate at Column (6) is 1.41% lower than baseline level, and the wage rate is 0.27% higher than the baseline level.

I conduct a similar comparison in the last three columns in Table 8 to isolate the price channel that leads to the general equilibrium results in Table 7 Column (3) when completely removing college from the baseline model. In Column (4) of Table 8, the college option explains 16% of consumer welfare drop from baseline mode, holding all prices fixed. When relaxing wage rate to the new general equilibrium setting with no college in Column (5) (a 0.27% increase from baseline wage rate), consumer welfare increases by 2% from Column (4). Moving to total general equilibrium prices in Column (6) (with 1.4% reduction in interest rate), consumer welfare drops by 11% from Column (5). This accounts for about one-third of the total welfare drop between the general equilibrium without college and the baseline level.

Altogether, Table 8 shows that the price channel from general equilibrium rearrangement of individuals on human capital and asset holdings is essential in examining the welfare consequences of college access. It leads to about one-third of the total welfare measure of college and about half of the welfare value of flexible access to college. However, most of the adjustment in enrollment and degree completion once restricting college access is independent of the price channel. The following section explores the channels for remaining adjustment and welfare through lifecycle college valuation.

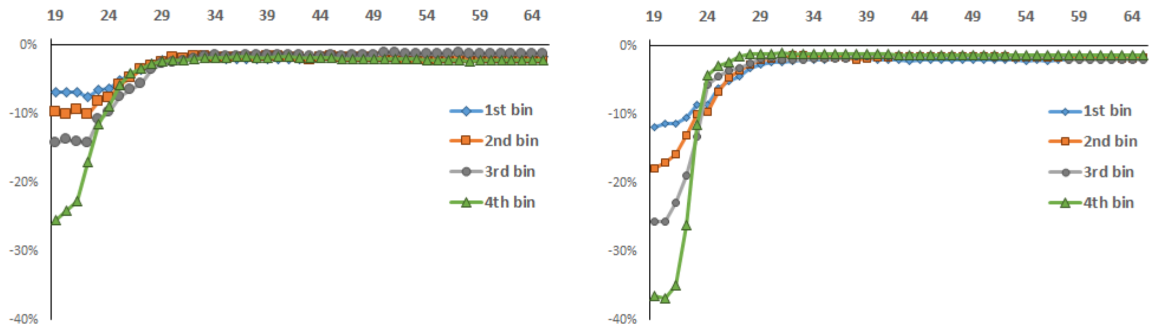
6.2 Channels through the values of college

Numerous studies investigate the investment value of school education, a direction initiated by Mincer (1974), Ben-Porath (1967) and Card (1994). More school education produces higher human capital, leading to higher labor income. Yet, human capital accumulation resembles physical asset accumulation, in which it embeds important propagation quality to lifecycle risk (e.g. Meghir and Pistaferri, 2011; Barrow and Malamud, 2015). Yang and Casner (2021) provides a theoretical account of how labor market risk and human capital returns of college transmit to the enrollment decision. In this section, I start by estimating the gross value of college for each age through one's lifecycle. Then, I decompose it into the investment value and the risk propagation value. A high investment value motivates school learning for young people, while a reduction of risk explains later age schooling. Lastly, I connect the values to initial conditions. The findings shed light on the heterogeneity in college enrollment and completion patterns.

6.2.1 Gross value of college

I present the gross value of college for each age by the initial conditions in Figure 6. It is measured by the consumption equivalence when shutting down access to college for each age. All counterfactuals are simulated in partial equilibrium, keeping baseline prices constant. This ensures that all else equal, the consumption equivalence only comes from an individual's valuation of one additional year of college access. A negative consumption equivalence value

Figure 6: Heterogeneous gross value of college by age



(a) by initial human capital

(b) by initial wealth

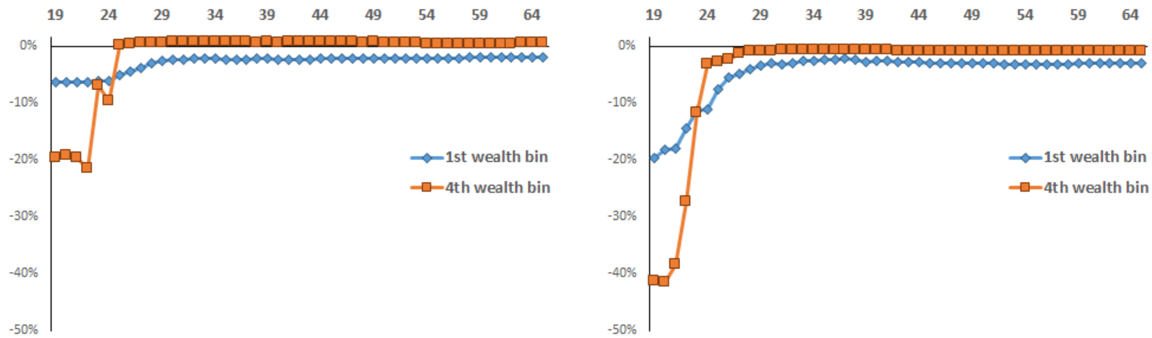
Notes: The plots present the consumption equivalence of removing each year of college, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of have college at age 19 is measured by comparing a model with no school and one with access to school only at age 19. The negative consumption equivalence value means that the individuals are willing to sacrifice the value from the baseline level consumption in order to keep the access to college at the age. I examine the valuation for each age for individuals at each initial human capital bin in Panel (a) and each initial wealth bin in Panel (b).

means that the individuals are willing to sacrifice the portion of baseline lifetime consumption to keep having access to college at the age.

Panel (a) presents the gross value of college for people at each initial human capital bin, and Panel (b) presents it for each initial wealth bin. Across all human capital and wealth bins, the value of college diminishes after age 29 but maintains at a relatively constant near-zero level afterward. The value is the highest at the youngest age, hence corresponds to Figure 3 where the majority of college enrollment and completion happens at an age before 30. Individuals with higher initial human capital or access to wealth have a higher gross value of college at age 19. Their valuation diminishes faster as one grows older. Those at the lowest human capital or wealth bin have the lowest valuation. However, it is still valued at around 10% of their baseline model lifetime consumption. It also decreases slower than the rate at the top endowment bins. This corresponds to the findings in Section 5.2 where ones from the first bins of wealth or human capital suffer more from losing access to flexible schooling.

Figure 7 limits the interaction between wealth and human capital. For Panel (a), I

Figure 7: Gross value of college by age, conditional on human capital



(a) 1st initial human capital bin (b) 4th initial human capital bin

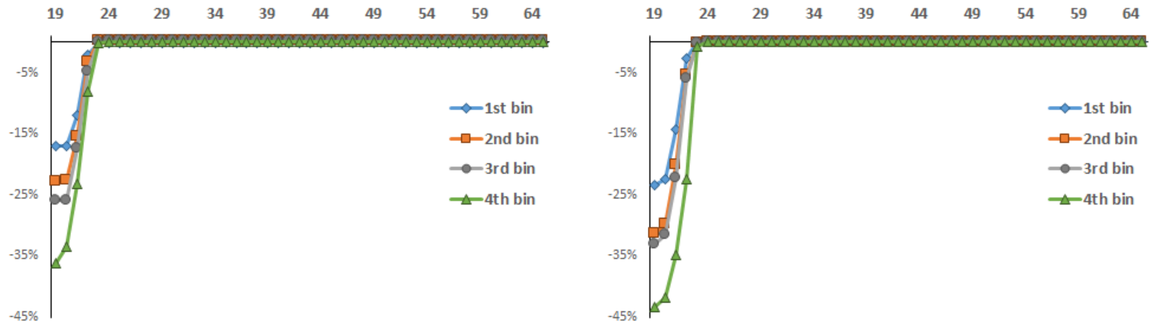
Notes: The plots present the consumption equivalence of removing each year of college, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of have college at age 19 is measured by comparing a model with no school and one with access to school only at age 19. The negative consumption equivalence value means that the individuals are willing to sacrifice the value from the baseline level consumption in order to keep the access to college at the age. Panel (a) examines the college valuation for all from the first initial human capital bin, and Panel (b) for all from the fourth initial human capital bin. The blue line with diamond plots those also in the first wealth bin and the red line with squares for those in the fourth initial wealth bin.

examine the impact of initial wealth on college valuation for all with the lowest initial human capital. Having college has a consistent positive value for individuals from the first human capital and wealth bins. But Individuals value college much more (20% of baseline value) at age 19 if they are from the fourth wealth bin. Interestingly, the valuation to college quickly disappears after age 24. The same pattern exists when comparing the gross value of college between the first and fourth wealth bins for the fourth initial human capital bin in Panel (b). The difference between Panel (a) and (b) is that individuals with higher initial human capital have a higher lifetime value of college, controlling for initial wealth. Higher initial wealth raises early age valuation and lowers later age valuation of college. Additionally, higher initial human capital levels up the valuation of college throughout life-cycle.

6.2.2 Investment value of college

I measure the investment value of college in Figure 8 by calculating the consumption equivalence of having access to college at each age while isolating the idiosyncratic human capital

Figure 8: Heterogeneous investment value of college by age



(a) by initial human capital (b) by initial family wealth

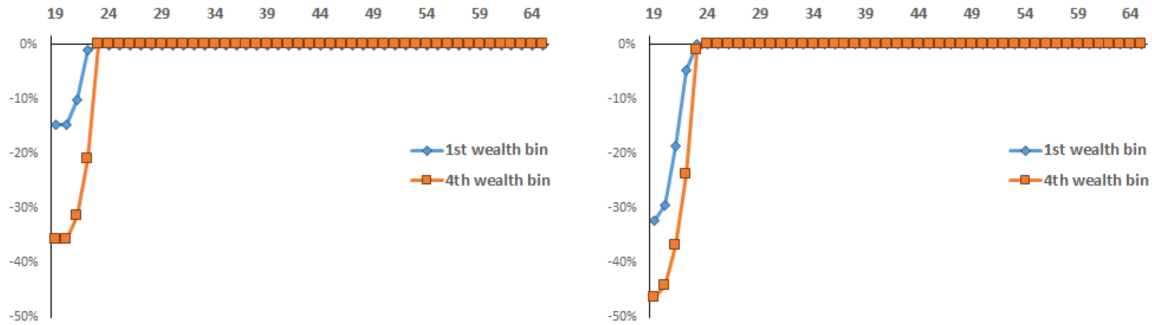
Notes: The plots present the consumption equivalence of removing each year of college in an environment with no exogenous uncertainty, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of have college at age 19 is measured by comparing a model with no school no risk and one with access to school only at age 19 without risk. The negative consumption equivalence value means that the individuals are willing to sacrifice the value from the baseline level consumption in order to keep the access to college at the age. I examine the valuation for each age for individuals at each initial human capital bin in Panel (a) and each initial wealth bin in Panel (b).

shock ϵ in the model. After removing ϵ from the baseline model, the remaining welfare value from college comes from the human capital production from schooling, not perturbed by exogenous factors.[16]

The investment value of college largely mimics the gross value in Figure 6. Individuals with the highest human capital or wealth endowment have the highest investment value. This is because human capital production is multiplicative. The higher human capital, the easier it reproduces, corresponding to the self-productive and dynamically complementary qualities described by Cunha et al. (2006). The investment value of college diminishes faster than the gross value and nearly vanishes after age 24. This corresponds to the extensive literature on returns to college, where its value motivates early age schooling to accumulate lifetime returns. After a certain age, the lifetime returns to college may be outweighed by its cost (e.g. Becker, 1975). Hence lifecycle models often consider college only in the first model stage before engaging in the labor market with no-repeat afterward (e.g. Heathcote,

[16]Even though the return to college becomes deterministic, it is still important to measure its value through consumption equivalence than monetary return. This is because of the differential utility cost between schooling and working(Belley and Lochner, 2007; Yang and Casner, 2021).

Figure 9: Investment value of college by age, conditional on human capital



(a) 1st initial human capital bin (b) 4th initial human capital bin

Notes: The plots present the consumption equivalence of removing each year of college in an environment with no exogenous uncertainty, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of have college at age 19 is measured by comparing a model with no school no risk and one with access to school only at age 19 with no risk. The negative consumption equivalence value means that the individuals are willing to sacrifice the value from the baseline level consumption in order to keep the access to college at the age. Panel (a) examines the college valuation for all from the first initial human capital bin, and Panel (b) for all from the fourth initial human capital bin. The blue line with diamond plots those also in the first wealth bin and the red line with squares for those in the fourth initial wealth bin.

Storesletten, and Violante, 2010; Kim, 2021).

Figure 9 examines the impact of initial conditions on investment value. It is worth noting that initial wealth endowment plays a significant role in college valuation, even controlling for the human capital endowment. Panel (a) shows the difference in investment value by wealth for all in the first initial human capital bin. Those from the fourth wealth bin have more than double the investment value at age 19 than those from the first wealth bin. The investment value disappears for all after age 24. Panel (b) shows the valuation for all from the fourth human capital bin. It has a similar pattern as Panel (a), although the difference in investment value between the first and fourth wealth bins is much smaller in Panel (b). Overall, ones from higher initial wealth and human capital bins have a higher investment value of college. After age 24, the investment value disappears for everyone.

6.2.3 Risk propagation value of college

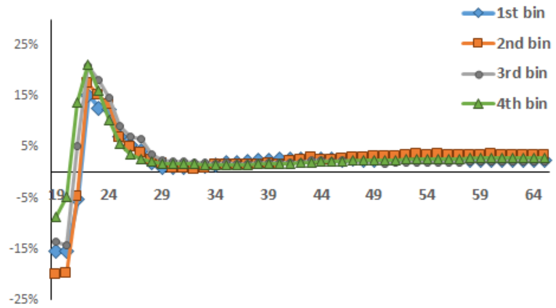
The difference between the gross value of college and the investment value suggests that risk perceptions alter the value of college, an aspect largely omitted by the literature. Without considering the flexible access to college, Kim (2021) and Schweri et al. (2011) show that college-educated workers have more volatile life-cycle earnings paths. Yet, Meghir and Pistaferri (2011) project that individuals mitigate lifecycle risk through means of self-insurance, either as *ex-ante* precautionary saving or *ex-post* adjustment. I explore the risk propagation of college by examining the welfare differential of risk between models without and with school. I first measure the consumption equivalence of risk from a model with risk and without school to a model without risk and without school for each age. I then calculate the risk valuation with school by measuring the consumption equivalence from baseline to a counterfactual model without risk. The difference between the two risk valuations reflects the role of college in the risky environment. In a model with risk averse agent, risk generates welfare loss, measured as a positive value in consumption equivalence by construction. Hence, if the difference of risk valuation is positive, it indicates that a portion of consumer welfare loss from risk is removed by accessing college, showing risk reduction due to college. Conversely, a negative value represents an amplification of risk by the college.

Figure 10 shows the lifecycle risk propagation value of college. For Panels (a) and (b), college amplifies the cost of risk before age 22. However, college largely removes the welfare cost of risk, a risk reduction value between age 22 and 29. After age 29, the college provides a small but persistent effect in alleviating the welfare cost of risk. For younger people, the lower the human capital or wealth endowments, the more substantial the college amplifies risk. For older people, college reduces risk loss more for ones with larger initial endowments.

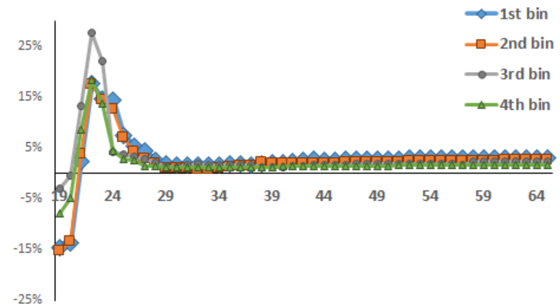
After the investment value of attending college in Figure 8 disappears, the risk reduction quality of college explains the importance of welfare gain associated with having flexible access to college in Table 7 and the later age college enrollment in Figure 1.

Figure 11 isolates the impact of initial conditions in the risk propagation value of college.

Figure 10: Heterogeneous risk propagation value of college by age



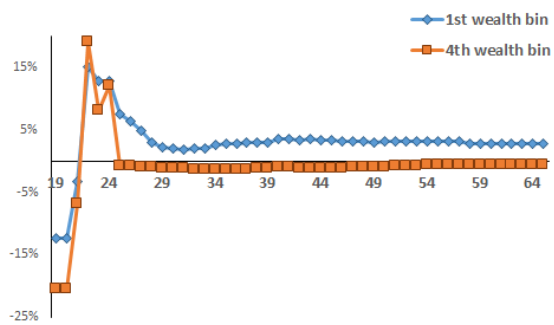
(a) by initial human capital



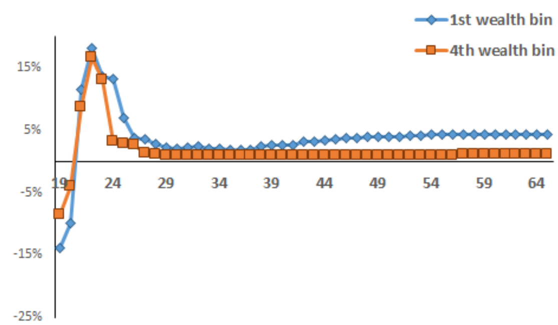
(b) by initial wealth

Notes: The plots present the risk propagation value of college for each initial human capital bin, Panel (a), and for each initial wealth bin, Panel (b). The risk propagation value is calculated as the difference of consumption equivalence to having risk between models without school and models with school for each age. The negative value means that the individuals face a higher cost of risk due to college, and the positive value means that individuals face a lower cost of risk due to college.

Figure 11: Risk propagation value of college by age, conditional on human capital



(a) 1st initial human capital bin



(b) 4th initial human capital bin

Notes: The plots present the risk propagation value of college for each initial human capital bin, Panel (a), and for each initial wealth bin, Panel (b). The risk propagation value is calculated as the difference of consumption equivalence to having risk between models without school and models with school for each age. The negative value means that the individuals face a higher cost of risk due to college, and the positive value means that individuals face a lower cost of risk due to college. Panel (a) examines the risk propagation valuation for all from the first initial human capital bin, and Panel (b) for all from the fourth initial human capital bin. The blue line with diamond plots those also in the first wealth bin and the red line with squares for those in the fourth initial wealth bin.

Panel (a) plots the risk propagation value for the first and fourth wealth bins while limiting the human capital within the first bin. Panel (b) plots them for all from the fourth human capital bin. College provides a more prominent risk reduction value to low initial wealth bins after age 22 in both panels. For ages before 22, college amplifies the risk loss more for the fourth wealth bin when one is at the first human capital bin (Panel (a)) and amplifies it less for ones at the fourth human capital bin.

Overall, having access to college provides a risk reduction value, reducing the welfare cost of risk to all after age 22. This explains the later age enrollment patterns from data and welfare values of flexible access to college. For ages younger than 22, college amplifies risk. In a heterogeneous agent model, Yang and Casner (2021) argue that depending on the relative scale of risk and returns to college, the precautionary savings motive and risk aversion can compound or negate each other in propelling one to enroll in school. The sizeable gross value of college in Figure 6 indicates that the investment value outweighs the risk augmentation at a young age.

6.2.4 Removing welfare aggregation in values of college and college attainment

The life-cycle valuations of college measured in Section 6.2.1, Section 6.2.2 and Section 6.2.3 aggregate individuals from each bin for welfare measure, following Mukoyama (2010). In this subsection, I examine the contribution of initial condition to college value and college timing without aggregation through regression analysis.

First, I explore how each initial condition impacts the value of college. I run OLS regressions with dependent variables as gross value, investment value, and risk propagation value of college at age 19, the starting age of the model. For each regression, I include independent variables from initial human capital, initial family wealth, and the present value of lifetime consumption. The regression results are reported in Table 9. The consumption equivalence calculated for gross value and investment values from Section 6.2.1 and Section 6.2.2 is negative to reflect the cost of removing college. I take the inverse value so that the explanation of the regression coefficient is consistent with the direction of risk reduction of college. I also standardize all coefficients to the distribution of each variable for ease of explanation.

Table 9: Initial conditions and college value

	Gross value	Investment value	Risk reduction value
initial human capital	0.316***	0.760***	0.111***
initial family financial	0.196***	0.419***	0.207***
lifetime consumption	✓	✓	✓
R^2	0.451	0.935	0.396

Notes: This table reports the standardized coefficient for each regression. The regression runs on a simulation of 50,000 individuals from the baseline model. The gross value, investment value and risk reduction value are calculated as the relevant value of having access to college at age 19.

Table 9 shows that a one standard deviation increase of initial human capital leads to a 0.32 standard deviation increase of gross value, 0.76 standard deviation increase of investment value, and 0.11 standard deviation increase of risk reduction value of college. The initial wealth condition has a minor positive impact on the gross value and investment value of college but nearly double the effect on the risk reduction value of college (0.21 standard deviation increase). This shows that when considering the policy implication of initial family background, though more minor, the wealth condition plays a vital role in the risk reduction consideration of college in a risky environment.

Table 10: Investment and risk reduction values and college timing

	College experience	BA completion	BA completion age
investment value	0.509***	0.412***	-0.463***
risk reduction value	0.208***	0.405***	-0.046***
lifetime consumption	✓	✓	✓
R^2	0.391	0.364	0.330

Notes: This table reports the standardized coefficient for each regression. The first two regressions run on a simulation of 50,000 individuals from the baseline model. The last regression runs on a subsample of all with college degree from the simulated sample. The gross value, investment value and risk reduction value are calculated as the relevant value of having access to college at age 19.

Next, I conduct regression analysis linking the investment value and risk reduction value of college for individuals age 19 to the college intermittence pattern. Table 10 displays the regression results for dependent variables: college experience, college completion, and age of completion while controlling the investment, risk reduction values, and lifetime consumption. For the last column, BA completion age, I include only simulated observations of all who completed college.

Investment value plays a dominant role in people's decision to enroll in college. One standard deviation increase of investment value leads to a 0.51 standard deviation increase of college experience. Both investment and risk reduction values have comparable contributions to college completion (0.41 standard deviation increase from either value). Investment value also largely contributes to the early completion of college (reduces BA completion age by 0.46 standard deviation). One standard deviation increase of risk reduction value reduces BA completion age by 0.05 standard deviation.

In conclusion, initial human capital and wealth endowments play an important role in college valuation. The more substantial college investment and risk reduction values increase college enrollment, attainment, and early completion. Therefore, policies aiming at improving college attainment should consider the role both conditions play.

7 Impact of initial inequality

Policies aiming at boosting college enrollment and completion should consider raising initial human capital and the initial wealth positions for young people. Prevalent applicable policies include pre-college training programs that improve college preparedness for high schoolers with lower human capital endowment and need-based financial aid that targets less wealthy students. These policies mitigate the severity of initial endowment inequalities as shown in Table B.1 by reallocating initially less advantageous students to better positions. This section examines the welfare consequence of initial endowment inequalities. I compare the baseline model with unequal initial distribution to one with a uniform distribution of individuals on the same support. This is different from the literature, such as Huggett et al. (2011)

and Griffy (2021), where an equal economy is set by reducing the spread of support for the distribution. My exercise relates to executable policies and sheds light on their potential long-run welfare.

I impose a uniform distribution of individuals along one dimension at a time. Going from an unequal baseline distribution to a uniform distribution creates two channels impacting the aggregate economy in general equilibrium: first, more individuals move to upper initial value bins invoking more substantial investment and risk reduction values of college; second, rearranging the distribution along human capital and wealth changes the effective labor and capital supplies, leading to a general equilibrium adjustment of efficiency wage rate and interest rate. I show the impact of having uniform initial distribution in Table 11.

Table 11: Aggregate impact from removing initial inequality

	uniform initial human capital			uniform initial family wealth		
	fixed r & w (1)	fixed r (2)	GE (3)	fixed r & w (4)	fixed r (5)	GE (6)
enrollment/pop.	9.97%	-0.80%	-0.71%	32.72%	-0.01%	-0.73%
BA attainment/pop.	6.94%	-0.53%	-1.07%	109.19%	-0.02%	-0.52%
employment/pop.	-0.48%	0.08%	0.08%	-2.56%	0.01%	0.06%
K/Y	0.60%	0.19%	-1.23%	-0.57%	0.01%	-0.02%
Y	0.12%	-0.27%	0.08%	0.05%	0.00%	0.01%
C/Y	0.05%	-0.18%	0.18%	0.04%	0.00%	-0.13%
consump. equivalence	2.57%	-7.14%	-3.86%	23.05%	0.04%	-10.09%

Notes: Column (1) - (3) present the change of aggregate variables after imposing a uniform initial human capital distribution. Column (1) keeps the interest and wage rates at the baseline level. It reports the change of values compared to baseline model. Column (2) keeps the interest value at the baseline level, and the wage rate at the new general equilibrium level with uniform human capital distribution. It compares the values to Column (1) level. Column (3) allows interest and wage rates to adjust to the new general equilibrium level. The general equilibrium interest rate at Column (3) is 1.76% higher than baseline level, and the wage rate is 0.3% lower than the baseline level. Similarly, Column (4) - (6) present the change of aggregate variables after imposing uniform initial wealth distribution. The rest of the reporting follows Column (1)-(3). The general equilibrium interest rate at Column (6) is 0.03% higher than baseline level, and the wage rate is 0.003% lower than the baseline level.

Column (1) - (3) in Table 11 present the change of aggregate variables after imposing a uniform initial human capital distribution. Column (1) fixes the interest and wage rate at the baseline level and compares baseline values. The effect corresponds to the discussion in Section 6.2. All else equal, more individuals with higher human capital leads to higher enrollment, degree completion, and consumer welfare. Column (2) allows the wage rate to adjust to the general equilibrium level with a uniform initial human capital condition (0.3% lower than the baseline level). The reported values are changes compared to Column (1). The difference isolates the wage effect from the rearrangement of individual values.

The lower wage rate from uniformly distributed initial human capital reduces enrollment and degree attainment (0.8% and 0.5%). This reduces labor productivity by 0.3%. As a result, consumer welfare drops by 7%. In Column (3), I further relax the interest rate to complete general equilibrium from uniform initial human capital distribution. In this case, the interest rate raises by 1.76% from the baseline level. This makes physical capital investment more attractive, leading to a slight decrease in enrollment and degree completion from the economy with a fixed interest rate. Consumer welfare decrease by 3.9% from Column (2). Altogether, this shows that general equilibrium wage and interest rate adjustment in an economy with uniformly distributed initial human capital generates an 8% lower consumer welfare from the baseline model with the right-skewed initial human capital distribution.

Column (4) - (6) in Table 11 show similar exercises but for uniform initial wealth endowment. Column (4) compared the partial equilibrium results with baseline values for interest and wage rate. The results follow from Section 6.2. A uniformly distributed initial family wealth moves more individuals to higher initial wealth bins, creating a strong incentive to enroll and complete college. It leads to a 3% increase in labor productivity and a 23% increase in consumer welfare. As I move to Column (5), relaxing the wage rate to adjust to the new general equilibrium level (0.003% lower), much of the economy is unchanged. This is because wage adjustment is quite limited. As I further relax interest to the new general equilibrium in Column (6), the interest rate increases by 0.03% from the baseline. The consumer welfare decreases by 10%. Nevertheless, comparing to the baseline level, consumer welfare still raises by 10.7%. In summary, policies creating a more equally distributed initial wealth creates large and positive general equilibrium welfare gain to consumers.

8 Conclusion

I show empirical evidence that most individuals do not complete their post-secondary education at once and experience delays and interruptions before completing their college degrees. The college timing is strongly related to the age 18 human capital and wealth endowments. Individuals with higher initial wealth and human capital endowments are more likely to complete college and do so earlier. I construct a life-cycle model with endogenous age-by-age college entry and exit in general equilibrium to investigate the aggregate and distributional consequences of flexible college access. In aggregate, flexible access to college leads to significant welfare gains and accounts for over 2/3 of the welfare value of college. At the micro-level, individuals with a less advantageous background benefit more from having flexible access to college.

Examining the mechanism, I find three channels in which flexible access to college impacts the economy: price, investment, and risk propagation. In general equilibrium, allowing flexible access to college alters the distribution of individuals on human capital and wealth and encourages more college attainment. The investment value of college raises human capital realizable in the labor market for higher wage income. The investment value is high for ages before 24 but disappears afterward. The value of college for the remaining lifecycle comes from risk reduction. Having access to college at a later age reduces lifecycle welfare loss to risk. Initially, wealthier and more prepared individuals have a higher investment value of college, hence more likely to complete college without interruptions. Initially less advantageous individuals find sizable risk reduction values, especially at a later age. Therefore, flexible access to college benefits them more.

Lastly, an equally distributed initial condition moves otherwise less advantageous individuals to better positions. A uniformly distributed initial human capital endowment creates short-run welfare improvement due to increased enrollment and college completion but long-run negative welfare consequences due to the general equilibrium price effect. Despite price adjustment, a uniformly distributed initial wealth endowment creates welfare improvement compared to the baseline setting for both short-run and long-run. This exercise suggests that college prep classes and financial aid policies can encourage college attainment, but financial aid policies may have lasting long-run welfare gains.

Appendix A NLSY79 and data construction for education pattern

NLSY79 is the uniquely available nationally representative longitudinal survey that starts with respondents from age 14-22 in 1979 to current, almost the entire working life, thereby providing complete details of heterogeneous decision-making information to discipline this study. Following Light (1995a) and Light (1995b) in constructing the panel from NLSY79, I select sample year from 1979 to 2016. I restrict the sample to respondents younger than 20 years old by 1979, the starting year of the survey. I exclude those without AFQT scores, a key variable for further comparisons. Due to inconsistency in degree reporting, high school graduation is loosely defined if one has a high school diploma or, by the retrospective variable, the highest degree completed between 11 and 13 years of education if one did not report high school degree information. I use monthly college enrollment and current enrollment information to trace one's college enrollment and stopout/dropout history. Stop-out means that one temporarily leaves school but later returns to complete a degree or gain more education. This is different from dropout, which means that one leaves school and never returns. Since I only consider formal school enrollment, less than four months of enrollment each year is excluded from "enrolled in the year". I further use reports on college enrollment, retrospective and ongoing highest degree completed variables, full/part-time college enrollment, and college enrollment history to cross-validate each person's college enrollment history. I only consider 4-year college and above as having a college degree and do not differentiate 2-year degrees from the rest of college dropouts. This is a reasonable simplification. According to Athreya and Eberly (2021), 4-year college degree wage premium is 1.74 over the high school, while the premium of some college is only 1.2. Similarly, Kane and Rouse (1995) report a 2-year college degree premium of about 1.1.

Appendix B Initial conditions

Table B.1 reports the distribution of individuals on the age 18 human capital and family financial conditions, that is directly imported in the optimization and simulation of baseline model.

Table B.1: Distribution of individuals on initial conditions

	Wealth approximation cutoff																				
AFQT cutoff	$ 5,296	$ 10,593	$ 15,890	$ 21,187	$ 31,780	$ 42,374	$ 52,968	$ 63,561	$ 74,155	$ 84,748	$ 95,342	$ 105,935	$ 116,529	$ 127,122	$ 137,716	$ 148,309	$ 158,904	$ 169,496	$ 180,091	$ 190,683	$ 201,278	$ 211,880
0-5	0.0031	0.0039	0.0042	0.0059	0.0072	0.0037	0.0013	0.0013	0.0009	0.0013	0.0009	0.0007	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5-10	0.0037	0.0048	0.0074	0.0079	0.0107	0.0083	0.0053	0.0028	0.0031	0.0011	0.0009	0.0009	0.0002	0.0002	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
10-15	0.0044	0.0057	0.0085	0.0066	0.0094	0.0061	0.0059	0.0042	0.0013	0.0042	0.0018	0.0011	0.0004	0.0000	0.0007	0.0002	0.0004	0.0002	0.0002	0.0000	0.0002	0.0000
15-20	0.0044	0.0053	0.0074	0.0068	0.0140	0.0085	0.0053	0.0079	0.0061	0.0050	0.0018	0.0024	0.0002	0.0007	0.0004	0.0004	0.0000	0.0007	0.0000	0.0000	0.0002	0.0000
20-25	0.0022	0.0044	0.0070	0.0077	0.0105	0.0079	0.0068	0.0035	0.0022	0.0028	0.0035	0.0015	0.0011	0.0007	0.0007	0.0002	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000
25-30	0.0018	0.0033	0.0103	0.0074	0.0129	0.0081	0.0103	0.0088	0.0055	0.0028	0.0022	0.0007	0.0007	0.0009	0.0000	0.0002	0.0002	0.0002	0.0002	0.0000	0.0000	0.0000
30-35	0.0013	0.0020	0.0031	0.0037	0.0072	0.0077	0.0059	0.0059	0.0035	0.0018	0.0022	0.0013	0.0007	0.0007	0.0004	0.0000	0.0007	0.0002	0.0002	0.0000	0.0000	0.0000
35-40	0.0009	0.0039	0.0079	0.0057	0.0092	0.0085	0.0066	0.0057	0.0035	0.0026	0.0026	0.0013	0.0022	0.0009	0.0007	0.0004	0.0000	0.0007	0.0002	0.0002	0.0000	0.0000
40-45	0.0013	0.0039	0.0064	0.0044	0.0068	0.0083	0.0085	0.0031	0.0039	0.0037	0.0015	0.0022	0.0018	0.0013	0.0004	0.0009	0.0000	0.0009	0.0002	0.0000	0.0000	0.0000
45-50	0.0011	0.0020	0.0044	0.0055	0.0099	0.0046	0.0068	0.0042	0.0039	0.0033	0.0020	0.0015	0.0013	0.0015	0.0000	0.0002	0.0000	0.0000	0.0007	0.0004	0.0000	0.0002
50-55	0.0007	0.0009	0.0053	0.0046	0.0066	0.0046	0.0061	0.0055	0.0050	0.0044	0.0035	0.0015	0.0009	0.0015	0.0009	0.0004	0.0007	0.0002	0.0000	0.0000	0.0000	0.0000
55-60	0.0007	0.0009	0.0046	0.0048	0.0059	0.0042	0.0050	0.0039	0.0048	0.0031	0.0037	0.0018	0.0013	0.0007	0.0004	0.0002	0.0002	0.0004	0.0009	0.0002	0.0000	0.0000
60-65	0.0007	0.0007	0.0024	0.0024	0.0064	0.0053	0.0028	0.0039	0.0037	0.0026	0.0031	0.0033	0.0009	0.0002	0.0009	0.0004	0.0002	0.0000	0.0004	0.0000	0.0000	0.0000
65-70	0.0004	0.0015	0.0037	0.0031	0.0068	0.0050	0.0028	0.0061	0.0042	0.0037	0.0026	0.0022	0.0026	0.0007	0.0013	0.0007	0.0004	0.0002	0.0000	0.0000	0.0000	0.0000
70-75	0.0009	0.0013	0.0037	0.0031	0.0048	0.0031	0.0048	0.0035	0.0044	0.0048	0.0026	0.0024	0.0007	0.0011	0.0007	0.0007	0.0004	0.0002	0.0000	0.0002	0.0000	0.0000
75-80	0.0007	0.0018	0.0015	0.0015	0.0055	0.0044	0.0031	0.0037	0.0033	0.0028	0.0020	0.0009	0.0018	0.0011	0.0011	0.0004	0.0002	0.0007	0.0002	0.0000	0.0000	0.0000
80-85	0.0011	0.0018	0.0026	0.0022	0.0037	0.0048	0.0031	0.0053	0.0033	0.0024	0.0026	0.0011	0.0009	0.0020	0.0011	0.0002	0.0002	0.0015	0.0002	0.0000	0.0000	0.0000
85-90	0.0000	0.0002	0.0020	0.0018	0.0033	0.0022	0.0020	0.0042	0.0039	0.0031	0.0033	0.0015	0.0013	0.0011	0.0007	0.0000	0.0009	0.0013	0.0000	0.0002	0.0000	0.0000
90-95	0.0002	0.0011	0.0015	0.0009	0.0035	0.0042	0.0031	0.0028	0.0024	0.0028	0.0011	0.0013	0.0007	0.0011	0.0004	0.0007	0.0007	0.0009	0.0002	0.0000	0.0000	0.0000
95-100	0.0004	0.0011	0.0015	0.0011	0.0031	0.0011	0.0022	0.0033	0.0035	0.0022	0.0007	0.0018	0.0018	0.0018	0.0022	0.0007	0.0009	0.0011	0.0002	0.0004	0.0002	0.0004

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