Best Time for College? A tale of two endowments *

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Abstract

People often delay starting college or temporarily leave college to work. To examine the welfare implication of intermittent college attendance, I incorporate flexible age-by-age college enrollment choice in a life-cycle model in general equilibrium. College serves as an investment device for the young and reduces risk for the old. Removing flexible access reduces the total welfare value of college by two-thirds. Moreover, higher wealth and better human capital preparedness at age 18 incentivize early-age degree completion. But accessing college at a later age matters more for those initially less advantaged. Thus, policies alleviating financial cost generates considerable long-term welfare improvement.

JEL classification: E2, I24, J24, J31.

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1 Introduction

Most studies examining college decisions focus on one-time enrollment or dropout in students' early twenties prior to their entering the labor market. The decision-making largely depends on the expected level and fluctuations of future earnings (e.g. Kim, 2021; Schweri, Hartog, and Wolter, 2011). However, a substantial proportion of the population delay initial entry or complete college over multiple spells while working in-between.[1] In the National Longitudinal Survey of Youth 1979 (NLSY79), for example, people access college flexibly throughout their lifetime and transition from college to work and back to college on average 1.7 times. As a result, 16% of all with a bachelor's degree complete college after age 30. Each episode of intermittent college enrollment interrupts a span of labor market activity. What additional factors are people considering while moving between work and college? What role does intermittent college education play in a life-cycle with uncertainties? In this paper, I investigate the channels behind college enrollment and completion patterns and evaluate the welfare consequence of having *flexible* access to college through one's life-cycle.

I show empirical evidence that intermittent college attendance is strongly associated with family wealth background 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 human capital and wealth endowments at age 18 to lifetime welfare, I construct an incomplete market life-cycle model in general equilibrium. The primary source of life-cycle risk comes from the idiosyncratic human capital productivity shock to working individuals, similar to Huggett, Ventura, and Yaron (2011). One main innovation is human capital acquisition: individuals can accumulate human capital through college education at any working age, in addition to learning on the job. I feed the model with the empirical distribution of individuals on wealth and human capital at age 18 and calibrate it to life-cycle schooling profiles. The model successfully replicates intermittent college attendance patterns across individuals and generates empirically relevant heterogeneous income processes.

After replicating the intermittent college patterns as well as the earnings profile, I calculate the consumption equivalence from the model as a measurement for the welfare effect of having flexible college access, a method Mukoyama (2010) outlined.[2] While most of the literature evaluates

[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).

[2] I measure the welfare of the flexible access as the consumption equivalence when restricting initial enrollment to college only at age 18 and removing subsequent re-enrollment once a person exits college. Similarly, I measure the gross welfare value of college as the consumption equivalence when removing college completely.

the financial returns of college[3], the welfare value of having access to college at each age extends beyond its financial value. When there is a relative psychic cost between schooling and working, the utility return of college does not align with its financial return (Belley and Lochner, 2007; Yang and Casner, 2021). Moreover, completing each year of college in a life-cycle setting embeds sequential consequences, such as opening doors to a new career or further educational opportunities, thereby 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 initially less advantageous people. Consumer welfare drops by nearly 16% in a counterfactual economy when agents cannot flexibly arrange their college enrollment in the life-cycle. The flexibility of college access accounts for two-thirds of the gross welfare value of college. At age 18, individuals with the lowest wealth endowment value flexible college access twice as much as those with the highest wealth endowment, although better-prepared young people with wealthier backgrounds value general access to college more. Over the life-cycle, having access to college before age 29 generates much higher welfare value, yet later college access presents a more minor but positive welfare.

I explain the heterogeneous welfare value of accessing college over the life-cycle in general equilibrium through three channels: price, investment, and risk propagation. The price channel comes from an adjustment of interest and wage rates in general equilibrium if there is a restriction on access to college. Rather than paying for tuition-related costs, individuals can accumulate more assets, raising the supply of capital. Meanwhile, restricted access to college also lowers the supply of more productive college-educated labor. As a result, the 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, the price channel accounts for nearly half of the aggregate welfare loss from restricting flexible access to college, and about one-third of the aggregate loss from removing college entirely.

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 my model, the idiosyncratic productivity shock perturbs a person's human capital.[4] To isolate the shock, I measure the investment value as the consumption equivalence of having access to each additional year of college without exogenous uncertainty. Overall, it peaks at age 19 but diminishes quickly and disappears by age 24. This

[3]Barrow and Malamud (2015) and Aina, Baici, Casalone, and Pastore (2018) provide a more recent review of studies on college decisions and returns.

[4]In comparison, most studies following Mincer (1974) and Ben-Porath (1967) examine human capital investment in a risk-free environment. Hartog and Diaz-Serrano (2015) provide a review of the literature and discuss studies modeling risk in schooling.

explains why most college enrollment concentrates on the early 20s. Early age college enrollment also favors the initially more advantageous individuals. 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 endowments. This is because of the relatively lower cost of college for wealthier individuals and the higher returns to human capital than savings returns. The initial investment value of college at age 18 is worth near 45% of lifetime consumption among individuals with the largest wealth endowment and over 35% for those with the highest human capital endowment.

The risk propagation channel considers the role that college plays in transmitting an 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. College may also reduce the cost from risk if a person chooses to attend college as a response to current and expected future shock.[5] I approximate the risk propagation 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. I find that accessing college before age 22 augments the welfare loss of risk while attending college afterward reduces it. This is because younger individuals have lower wealth and higher risk aversion, but as one ages, resources accumulate, and risk aversion reduces. As a result, 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-advantaged individuals experience a more extensive risk augmentation from college at a younger age. But having flexible access to college at a later age presents a more prominent risk reduction, especially for those with lower wealth endowment at age 18, even controlling for the initial human capital endowment.

It is worth noting that one can examine the three channels for college in a model with individuals who only choose to complete college after high school without intermittence. However, allowing for flexible access to college in the model reveals prolonged investment value after age 18 and changing lifetime risk reduction value, which explains the intermittent college enrollment and completion patterns in the data.

The three channels imply that the heterogeneity of initial wealth and human capital endowments can translate to a life-cycle welfare difference through unequal college valuation and timing

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

of 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 attendance and completion.

I extend the model to assess two policies that encourage college attendance: College Promise Program and tax incentive program. A public-funded nationwide College Promise Program offers free tuition to all college attendees. It doubles early college completion and drastically increases total college completion from the baseline of 25% to 78%. Though funding the program creates a tax burden, the tripling college completion rate raises overall welfare by 15%. A tax incentive program provides labor income tax exemption for all part-time student-workers. Compared to the College Promise Program, the tax incentive program targets later college attendance and is less generous. The overall tax burden still increases to fund the exemptions. As a result, it only increases college completion by five percentage points from the baseline level, and the welfare drops by 10%.

This paper contributes to the literature examining the causes and consequences of college over the life-cycle. The recent macro-education literature examines the value of college through finding 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). I break down college enrollment through the life-cycle and investigates the sequential decisions on each year of college and the option values they create. Rather than estimating the financial returns, this project assesses the welfare valuation of college at each age.

College is a risky investment.[6] 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, 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 life-cycle model. My approach assesses the impact of college on risk percep-

[6]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).

tion 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 life-cycle. 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 in generating 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). After controlling for the readiness, wealth background matters less in college decisions. Nevertheless, financial constraints are 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.

This paper also adds to the literature discussing means of self-insurance against life-cycle uncertainties and the sources of lifetime inequalities, facilitated by Meghir and Pistaferri (2011) and Huggett et al. (2011). Recently, Chang, Hong, and Karabarbounis (2018) and Chang, Hong, Karabarbounis, Wang, and Zhang (2022) explore the interactions of labor income and financial portfolio risks. Jang (2020) and Jung, Tran, et al. (2019) examine the role of health insurance and default choices against health shocks. Kunz and Staub (2020) and Griffy (2021) study the role of job moving against labor market risk. Traditionally, the life-cycle 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 life-cycle. 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 the discussion by examining various policies and robustness checking the results. Section 8 concludes the findings.

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 undergraduate 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% complete their degree after age 35. I link the timing and completion of college to a person's wealth and human capital endowments at age 18 and find that individuals from wealthier families or with higher human capital are more likely to complete college at a younger age.

2.1 Intermittent college education profile

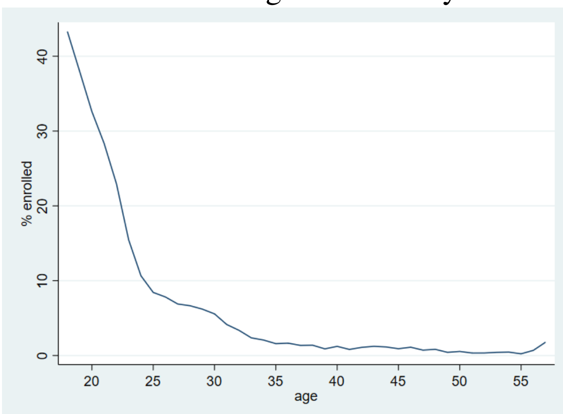
I use data from the National Longitudinal Survey of Youth 1979 (NLSY79) to summarize the life-cycle education profile. Respondents in NLSY79 have been continuously surveyed from 1979, covering an age range from 14 to 59.[7] For college enrollment, I define it as attending formal credited degree-granting college courses 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 obtains a bachelor's degree throughout the life-cycle.

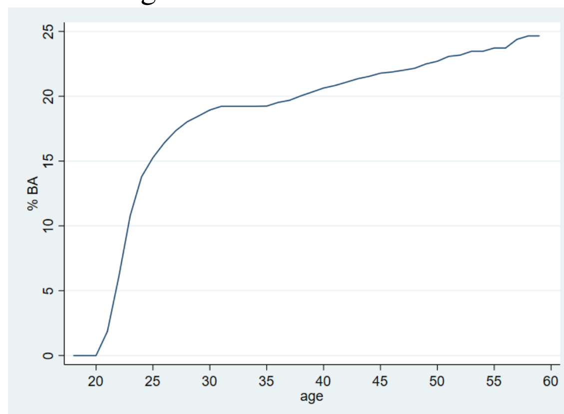
Table 1 describes respondents' college completion and the timing of completion. About 39% of the sample report to have never enrolled in college. Only 9.3% of the sample complete college by age 22. These are the individuals described by the "traditional" consensus in life-cycle human capital acquisition 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 two-thirds 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, but over 10% receive it after age 35.

[7] See Appendix A for detailed sample construction.

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 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 a 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.

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

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), and 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 20s, especially if one cohabits with parents; likewise, 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 from the 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. Studies have shown a strong positive correlation between income and family wealth (e.g. Kuhn, Schularick, and Steins, 2020). In addition, averaging net income over three years further smooths out inaccuracies of temporary income fluctuations.

For the dimensions of human capital and learning ability, I use the AFQT (Army Forces Qualification Test) score as an approximation[8]. 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, 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 proxy for human capital, though its accuracy has been criticized (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 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 two wealth bins, individuals are more likely to have a high human capital endowment. For those at the lowest two wealth bins, individuals are more likely to have

[8]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 endowment				
		23.16	25.18	21.41	16.85	13.41
Wealth endowment		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 percentage of sample in each human capital bin, measured by AFQT scores. The values on the first row reports unconditional distribution along the human capital dimension. The columns describe the percentage of the sample in each wealth bins, measured by average of net family wealth at ages 17-18-19. 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.

lower human capital endowment.

2.3 Age 18 conditions and intermittent college education

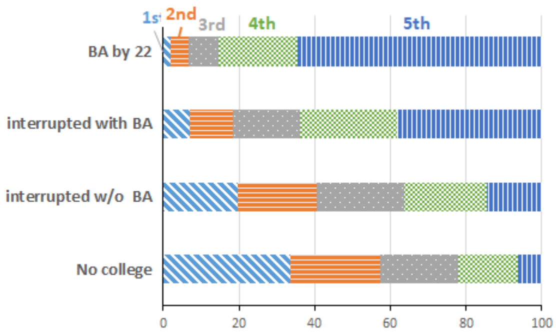
In this subsection, I provide descriptive statistics connecting age 18 endowments to the timing and completion of college. In Figure 2, I split individuals into five human capital and wealth quintiles, rather than equal-valued bins as in Table 2.[9] Panel (a) and Panel (b) describe the various patterns of college completion in relationship to age 18 human capital and wealth endowments. Individuals at the top 20% of human capital and wealth endowments are more likely to complete college by age 22. Conversely, individuals at the bottom 20% of human capital and wealth endowments 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, those with the top human capital and wealth endowments are more likely to obtain the degree at a younger age and before age 25. By contrast, those from the bottom 20% of the age 18 human capital and wealth endowments are more likely to receive the college degree after age 35.

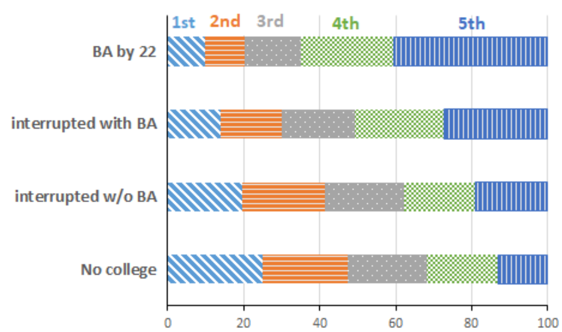
These patterns describe the correlation of intermittent college education with age 18 wealth and human capital endowments. In the next section, I construct a life-cycle model in general equilibrium to examine the theoretical channels of how age 18 endowments translate to college education choices and their welfare implications.

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

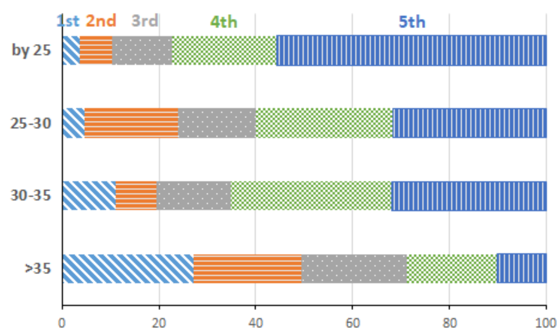
Figure 2: Initial conditions and patterns of intermittent college



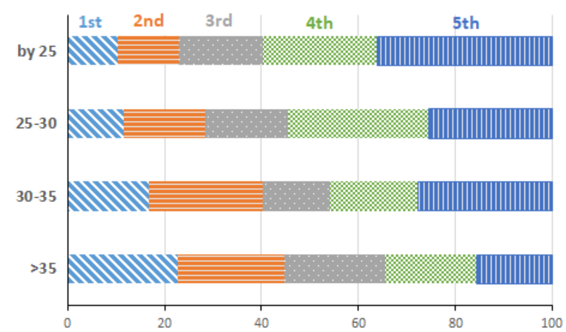
(a) Age 18 human capital and college completion



(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 that the percentage 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). For example, in Panel (a), the dark blue vertical striped bar marked as 5th in BA by 22 means that over 60% of all who completed BA by age 22 come from the 5th quintile of the human capital endowment. Panel (c) and Panel (d) show the percentage of the sample in each college degree completion category from each quintile, with the following categories: 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%

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 for a total of 67 years. One representative firm hires effective units of labor and rents capital from individuals to produce a single output.

3.1 Individuals' problem

Every period, Ω of new individuals enter the model, and Ω exit. I normalize the total population to be 1. Therefore, Ω assigns value 1/67. Individuals maximize expected lifetime utility, given initial financial wealth s_0 and initial human capital h_0.

Table 3 describes the timeline for individuals' life-cycle labor status decisions. From the age of 19 to 65, each individual chooses one of the four discrete decisions e: working full time *emp*, 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 yr. The maximum number of full time education years after high school is set to be 4. Together, individuals are heterogeneous in the idiosyncratic states: $\phi \equiv \{h, s, yr, e, age\}$.[10]

Based on their decisions, individuals evolve on each dimension of the idiosyncratic states every period. We have an endogenous aggregate state μ, which is a probability measure of individuals on each idiosyncratic state.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 $\{h, s, age\}$.

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 life-cycle comes from human capital accumulation shock, ε, which 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

[10] One potential challenge for the project is that it abstracts away from many demographic dimensions of heterogeneity, such as race, gender, geographical locations, industry, etc. With the key question in examining the school option in a general equilibrium framework, the computation capacity leads to the sacrifice of many refined dimensions. As a second-best, I do not exclude observations on these differences in the calibration, as suggested by Borella, De Nardi, and Yang (2018). The calibrated idiosyncratic human capital shock and the psychic cost of schooling help absorb many demographic differences and better reproduce aggregate moments.

decisions before retirement ($age \leq 47$). Individuals maximize lifetime value V by choosing e given the beginning of the period states. V^{emp}, V^{pt}, V^{sch}, and V^{nonemp} describe the values for one's choice of $e = [emp, pt, sch, nonemp]$.

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

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 wages paid to the efficient units of labor h and interest income rs if holding positive wealth (or interest payment if holding negative wealth). Every period, employed individuals pay social security tax at rate τ and lump sum income tax Υ. If one needs to borrow, the person may borrow a non-defaultable bond 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 person's life-cycle. If a person's natural debt limit is more strict than the economy-wide limit, the borrowing follows the person's natural debt limit. Regardless of working status or age, everyone receives an equal lump-sum profit rebate from firms, Π.

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

If an individual decides to go to college 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 college. 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 if having negative savings) 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 $\Delta(yr)$, a function based on years of education. It is also subject to the learning curvature a.

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

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 college 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.

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

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 for leisure (normalized to zero compared to disutility from school and working). However, the human capital depreciates deterministically by the rate δ_h 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 college. The distribution of individuals 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.

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

Standard concave utility qualities apply. In particular, $V^{emp}, V^{pt}, V^{sch}, V^{nonemp}$ 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

A representative firm employs efficient units of labor and rents capital for final goods production as in Equation (7). Capital K^d comes from individuals' savings s. Capital depreciates at a rate of δ.

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

The markets operate competitively. Given the constant returns to scale production technology, firms pay prices at the 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, and E be the space for employment-schooling status. Let ϕ_{age} be the idiosyncratic state variables for individuals $\{h, s, yr, e\}$ at a given age, and μ and μ_{re} be the distribution of all individuals before retirement and after retirement in idiosyncratic states. A stationary recursive competitive equilibrium is a collection of factor prices $w(\mu, \mu_{re})$, $r(\mu, \mu_{re})$, individuals' decision rules $s_{age+1}(\phi_{age}, \mu, \mu_{re})$, $h_{age+1}(\phi_{age}, \mu, \mu_{re})$, $e_{age}(\phi_{age}, \mu, \mu_{re})$, $c_{age}(\phi_{age}, \mu, \mu_{re})$, $yr_{age}(\phi_{age}, \mu, \mu_{re})$, and value function $V_{age}(\phi_{age}, \mu, \mu_{re})$ 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 have:

$$L^s = \sum_{age=1}^{47} \sum_{yr=0}^{4} \int_H \int_S ((h_{age,e,yr,s,h} I_{\{e=emp\}}) + \frac{1}{2}(h_{age,e,yr,s,h} I_{\{e=pt\}}))\mu(age, e, yr, h, s)dsdh$$

4. Aggregate savings have:

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

5. Aggregate consumption has:

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

6. Aggregate tuition cost has:

$$Tuition = \sum_{age=1}^{47} \sum_{yr=0}^{4} \int_H \int_S (\kappa I_{\{e_{age,e,yr,s,h}=sch\}} + \frac{1}{2}\kappa I_{\{e_{age,e,yr,s,h}=pt\}})\mu(age, e, yr, h, s)dsdh$$

7. Market clearing requires:

$$L^s = L^d$$

$$K^s = K^d$$

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

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

9. Individual decision rules are consistent with the aggregate law of motion, 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 describes 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 4, or jointly determined by minimizing the distance between model-generated moments and targeted statistics, as listed the top panel of Table 4 and in Table C.1. 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 describes 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 life-cycle 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 life-cycle 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.[11]

For the initial wealth dimension, I first split the proxy for family wealth described in Section 2.2 into 20 equal-valued 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 four equally spaced sub-groups. The first three sub-groups account for 17.57% of the sample. When fitting

[11]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.

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 and 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.[12] Same as the fitting 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 in section Appendix B 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 minimize the distance between model generated and data moments. The lower portion of Table 4 lists five parameters chosen externally. The first two relate to the tax system, in which the government imposes a social security tax on all working individuals before the retirement age of 65 and transfers an 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 ($B(h) = \omega \bar{wh}$). It transfers $\omega = 40\%$ of an individual's end of working-age income $\bar{hw}$, allowing the heterogeneity of income persisting into retirement. I set the production function as $Y = L^{\alpha}K^{(1-\alpha)}$. The third parameter, α governs the labor share of income, set as 0.64.

I parameterize the utility function as a summation of three portions: consumption, labor-leisure, and college psychic cost. 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).

The rest of the parameters are jointly calibrated to minimize the distance between empirical 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

[12]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.

Table 4: 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	college learning pre BA	some college premium	1.03	1.03
Δ_2	1.4305	college learning by BA	college premium	1.06	1.04
δ_h	0.0375	human capital depreciation	mean unemp wage loss	0.04	0.05
κ	1.0944	college 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 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.

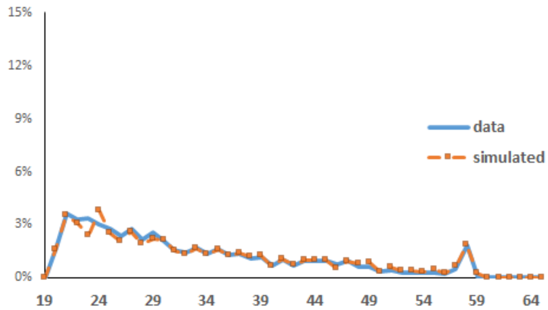
as $disu_{sch}(h, age, e, yr, ft) = n_{sch}(dis(e, age, yr) - h)$.[13] $n_{sch} = 1$ is for full-time college schooling and $n_{sch} = 0.5$ for part-time schooling. The psychic cost is relative to the size of human capital, h, that the person already has, following the self-productive nature of learning[14]. Human capital investment is time-sensitive. Whether it is through learning on the job or college, 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 college than one currently away from school.[15] Lastly, if one is near completing a degree, the student may find a different psychological challenge than at the beginning of college. Therefore, I model $dis(e, age, yr)$ to represent a set

[13]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.

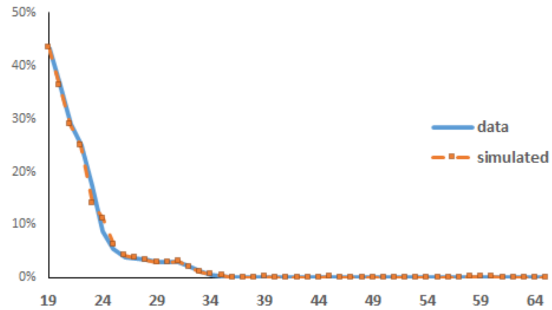
[14]See for example Macdonald (1981), Card (1994), Card (2001), Johnson (2013), Hai and Heckman (2017), Guo (2018), Abbott et al. (2019), and Cunha et al. (2006). The higher the human capital, the easier it is to gain more via education.

[15]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.

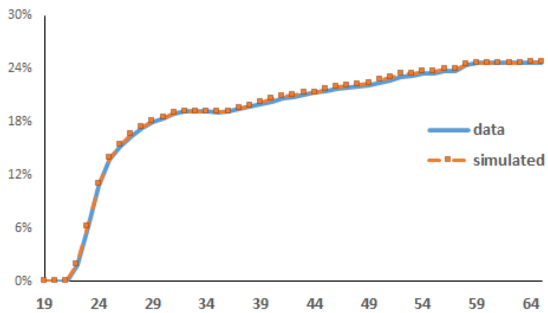
Figure 3: Life-cycle enrollment and degree attainment: data and model moments



(a) new enrollment by age



(b) continuous enrollment by age



(c) completed BA by age

Notes: This figure compares model simulated life-cycle 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 percentage of the sample at each age newly enrolling in college. Panel (b) reports the percentage of the sample at each age continuously enrolling in college (including full time and part time enrollments). Panel (c) reports the percentage of the sample at each age with a bachelor's degree.

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 C.1 in section Appendix C. These parameters are calibrated to target the new and continuing college enrollment and BA attainment statistics at each age as shown in Figure 3.[16]

The rest of the calibrated parameters and their most relevant moments are reported in Table 4. 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.

Human capital can move along three trajectories: accumulating on the job (or, loosely speaking, "learning" on the job), learning in college, and depreciating while enjoying full-time leisure.

[16]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.

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[17]. Models following Huggett et al. (2011) use a separate continuous time choice devoted to learning (e.g. Griffy, 2021). The core of human capital production in this model is deterministic, depending on employment status. Parameter A governs the rate of return to learning on the job; Δ's govern the efficiency of college 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 the human capital return 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 the 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_h is used to identify the average depreciation rate of 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).

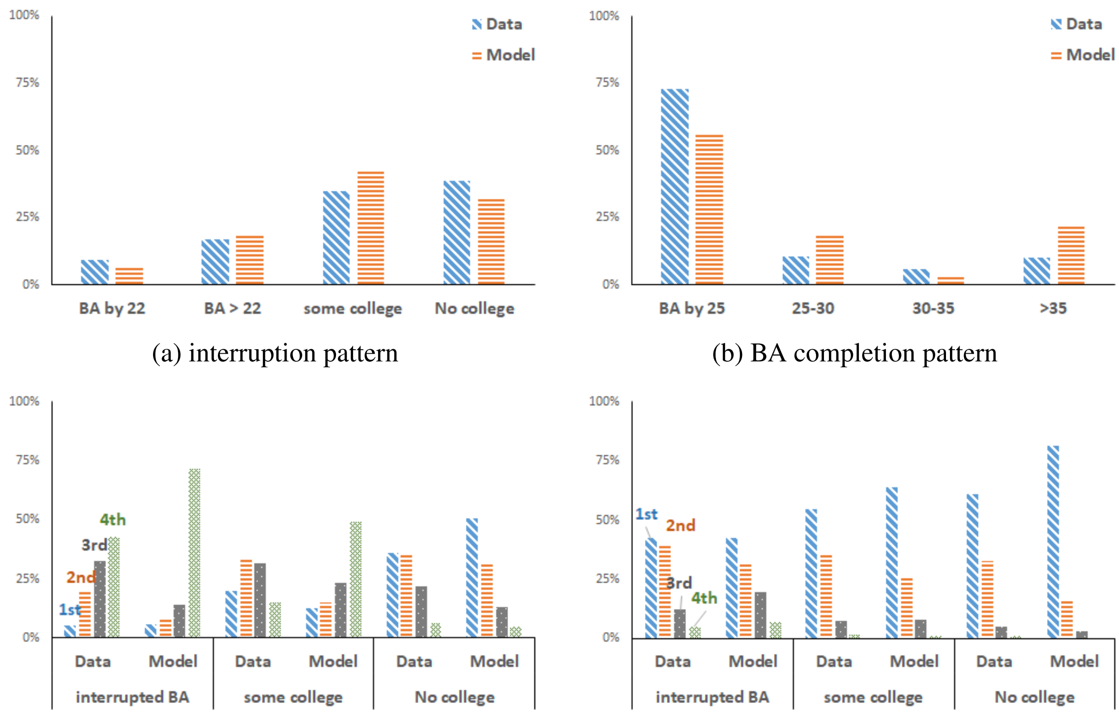
Lastly, β calibrates to the annual risk-free interest rate of 0.04, and δ calibrates to the capital-output ratio of 3.23 estimated by Fernandez-Villaverde, Krueger, et al. (2011). The earnings shock, ε, serves as the primary source of life-cycle uncertainty. Similar to Huggett et al. (2011), ε follows an *iid* process across time and individuals, and it describes the risk that affects human capital production on the job. Huggett (1993) calibrates $ln\varepsilon$ 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 and 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 the data and the model simulation. Panel (a) compares college interruption patterns, and Panel (b) compares ages of individuals completing a bachelor's degree. The model generates similar patterns compared to the data. Panel (c) and Panel (d) further compare the relationship between age 18 human capital and wealth conditions

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

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 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 a bachelor's degree who completes the degree within each age range. Panel (c) plots the percentage of the sample in each interruption pattern that comes from each of initial human capital bin. Panel (d) plots the percentage of each interruption pattern that comes from each initial wealth bin.

to college interruption patterns. I split the initial conditions into four equal-valued bins. The patterns to compare are individuals who obtain the BA after some interruptions, individuals with some college experience but not completing the degree, and those without college experience at all. Both the data and model show that those with higher human capital endowment are more likely to complete a BA and less likely not to have college experience. Similarly, ones with higher wealth endowment 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 the 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 vital to validate the baseline model generated heterogeneous life-cycle earnings dynamics with an empirical estimation. 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 life-cycle earnings:

$$y^i_{h,t} = g(\theta_t, X^i_{h,t}) + f(\alpha^i, \beta^i, X^i_{h,t}) + z^i_{h,t} + \varepsilon^i_{h,t}$$
$$z^i_{h,t} = \rho z^i_{h-1,t-1} + \eta^i_{h,t},\ z^i_{0,t} = 0$$

where $\{i,h,t\}$ describes individual, age, and time; $\{\rho, \sigma^2_\alpha, \sigma^2_\beta, \sigma^2_\eta, \sigma^2_\varepsilon, corr_{\alpha\beta}\}$ describe persistence, variances and co-variances of the earnings process. $g(\theta_t, X^i_{h,t})$ describes the common 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; $\varepsilon^i_{h,t}$ 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 the age to earnings equation and examine the residual process. I use a minimum distance estimation to find the parameters of the income process. Compared to HIP, RIP removes individual slope differences β. Table 5 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. This result adds to Chang et al. (2018) by introducing repeated lumpy human capital investment decisions that create age- and path-dependent lifecycle risk and portfolio choices.

Table 5: 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 simulating the baseline model 50,000 times and fitting 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 aggregate variables between the baseline economy and the counterfactuals restricting college access in general equilibrium. I measure the welfare value using each person's lifetime consumption equivalence between the baseline and the counterfactual economies, and aggregate using the average of individuals' welfare measure as outlined by Mukoyama (2010). A negative consumption equivalence means households prefer the original model, while a positive value means households prefer the counterfactual model. A negative value is interpreted as the percentage of original consumption that households are willing to give up to keep the original setting. A positive value is interpreted as the percentage of original consumption that households need to be compensated to maintain the original setting. Then, I inspect the heterogeneous impact of having access to college on people with different endowments at age 18.

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 6. The first column reports the baseline values. The second column reports the percentage 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 6: Aggregate effect of college

	Baseline (1)	No flexible access (2)	No college (3)
BA attainment/population	0.25	-28.48%	
employment/population	0.61	4.02%	-1.06%
Y	6.00	0.41%	5.64%
K/Y	3.23	0.02%	0.41%
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 the 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 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) of 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 degree attainment by 28%. More people are working, and more assets are saved 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%. The consumption equivalence reduces by 16%, indicating that flexible college access embeds 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%). Consequently, output, capital, and consumption increase more. However, consumer welfare decreases by nearly 24%, representing the gross welfare value of college.

Overall, Table 6 shows a difference in enrollment and degree attainment responses suggesting the importance of separating an intensive margin, as college enrollment, from an extensive margin, as college degree completion. Moreover, college has a significant impact on consumer welfare for the aggregate economy. When comparing the consumption equivalence between Columns (2) and (3), flexible college access accounts for 66% of the gross welfare value of college.

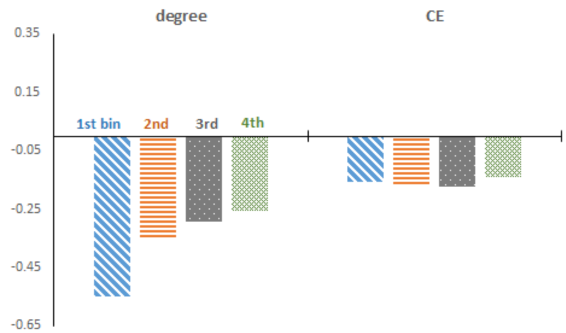
5.2 Heterogeneous impact of access to college

Empirical evidence suggests a connection of initial endowments with college patterns. In this subsection, I examine the heterogeneous value of flexible access to college on individuals with different initial conditions and the alternative heterogeneous behaviors 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 degree attainment and welfare for each bin after restricting college access.

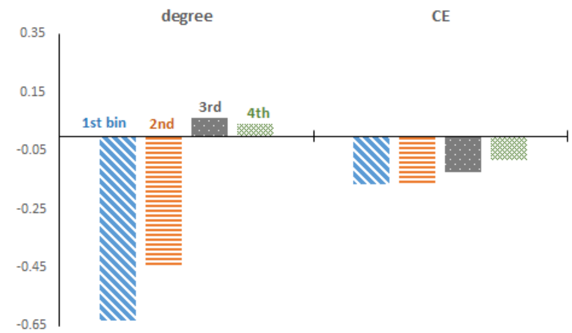
The first row in Figure 5 compares the baseline values to the counterfactual model of removing flexible access to college. Panel (a) examines the changes in degree attainment and consumption equivalence along the initial human capital margins, and Panel (b) examines the changes along the initial wealth margin.

People with higher human capital endowment 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 completion. About 60% of those from the lowest bin can no longer complete their degree without flexible access to college. This shows that individuals with the highest wealth or human capital endowment are

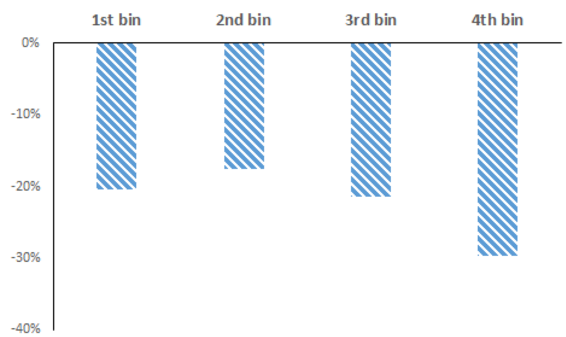
Figure 5: Heterogeneous impact of flexible college access and gross welfare value of college



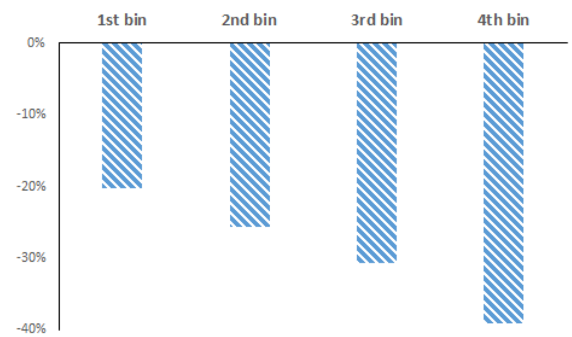
(a) impact of flexible access - initial human capital



(b) impact of flexible access - initial wealth



(c) Consump. equivalence of college - initial human capital



(d) Consump. equivalence of college - initial wealth

Notes: The first row reports the change of values compared to the 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. Initial human capital is split into four equal-valued bins. The first bin has the lowest value and the fourth bin has the highest value. The changes examined are 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).

less affected by flexible access to college. Those with the lowest initial human capital values rely heavily on later and flexible access to college.

Everyone suffers from reduced welfare in terms of consumption equivalence when removing flexible access to college. Those from lower wealth bins pay a higher welfare cost, similar to those from the middle human capital bins. Individuals 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. Comparatively, those from lower wealth or human capital bins generally suffer from less severe welfare loss, except those from the lowest human capital bin encountering a comparable loss from the third human capital bin.

The nearly reverse welfare effect between the top and bottom panels of Figure 5 suggests that people with higher initial wealth and human capital endowment 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. 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 the human capital accumulation and risk perception change due to attending college. Finally, I focus on the heterogeneity of initial endowments while studying investment and risk propagation channels.

6.1 General equilibrium price channel

Table 6 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 7 the difference of aggregate variables when restricting college access with the baseline prices and with the new general equilibrium prices.

Columns (1) - (3) in Table 7 present the change of aggregate variables after removing flexible access to college. Overall, the majority of the decrease in degree completion in Table 6 Column (2) comes from Column (1) in Table 7. 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 a 32% reduction in degree completion, and consumer welfare reduces by 8.8%. In Column (2), I relax only the wage rate to the general equilibrium level (about 0.24% higher than the baseline level) when there is no flexible access to college. The interest rate remains at the baseline level. All values in Column (2) compare to the levels in the Column (1) experiment. A higher wage rate leads to a higher return to human capital investment, inducing a slight increase in college activities than in Column (1) (0.42% increase in degree attainment). But 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) compare to Column (2) experiment levels.[18] 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, degree completion continue to increase by 5% 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 reduces consumer welfare by 7.6% from Column (2). Comparing with the welfare change in Column (1), the welfare change due to price adjustments from Columns (2) and (3) explains over half of the 15.7% total welfare reduction in Table 6 when restricting flexible access to college.

I conduct a similar comparison in the last three columns in Table 7 to isolate the price channel that leads to the general equilibrium results in Column (3) of Table 6 when completely removing college from the baseline model. In Column (4) of Table 7, the college option explains 16% of the consumer welfare drop from the baseline mode, holding all prices fixed. When relaxing the wage rate to the new general equilibrium with no college in Column (5) (a 0.27% increase from the baseline wage rate), consumer welfare increases by 2% from Column (4). After relaxing the interest rate in Column (6) (with 1.4% reduction in interest rate), consumer welfare drops by 11% from Column (5). Comparing the welfare change in Columns (5) and (6) to the 23.9% gross welfare value of college in Table 6, the price channel accounts for about one-third of the gross welfare value of college.

Altogether, Table 7 shows that the price channel from the 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 gross welfare measure of college and about half of the welfare value of flexible college access. The following section explores the channels that

[18]Note that Column (3) values in Table 7 are different from Column (2) Table 6. This is because Column (2) Table 6 reports the comparison between values in GE with no flexible college access to values in the baseline level. Same difference holds between Column (6) in Table 7 and Column (3) in Table 6.

Table 7: Aggregate effect of college from partial to general equilibrium

	No flexible access			No college		
	fixed r & w (1)	fixed r (2)	GE (3)	fixed r & w (4)	fixed r (5)	GE (6)
BA attainment/pop.	-31.87%	0.42%	4.54%			
employment/pop.	4.15%	-0.07%	-0.05%	-0.23%	-0.07%	-0.76%
Y	-0.84%	0.06%	1.20%	3.09%	0.03%	2.45%
K/Y	-1.14%	-0.24%	1.42%	-1.98%	-0.37%	2.81%
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%

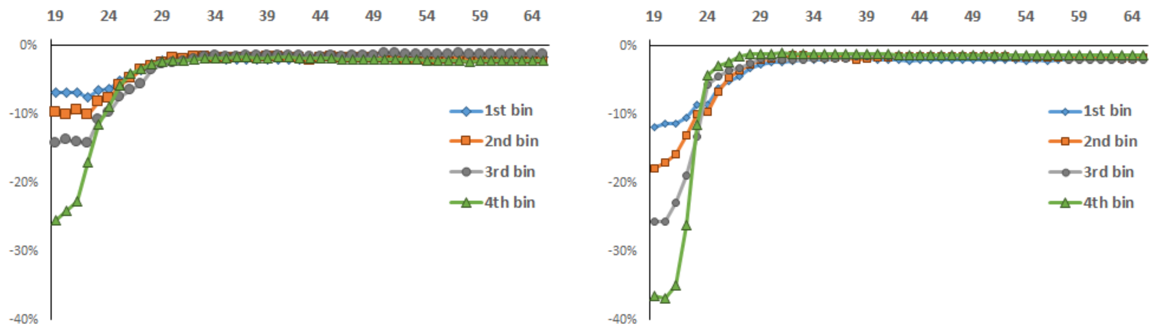
Notes: Columns (1) - (3) present the change of aggregate variables after shutting down flexible access to college. Individuals do not have access to college if they do not enroll at age 19, or leave college at any point. Column (1) keeps the interest and wage rates at the baseline level. It reports the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

explain the remaining adjustment and welfare through life-cycle 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 life-cycle risk (e.g. Meghir and Pistaferri, 2011; Barrow and Malamud, 2015). Yang and Casner (2021) provide a theoretical account of how labor market risk and college returns transmit to the enrollment decision. In this section, I start by estimating the gross value of college for each age through one's life-cycle. Then, I decompose this 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 endowments. The findings explain the heterogeneity in college enrollment and completion patterns.

Figure 6: Heterogeneous gross value of college by age



(a) bins by initial human capital

(b) bins 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 having access to 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 individuals are willing to sacrifice the value from the baseline level consumption in order to keep access to college at that 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).

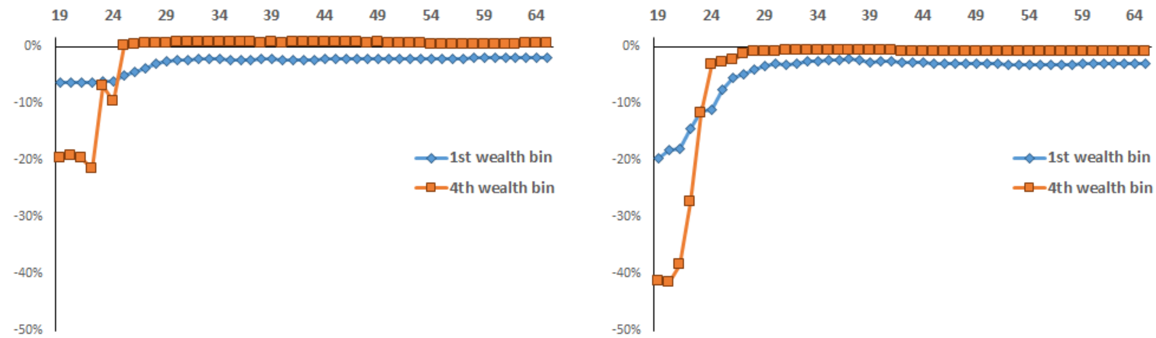
6.2.1 Gross value of college

I present the gross value of college for each age by the initial conditions in Figure 6. It is measured by the lifetime 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 having one additional year of college access.

Panel (a) presents the gross value of college for people in each initial human capital endowment bin, and Panel (b) presents the gross value of college for each initial wealth endowment bin. Across all human capital and wealth bins, the value of college reaches its peak near age 20 and diminishes quickly until age 29. It maintains at a relatively constant near-zero level afterward. This corresponds to Figure 3 where the majority of college enrollment and completion happens before age 30. Individuals with higher initial human capital or wealth have a higher gross value of college at age 19, and 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 at the starting age, and it also decreases slower than the rate at the top endowment bins.

Figure 7 decomposes the interaction between wealth and human capital. For Panel (a), I examine the impact of initial wealth on college valuation for all with the lowest initial human capital. Having access to 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

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 having access to 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 access to college at that 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 diamonds plots those also in the first wealth bin and the red line with squares those in the fourth initial wealth bin.

if they are from the fourth wealth bin. Interestingly, their valuation of college quickly disappears after age 24. The same pattern persists 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. In summary, higher initial wealth raises early age valuation and lowers later age valuation of college. Higher initial human capital increases the valuation of college throughout life-cycle.

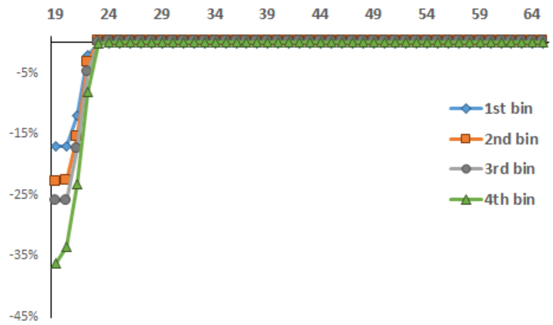
6.2.2 Investment value of college

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 shock ε in the model. After removing ε from the baseline model, the remaining welfare value from college comes from human capital production at college, not perturbed by exogenous factors.[19]

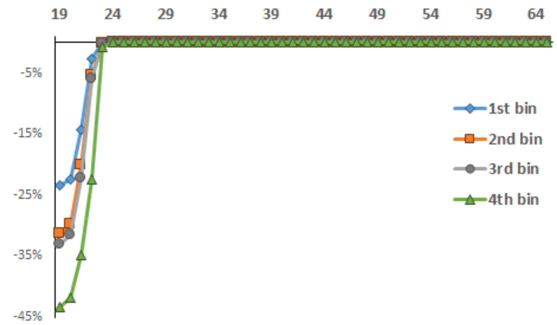
The investment value of college largely mimics the gross value in Figure 6. Individuals with the highest human capital or wealth endowment have the highest investment value. This is because human capital production is multiplicative. The higher human capital, the easier it reproduces, corresponding to the self-productive and dynamically complementary qualities described by Cunha

[19]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 8: Heterogeneous investment value of college by age



(a) bins by initial human capital



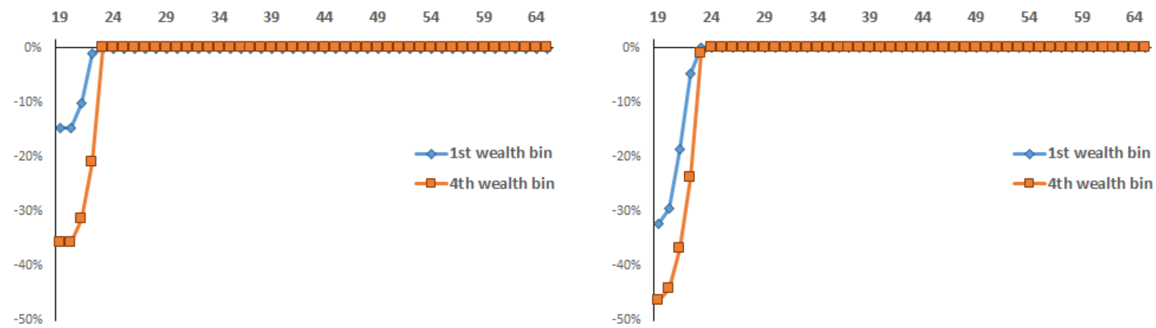
(b) bins by initial family wealth

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 having access to college at age 19 is measured by comparing a model with no school and 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 access to college at that 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).

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 of college may be outweighed by its cost (e.g. Becker, 1975). Hence life-cycle models often consider college only in the first model stage before engaging in the labor market with no-repeat afterward (e.g. Heathcote, 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 human capital endowment. This is because college tuition as a fixed direct cost consists of a smaller share as the wealth endowment increases. However, the lifetime return to human capital dominates the savings return. Panel (a) shows the difference in investment value by wealth for individuals 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 to Panel (a), although the difference in investment value between the first and fourth wealth bins is much smaller in Panel (b). Overall, individuals from higher initial wealth and human capital bins have a higher investment value of college. After age 24, the investment value disappears for everyone.

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



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

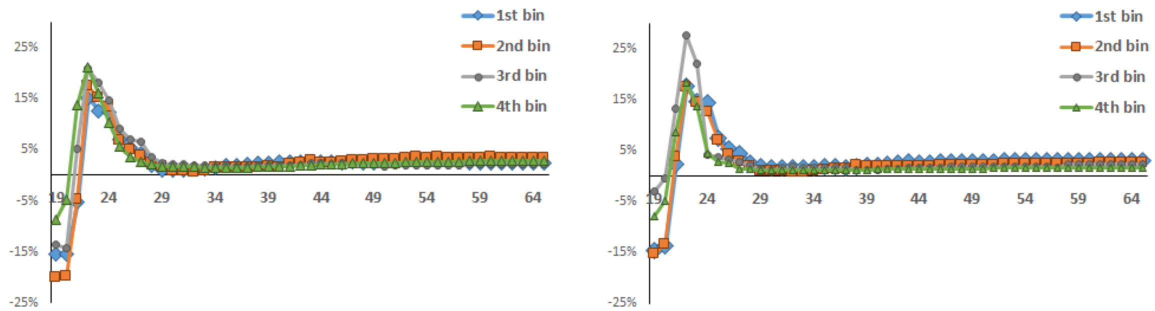
Notes: The plots present the consumption equivalence of removing each year of college in an environment with no exogenous uncertainty, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of having access to college at age 19 is measured by comparing a model with no school and no risk, to 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 that 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 diamonds plots those in the first wealth bin and the red line with squares for those in the fourth initial wealth bin.

6.2.3 Risk propagation value of college

The difference between the gross value of college and the investment value suggests that risk alters the welfare value of college, an aspect largely omitted by the literature. Without considering 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 life-cycle 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 college. I first measure the risk valuation in models with no college. This is calculated by using the consumption equivalence from a model with risk to a model without risk for each age, and both models have no access to college. I then repeat the calculation for risk valuation but between two models with access to college. The difference between the two risk valuations reflects the role of college in a 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 valuations 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 college.

Figure 10 shows the life-cycle 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, resulting in a risk reduction value between age 22 and 29. After age 29, college provides a small

Figure 10: Heterogeneous risk propagation of college by age



(a) bins by initial human capital (b) bins 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 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.

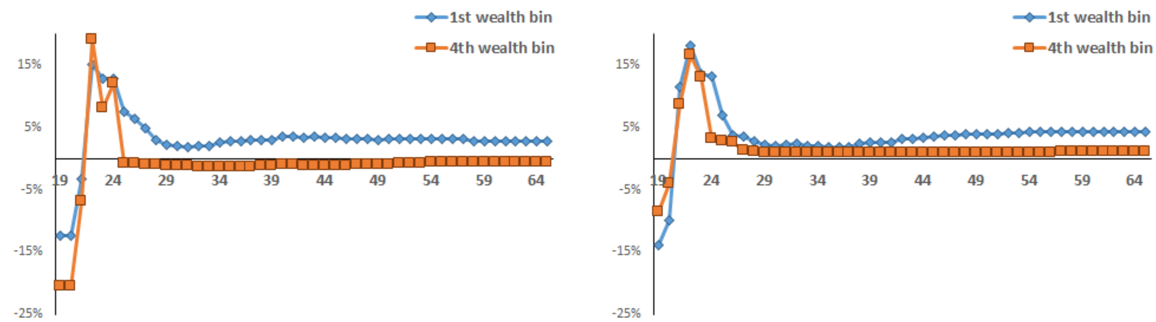
but persistent effect in alleviating the welfare cost of risk. For younger people, the lower the human capital or wealth endowments, the more substantial the college-amplified risk. For older people, college reduces risk loss more for those with larger initial endowments.

After the age where the investment value of attending college in Figure 8 disappears, the emergence of the risk reduction quality of college explains the importance of welfare gain associated with having flexible access to college shown in Table 6 and the later age college enrollment in Figure 1.

Figure 11 isolates the interactions of initial endowments in the risk propagation value of college. 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 individuals are in the first human capital bin (Panel (a)) and amplifies it less for those in 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 from 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.

Figure 11: Risk propagation 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 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 diamonds plots those also in the first wealth bin and the red line with squares those in the fourth initial wealth bin.

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 the average weighting as 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 endowment 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 wealth, and the present value of lifetime consumption. The regression results are reported in Table 8. 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 their inverse value so that the explanation of the regression coefficient is consistent with the direction of the risk reduction of college. I also standardize all coefficients to the distribution of each variable for ease of explanation.

Table 8 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 endowment 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

Table 8: Initial endowments and college value

	Gross value	Investment value	Risk reduction value
human capital endowment	0.316***	0.760***	0.111***
wealth endowment	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.

shows that when considering the policy implication of initial background, though more minor, the wealth endowment plays a vital role in the risk reduction consideration of college in a risky environment.

Table 9: 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

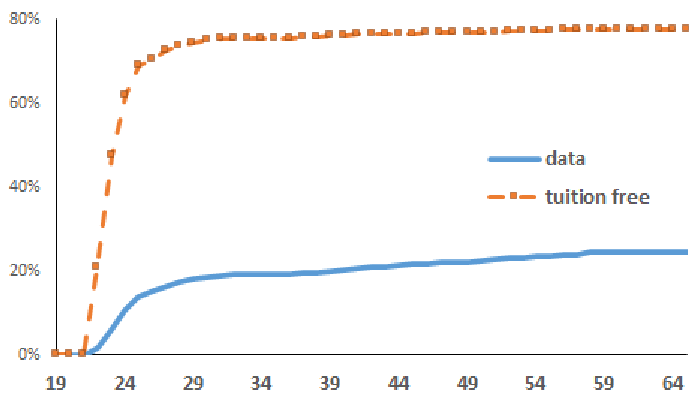
Notes: This table reports the standardized coefficient for each regression. The first two regressions run on a simulation of 50,000 individuals from the baseline model. The last regression runs on a subsample of all with a college degree from the simulated sample. The gross value, investment value and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

Next, I conduct regression analyses linking the investment value and risk reduction value of college for individuals at age 19 to the college intermittence pattern. Table 9 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. A one standard deviation increase of investment value leads to a 0.51 standard deviation increase of college enrollment. Both investment and risk reduction values have comparable contributions to college completion (near 0.41 standard deviation increase from either value). Investment value also largely contributes to the earlier age 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 a 0.05 standard deviation.

In conclusion, initial human capital and wealth endowments play an important role in college valuation. A more substantial college investment or risk reduction value increases college

Figure 12: Life-cycle degree attainment: data vs tuition free program



Notes: This figure compares data moments to model simulated life-cycle college degree completion when college attendees receive free tuition and education cost is funded by public tax revenue. The blue hard line reports data values, and the red dotted line reports model simulated moments.

enrollment, attainment, and early completion. Therefore, policies aiming at improving college attainment should consider the role both endowments play.

7 Extension discussions

7.1 Policy evaluation: College Promise Programs

Growing empirical studies have examined the place-based College Promise Programs that offer tuition coverage to students from certain locations, such as Kalamazoo Promise (Bartik, Hershbein, and Lachowska, 2021), Georgia Hope (Singell Jr, Waddell, and Curs, 2006), Tennessee Promise (Nguyen, 2020), Pittsburgh Promise and Denver Scholarship (LeGower and Walsh, 2017), etc. Lavy (2021) shows heterogeneous positive long-term gains by gender from a free school program. Miller-Adams (2021) summarizes the literature on various College Promise Programs and argues that they support college attendance and completion and have positive spillover to the implementation region.

In this section, I extend the place-based tuition-free College Promise Program nationwide. While many place-based programs are funded by private entities and charitable foundations, I experiment with a nationwide public-funded tuition-free program. In my model, all college attendees receive a tuition-free voucher with the value of κ, the baseline model college cost. The total college cost is calculated as the sum of all vouchers redeemed in the economy. Though individual students do not pay for college, the government pays the aggregate tuition cost through its tax revenue.

Figure 12 shows that the tuition-free program drastically increases the college completion rate from a young age. About 89% of degree holders complete college before age 25, compared to the data of 56%. Although it removes the direct financial cost, attending college still bears opportunity and utility costs. About 22% of the population still do not have a college degree.

Table 10: Impact of nationwide public funded tuition free program

	Baseline (1)	Tuition free (2)
BA attainment/pop.	0.25	212.79%
employment/pop.	0.61	-2.87%
Y	6.00	-0.86%
K/Y	3.23	0.85%
C/Y	0.76	0.63%
Consumption equivalence		14.82%

Notes: The first column reports the baseline values. The second column reports the change of values from the baseline model, when college attendees receive free tuition and the government pays total tuition cost through balancing budget.

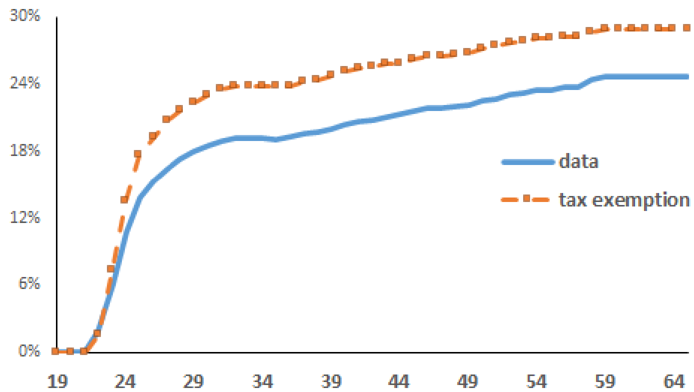
Table 10 describes the aggregate impact of the tuition-free program. The percentage of college degree holders increase from 25% to 78%. The employment to population ratio decreases by 2.9%. However, output only reduces by 0.86%, while the capital-output and consumption-output ratios increase by 0.85% and 0.63%. This is because individuals save less for tuition and generally have higher take-home labor income because of college completion and skill upgrading from a young age. Though college is funded by public tax revenue, which raises the lump-sum tax by 8%, the nationwide tuition-free College Promise Program brings a nearly 15% welfare increase in general equilibrium.

7.2 Policy evaluation: Tax incentive

Previous sections establish that having flexible access to college creates important welfare values for the aggregate economy, especially for initially less advantaged individuals. In this subsection, I conduct a fiscal policy by granting labor income tax exemption to all workers who attend college part-time. This is an implementable and targeted transfer policy that incentivizes college attendance, especially for those who value flexible college access.

Figure 13 compares the college completion rate over the life-cycle between data and the counterfactual model where part-time student-workers do not pay labor income tax. The total college completion rate increases from 25% to 29%. For individuals younger than age 24, the tax exemption policy does not significantly impact college completion. This is because they are primarily full-time students with financial resources. However, the policy vastly increases college completion for people between the age of 24 and 30. Figure 2 shows that individuals completing college at a later are likely from initially less advantaged human capital and/or family financial backgrounds.

Figure 13: Life-cycle degree attainment: data and tax exemption



Notes: This figure compares data to model simulated life-cycle college degree completion when exempt labor income tax for part time students. The blue hard line reports data values, and the red dotted line reports model simulated moments.

The tax-exempt policy specifically targets less initially advantageous individuals and advances college completion for those otherwise delaying college further.

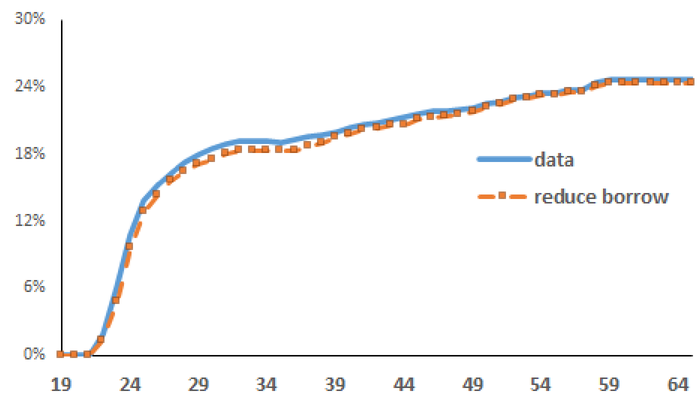
Table 11 provides the aggregate implications for the tax exemption policy. As the policy provides partial financial relief to initially less advantaged individuals for part-time college access, it raises degree completion by 17%, a less drastic increase than the tuition-free program in Table 10. Since the government still needs to balance the budget, the tax exemption is covered by the rise in lump-sum tax by 2%. This results in a slight increase in output and a decline in consumption-output and capital-output ratios. The tax exemption policy benefits a much smaller population than the tuition-free policy but increases the overall tax burden. Therefore, the economy incurs a 10% welfare loss in general equilibrium.

Table 11: Impact of tax exemption for part time students

	Baseline	tax exemption
	(1)	(2)
BA attainment/pop.	0.25	16.54%
employment/pop.	0.61	0.77%
Y	6.00	0.09%
K/Y	3.23	-0.38%
C/Y	0.76	-0.16%
Consumption equivalence		-10.41%

Notes: The first column reports the baseline values. The second column reports the change of values compared to the baseline model, from a model where I remove labor income tax for workers who are also part time students.

Figure 14: Life-cycle degree attainment: data and restricted borrowing



Notes: This figure compares model simulated life-cycle college degree completion when reducing borrowing limit to 85% of the natural limit to data moments. The blue hard line reports data values, and the red dotted line reports model simulated moments.

7.3 Robustness: Borrowing limit

This paper examines the impact of college education decision away from corner solution, while much of the literature focus on the marginal effect of the borrowing constraint (e.g., Hai and Heckman, 2017; Johnson, 2013; Ozdagli and Trachter, 2011; Rothstein and Rouse, 2011; Stinebrickner and Stinebrickner, 2008). This subsection provides a robustness check for the model when restricting the borrowing limit. The baseline model assumes a natural debt limit. I reduce borrowing to 85% of the natural limit in the restricted borrowing exercise. This raises the economy-wide negative asset holding from 18% at baseline to 20%.

Overall, the borrowing limit does not significantly impact the education and aggregate variables in my model. Figure 14 plots the college degree attainment over the lifecycle. With a tight borrowing limit, the optimal degree completion at each age does not have an observant difference from the data moments, which the baseline model in Figure 3 replicates. Moreover, Table 12 reports the aggregate moments between the baseline model and the model with restricted borrowing. Tightening borrowing constraints directly impacts capital accumulation, which leads to large responses in the interest rate and capital-output ratio. With more difficult access to the financial resource, total college completion reduces by 2%. This estimation follows the estimation in the literature on the impact of borrowing and student loan limits (e.g., Abbott et al., 2019; Hai and Heckman, 2017).

7.4 Robustness: Schooling uncertainty

An extensive literature documents the various sources of risk embedded in college education (e.g., Bound, Lovenheim, and Turner, 2010; Light and Strayer, 2000; Stinebrickner and Stinebrickner,

Table 12: Robustness check: impact of borrowing constraint

	Baseline (1)	Restricted borrowing (2)
BA attainment/pop.	0.25	-2.12%
employment/pop.	0.61	-0.49%
Y	6.00	-0.34%
K/Y	3.23	-1.41%
C/Y	0.76	-0.02%
w	1.24	-0.41%
r	0.04	2.16%

Notes: The first column reports the baseline values. The second column reports the change of values from the baseline model, when I reduce borrowing limit to 85% of the natural debt limit.

2012, 2014). Compared to labor market risk, Yang and Casner (2021) argue that the relative risk between school and work matters. In the main model, I construct and calibrate the labor market risk ε relative to the college risk to examine the insurance and investment qualities of college education against labor market risk. As a robustness check, I introduce a tuition shock ε_κ that approximates the various uncertainty associated with college attendance.[20] The tuition shock adopts from Yum (2020). The mean of ε_κ calibrates to the average education cost as a share of output, and its variance calibrates to the percentage of students completing college without gap and stopout.[21] In this setting, ε_κ removes its relevance from the labor productivity shock ε in the main model, leaving ε to capture the absolute labor market risk.

Column (1) of Table 13 presents the recalibrated aggregate moments with tuition shock, ε_κ. Column (2) reports the counterfactual values once removing flexible access to college from Column (1) and Column (3) removes college completely. Compared to the main results in Table 6, removing college and removing flexible access to college have smaller impacts on the aggregate economy. This is because removing the college options disproportionately removes the associated ε_κ in Table 13, while the results in Table 6 maintain the relative labor market risk ε with the counterfactuals. Nevertheless, the changes in aggregate variables stay relatively similar to Table 6.

[20] In previous versions, I also introduced a utility shock if one attends college to model the schooling uncertainty. After recalibration, the results stay the same. Additionally, I adopt a tuition shock exercise because the tuition shock also reflects the variations in college cost as Fu (2014).

[21] Different from my calibration, Yum (2020) calibrates the variance of tuition shock to college wage premium. To ease computation, I use two values from the distribution of ε_κ: $\kappa_l = 0.3199$ and $\kappa_h = 1.1020$. The rest of the model recalibrates to the set of data moments as in Section 4.

Table 13: Robustness check: aggregate effect of college - with tuition shock

	Baseline with ε_κ (1)	No flexible access (2)	No college (3)
BA attainment/pop.	0.25	-18.79%	
employment/pop.	0.61	3.53%	-0.55%
Y	6.00	-1.19%	5.59%
K/Y	3.23	-0.37%	0.08%
C/Y	0.76	1.02%	1.04%
w	1.24	-0.17%	0.10%
r	0.04	0.54%	-0.68%

Notes: The first column reports the alternative baseline values with tuition shock. The second column reports the change of values compared to the alternative 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 alternative baseline model, when I remove college completely.

8 Conclusion

I show empirical evidence that most individuals do not complete their post-secondary education at once and instead experience delays and interruptions before completing their college degrees. College timing is strongly related to human capital and wealth endowments at age 18: Individuals with higher initial wealth and human capital endowments are more likely to complete college and to 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 having flexible college access. In aggregate, flexible access to college leads to significant welfare gains and accounts for over two thirds 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 degree attainment. The price channel describes the general equilibrium adjustment of factor prices, leading to substitutions between human capital investment and physical asset savings. As such, the price channel accounts for over one third to one half of the welfare values of having college access. 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 life-cycle comes from risk reduction. Having access to college at a later age reduces life-cycle welfare loss to risk. Initially wealthier and more prepared individuals have a higher investment value of college, hence are more likely to complete college without interruptions. Initially less-advantaged individuals find sizable risk reduction value from attending college, especially at a later age; therefore, flexible access to college benefits them more.

Lastly, public policies such as a nationwide College Promise Program drastically increase college completion rates and generate large welfare gains. Providing part-time student-workers tax exemption can also increase college attendance, especially at an older age. But its overall response is at a smaller scale, and its relative cost may dominate the welfare gain.

Appendix A NLSY79 and data construction for education pattern

NLSY79 is a uniquely available nationally representative longitudinal survey that interviews respondents aged 14-22 in 1979 through to the present, spanning almost the entire working life of interviewees. Thereby, it provides 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 years 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 has 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 status and stopout/dropout history. Since I only consider formal college enrollment, less than five 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 college dropouts. This is a reasonable simplification. According to Athreya and Eberly (2021), the 4-year college degree wage premium is 1.74 over 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 wealth conditions, that is directly imported into the optimization and simulation of the baseline model.

Appendix C Disutility of college parameter values

Table C.1 reports the numerical values for the college psychic cost/disutility of college parameters.

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

Table C.1: College psychic cost parameters - numerical values

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 $dis(e, age, yr)$. For each age, I differentiate the utility cost (gain) from 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 college, 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 college, 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 current enrollment status.

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