Best Time for College? A tale of two endowments

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Abstract

People often experience multiple interruptions in college enrollment, especially those with a less advantageous background at age 18. Some extend the enrollment through the lifecycle. To examine the welfare consequence of college through the lifetime, I incorporate flexible access to college at each age in an overlapping generations model in a general equilibrium framework with an incomplete market. Flexible access to college matters more for initially less advantageous people and explains two-thirds of the total welfare value of college. Wealthier background and better human capital preparedness at age 18 boost the investment and insurance values of college, incentivizing enrollment and younger age completion. Compared to removing inequality in 18 human capital, an equal age 18 wealth distribution has more considerable welfare improvement from promoting college participation.

JEL classification: E2, I24, J24, J31.

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

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1 Introduction

Most studies examining the college decisions focus on a one-time enrollment or dropout in the twenties. However, people commonly experience intermittence in college education, stopping from school temporarily and return back to enrollment.[1] Using the National Longitudinal Survey of Youth 1979, I find that people repeat school-work transitions on average 1.7 times. Over 16% of all with a bachelor's degree complete college after age 30. Previous research finds that college education at the first stage of lifecycle shifts earnings profile up and raises earnings risk (e.g. Kim, 2021; Schweri, Hartog, and Wolter, 2011). What role does college education at *a later age* play in a lifecycle with uncertainty? Given college's potential in increasing human capital and bracing self-insurance, what determines the timing of attending college? The answers to these questions can uncover important transmission channels from early age human capital and wealth background to lifetime welfare in an incomplete-market model.

In this paper, I examine the welfare consequence of having flexible access to college through one's lifecycle and explore the mechanisms determining college timing. Empirical evidence shows that intermittent college enrollment and the age of degree completion are strongly associated with one's family background at age 18. 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 explore the relationship between age 18 family background and the heterogeneous college patterns, I construct an overlapping generations model in general equilibrium adapting from Huggett, Ventura, and Yaron (2011). The primary source of lifecycle earnings risk comes from the idiosyncratic human capital productivity shock to working individuals. One main difference is human capital acquisition: individuals can accumulate human capital through time devoted to work (learning on the

[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).

job) and through schooling at any working age. A key innovation resides in the model's successful replication of the intermittent college patterns across heterogeneous individuals over the lifecycle. Moreover, the model generates empirically relevant heterogeneous income processes after fitting the empirical distribution of individuals on wealth and human capital at age 18, and calibrating to lifecycle schooling profiles.

The primary message of this paper is that having flexible access to college has significant welfare gain, especially to the initially less advantageous people. College contributes to nearly 24% of the consumer welfare in the economy. About two-thirds of it is attributed to allowing for flexible college enrollment at any age. While better prepared young people with wealthier backgrounds value college more, individuals with the lowest wealth at age 18 value flexible college access twice as much as those from the highest wealth families. Over the lifecycle, having college access before age 29 translates to the highest lifetime welfare gain. Yet, allowing for access to college after age 29 presents a more minor but positive welfare value.

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

I explain the heterogeneous welfare value of college through three channels: price channel, investment value channel, and insurance value channel. The price channel defines the aggregate welfare from households' substitution between human capital and physical capi-

tal. The investment value channel dictates early age college enrollment, and the insurance value channel justifies later age enrollment. The sizeable early age investment value favors the initially more advantageous individuals, explaining the higher overall value of college to them. Conversely, the later life insurance value provides an important welfare gain for the initially less advantageous individuals.

The price channel comes from the 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 have more assets accumulated, raising the supply for capital. However, restricted access to college also lowers the supply of the more productive college-educated labor. As a result, interest rate decreases and wage rate increases when markets clear. Abbott, Gallipoli, Meghir, and Violante (2019) suggests the importance of examining welfare change in a general equilibrium framework. The price adjustment accounts for about one-third to one-half of the aggregate college welfare value.

I define the investment value as the lifetime valuation of college from its role in increasing human capital that can be realized in the labor market in an environment without uncertainty, following Mincer (1974). It is measured as the consumption equivalence of having access to an additional year of college in models without exogenous uncertainty shocks. The investment value is the highest among the most prepared individuals from the top wealth background. The investment nature of college at age 19 is worth near 45% of lifetime consumption among individuals with the highest initial wealth and over 35% for the individuals with the most prepared human capital. However, it diminishes quickly after age 19 and disappears by age 24. This explains the majority of college enrollment at a young age. Because of the self-productive nature of human capital production (Cunha, Heckman, Lochner, and Masterov, 2006), a young person's pre-college preparedness raises the overall investment value of college. Interestingly, among individuals with similar preparedness by the end of high school age, the investment value is higher for higher wealth backgrounds.

From the insurance channel, I consider the role that college plays in propagating the

exogenous risk in a person's lifetime welfare. Meghir and Pistaferri (2011) describe that schooling can serve as a tool to self-insure against lifecycle risk. *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. I approximate the insurance value of college by comparing the valuation of risk between models with and without access to college at each age, a method resembling Castex (2017). Interestingly, college augments lifecycle risk, a negative insurance value, for individuals younger than 22. It exacerbates the welfare loss of risk the highest among the lower wealth or less prepared individuals. This result echoes the empirical findings from Kim (2021) and Schweri et al. (2011), in which college-educated workers have higher lifecycle risk. However, having access to college after age 22 reduces lifetime welfare loss from risk, a positive insurance value. The peak of its insurance value happens around age 24, mitigating nearly 30% of the loss in welfare from risk. The positive insurance value persists, though to a lower level after age 29, throughout the lifetime. Ones with better prepared human capital backgrounds at age 18 encounter a more substantial initial risk augmentation from college. For people with similar preparedness pre-college, the positive insurance value in later life is more prominent among those from lower age 18 wealth background.

I find that age 18 wealth drives a significant wedge in college enrollment and completion, even controlling early age preparedness in human capital. It translates to large lifetime welfare differentials across unequal demographics. Much of the literature discusses the importance of early age human capital preparedness, indicating less importance of early age family wealth conditions (e.g. Keane and Wolpin, 1997; Huggett et al., 2011). More recent studies, such as Johnson (2013) and Hai and Heckman (2017) focus on the impact of borrowing limit from the wealth dimension. This paper shows that a one standard deviation increase of initial family wealth raises the insurance value of college by 0.21 standard deviation twice that of the impact from the pre-college preparedness in human capital. It also

raises the investment value of college by 0.42 standard deviation, though lower than the effect from pre-college human capital preparedness (0.76 standard deviations), all else equal. The investment value of college is especially effective in encouraging college enrollment and early age completion. The insurance value has a comparable impact in promoting the completion of college at all.

Lastly, I explore the welfare consequence of removing the initial inequality following the three channels. Data show that individuals are unequally distributed on the age 18 human capital and wealth dimensions. More individuals concentrate on the lower end of the wealth and the human capital values. I find that a society with equal age 18 conditions amplifies the investment and insurance value of college, raising welfare. But the associated adjustment in general equilibrium from the price channel may counter some of the welfare gains. Huggett et al. (2011) and Griffy (2021) study the cost of inequality by comparing a counterfactual economy with a smaller spread of an initial distribution. Contrarily, I compose a counterfactually equal economy through having uniformly distributed individuals on the original support. An economy with uniform human capital distribution at age 18 promotes college enrollment and completion through investment and insurance channels. It leads to higher tuition spending and lower asset supplied for physical capital, and a higher supply of college-educated workers. In general equilibrium, wage rate decreases and interest rate increases. The price channel dominates the welfare gain from having a higher share of college education, leading to an overall welfare loss. This suggests that policies target at boosting college preparedness for high school students can improve college enrollment and completion with significant short-term welfare gain, but may incur some long-run welfare loss, *all else equal*.

Contrastingly, removing initial wealth inequality generates large welfare gain. A uniformly distributed initial wealth condition raises college completion by more than double from the baseline unequal setting, creating a sizeable initial welfare gain in the partial equilibrium. Though more people hold more assets and more workers are college-educated, the

general equilibrium price channel cannot eliminate the initial welfare improvement. This exercise further strengthens that wealth matters beyond the borrowing limit. The distribution of wealth plays a crucial role in college timing and has large positive welfare consequences. This shows that aggressive financial aid policies that alleviate the monetary burden for less wealthy high school students may induce significant positive college responses and have persistent overall welfare gain.

This paper situates in the studies examining the causes and consequences of college over the lifecycle. Despite a large literature, the sequential process of deciding on each year of college and the option values it creates leave space for new insights[2]. The recent macro-education literature examines the returns to college based on its role in separating lifecycle career trajectories from people without college (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). Studies argue that ability drives college attendance and completion, especially for recent years (Hendricks, Herrington, and Schoellman, 2021; Belzil and Hansen, 2020; Abbott et al., 2019). Once controlling for ability, family background matters less in college decisions. However, financial constraint is still a barrier for college (Ozdagli and Trachter, 2011; Johnson, 2013; Hai and Heckman, 2017). College is also a risky investment. 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). Thus, 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). Rather than estimating the lifetime financial returns of college, this paper adds to

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

the discussion by assessing the heterogeneous welfare valuation of having access to college at each age. Instead of estimating an exogenous college dropout risk, I endogenize college enrollment and exit decisions. It allows me to investigate the insurance role each year of college education plays in a lifecycle model with labor market uncertainty. In exploring the insurance value of college, my approach provides an assessment of the impact of having access to college on the risk perception. It bypasses implicit bias and the difficulty in separating various factors constituting the risk attitude (Hartog and Diaz-Serrano, 2015). Given the role wealth plays in risk attitude, my paper also finds an important channel that wealth matters to human capital acquisition and lifecycle welfare. Germane to my paper, Castex (2017) investigates the risk and returns of college in a partial equilibrium framework with exogenous college completion risk. Matsuda (2020) examines the impact of financial aid on endogenous college completion in a general equilibrium setting. Their models do not allow returning to school after the second stage of the lifecycle. My model finds three channels that lead to endogenous schooling decisions and uncovers important welfare values for later age access to college.

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

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

2 Empirical facts

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

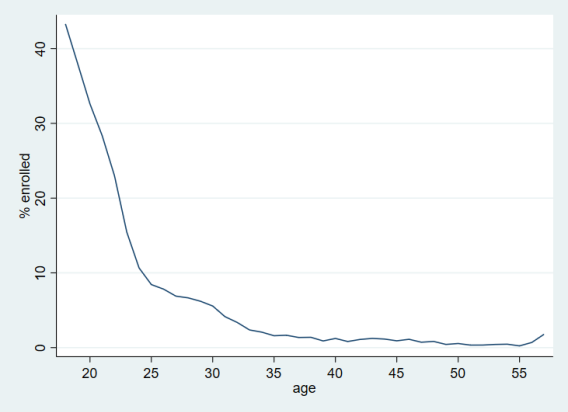
2.1 Intermittent college education profile

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.[3] For college enrollment, I define it as attending formal credited degree-granting college education for at least five months of a year, and college completion as completing 16 years of education, following the literature (Light, 1995a,b; Monks, 1997; Dynarski, 1999; Seftor and Turner, 2002; Johnson, 2013; Arcidiacono et al., 2016).

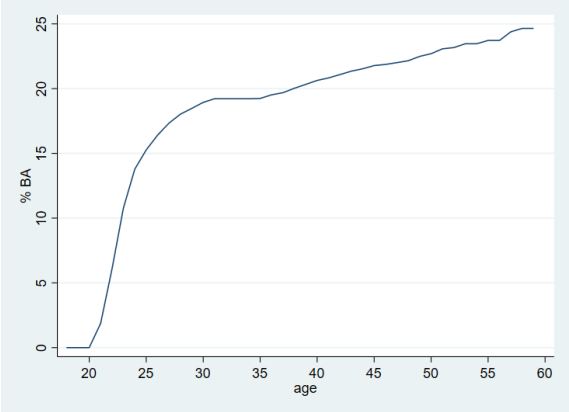
Figure 1 plots the life-cycle college enrollment and completion patterns. Panel (a) shows

[3]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 age by age. Panel (a) plots the average enrollment for each age starting at age 18. Panel (b) plots average bachelor level degree completion for each age. The data is smoothed with locally weighted regression with bandwidth of 0.15. I replace the older age value for average degree attainment by the previous age value if the older age attainment is lower than the previous age value.

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

Table 1 describes the college completion and timing of completion. About 39% of the sample report to have never enrolled in college. Only 9.3% of the sample complete college by age 22. These are the individuals described by the "traditional" consensus in lifecycle human capital acquisition literature, where one completes formal school training exclusively at the first stage of life.[4] 17% of the sample obtained a college degree after some interruptions, accounting for 2/3 of all with a bachelor's degree. About 35% have college experience but do not complete a degree. Examining all with a college degree, 73% obtain it at an age younger than 25. However, over 10% receive it after age 35.

[4]The early studies led by Ben-Porath (1967) and Mincer (1974) define lifecycle human capital acquisition as schooling at a young age and on-the-job training or learning through experience in the rest of the working age. Rubinstein and Weiss (2006) summarize the majority of the empirical studies following this structure.

Table 1: College completion and timing

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

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

2.2 Age 18 background conditions

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

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

For the dimension of human capital and learning ability, I use AFQT (Army Forces

Qualification Test) score as an approximation[5]. 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). For this paper, I take an agnostic stand and consider human capital as anything that makes an individual more productive in the labor market to measure labor income. Therefore, it is a broader set of definitions, including innate ability, learned human capital, and other factors contributing to school preparedness and labor productivity from an individual's perspective. AFQT has been widely used as a measurement for human capital, though criticized with its accuracy (e.g. Schofield, 2014; Rodgers III and Spriggs, 1996; Lang and Manove, 2011; Griliches and Mason, 1972). Nevertheless, it provides a useful approximation of one's relative position in the distribution of human capital that impacts learning in school and labor market earnings (Arcidiacono et al., 2010).

Table 2: Age 18 family wealth and AFQT

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

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

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

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

higher value bins than ones at the lower value bins for both conditions. Second, the wealth dimension is more skewed than the human capital endowment. Third, both conditions are positively correlated, with a correlation coefficient of 0.29. For the top wealth condition bins (top two bins), individuals are more likely to have a high human capital endowment (bin four and bin five). For those at the lower financial conditions (bin one and bin two), individuals are more likely to have lower human capital conditions (bin one and bin two).

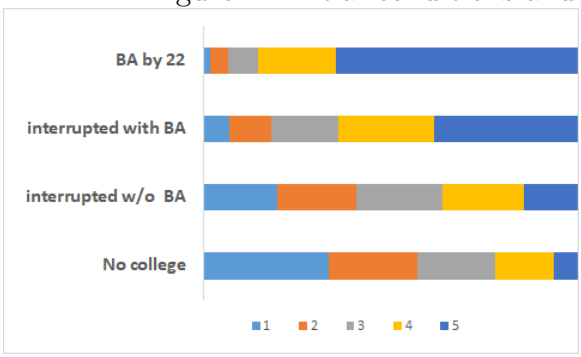
2.3 Age 18 conditions and intermittent college education

In this subsection, I provide descriptive statistics showing connections of age 18 conditions to the completion and timing of college. In Figure 2, I connect the age 18 differences in human capital and wealth conditions to the intermittent education pattern. In this graph, I split individuals into five human capital quintiles and five wealth quintiles, rather than the bins as in Table 2. Panel (a) and Panel (b) describe the various patterns of college completion in relationship to age 18 human capital endowment and wealth conditions. Individuals from the top 20% of the human capital and wealth conditions are more likely to complete college by age 22, and individuals from the bottom 20% of the human capital and wealth conditions are more likely to have never enrolled in college. Those from higher human capital and wealth conditions are also more likely to complete a bachelor's degree than those from lower endowments.

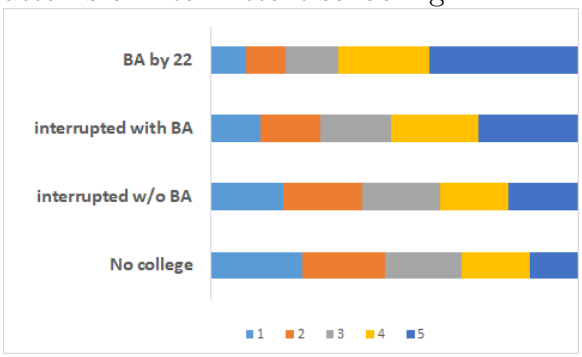
Further examining all with a college degree, in Panel (c) and Panel (d) of Figure 2, ones from the top human capital and wealth conditions are more likely to obtain the degree at a younger age, by 25. Conversely, among all who received the college degree after age 35, most are from the bottom 20% of the age 18 human capital and family financial conditions.

These patterns describe the intermittent college education. Such intermittent enrollment and delayed college degree completion profiles strongly correlate to the age 18 wealth and human capital position. In the next section, I construct a theoretical lifecycle model to systematically examine the impact of age 18 conditions on college education.

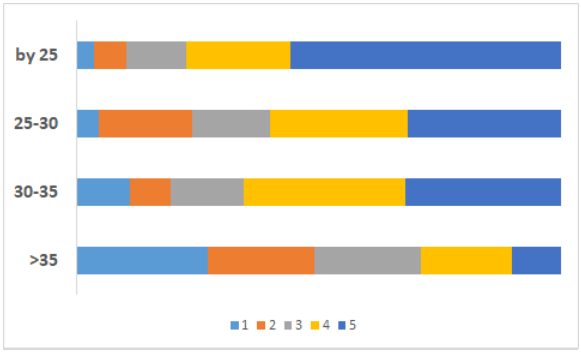
Figure 2: Initial conditions and patterns of intermittent schooling



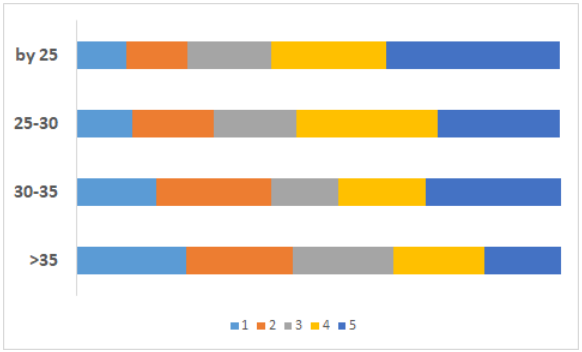
(a) Age 18 human capital and college completion



(b) Age 18 family financial and college completion



(c) Age 18 human capital and BA timing



(d) Age 18 family financial and BA timing

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

3 Model

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

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

3.1 Individuals' problem

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

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

Individuals are also differentiated on how many years of post-secondary schooling one has completed yrs. The maximum number of full time education years after high school

is set to be four. Together, individuals are heterogeneous in the idiosyncratic states: $\phi \equiv \{h, s, yrs, e, age\}$.

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

Table 3: Life-cycle time-line

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

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

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

In addition to the discrete e choice, each individual chooses consumption and saving to maximize the lifetime value.

For working individuals, as in Equation 2, human capital accumulates through learning on the job by a fixed parameter A with learning curvature a. Human capital shocks ϵ perturb the learning efficiency. ϵ abstracts from various individual-related factors impacting one's

productivity. ϵ is *iid* across individuals and time. But given its nature on h, a stock variable for human capital, the impact of ϵ is persistent.

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

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

If an individual decides to go to school full time, the person has to pay a fixed tuition cost, psychic cost, and opportunity cost of current earnings and learning on the job to enroll in school. As in Equation 3, the person incurs disutility $disu_{sch}$ from going to school. The disutility depends on a person's existing human capital, age, current schooling status, years of school completed, and full time/part time schooling status. The individual's income only comes from previous savings (or debt) and tax transfer, which must be allocated among

consumption, savings (or borrowing) for the future, and tuition payment κ. Human capital moves up by a scaling factor $\Delta(yrs)$, a function based on years of education.

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

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

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

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

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

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

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

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

3.2 Firm's problem

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

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

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

3.3 Stationary Equilibrium

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

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

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

3. Aggregate efficient units of labor supply has:

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

4. Aggregate savings has:

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

5. Aggregate consumption has:

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

6. Aggregate tuition cost has:

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

7. Market clearing requires:

$$L^s = L^d$$

$$K^s = K^d$$

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

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

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

4 Calibration

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

4.1 Initial distribution and grid setup

The initial distribution of individuals follow the Table 2 in Section 2.2. Literature follows Huggett et al. (2011) often construct a multivariate normal distribution with the dimensions describing wealth, human capital, and learning ability. The mean, variance, and covariance of the distribution are calibrated to generate lifecycle earnings profiles that target the empirical counterparts. However, Table 2 shows that individuals are not normally distributed on initial wealth and human capital and that the wealth dimension is highly skewed. Given the importance of initial conditions in generating lifecycle profiles, smoothing the patterns from the empirical distribution may lead to large consequences in the simulation results. Therefore, I take a more refined distribution from Table 2 and directly feed 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. The number of individuals from each bin is assigned to the corresponding grid position.[6]

For the initial wealth dimension, I first split the proxy for family wealth described in Section 2.2 into equal-valued 20 consecutive bins. The first bin holds 8% of the sample, and the second bin holds 18%. According to the Survey of Consumer Finance, 17% of people between the age of 17 and 19 have negative net wealth. To locate zero wealth, I split the first two bins into equally spaced four sub-groups. The first three sub-groups account for 17.57% of the sample. When fitting the initial wealth support into the model on the grid for asset, I set the last of the four subgroups at zero and the first three sub-groups on three equally spaced grid points below zero. The remaining 18 bins are mapped one-to-one on grid points valued above zero equally spaced with distance doubling that among the first four. In total, the support for initial wealth spans 22 grid points on the asset grid.[7] Same as the fitting

[6]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 the initial level. I assign 60 more grid positions after the highest initial human capital level to allow for human capital accumulation above the highest initial level.

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

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

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

4.2 Other parameters

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

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

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

Table 4: Disutility of schooling by age

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

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

pirical moments and model simulated moments. Motivated by Johnson (2013), Hai and Heckman (2017), Guo (2018) and Abbott et al. (2019), I parameterize the school psychic cost portion of the utility function as $disu_{sch}(h, age, e, yrs, ft) = n_{sch}(dis(e, age, yrs) - h)$.[8] $n_{sch} = 1$ is for full time schooling and $n_{sch} = 0.5$ for part time schooling. The psychic cost is relative to the size of human capital, h, that the person already has, following the self-productive nature of learning[9].

Literature also shows that human capital investment is time-sensitive. Learning in school may be more enjoyable in a certain age range (Cunha et al., 2006). The inertia of current work/school status makes the following period decision sticky. A current student may be more likely to continue enrolling in school than one who is currently away from school[10]. Lastly, if one is near completing a degree, the student may find a different psychological challenge compared to the beginning stage of college. Therefore, I model $dis(e, age, yrs)$ to represent a set of parameters describing the relative disutility of schooling by age, years of schooling completed, and continuing enrollment status. The three sets of dis parameters for each age are reported in Table 4. These parameters are calibrated to target the new and continuing enrollment and BA attainment statistics in Figure 3. This set of parameters are calibrated to target the average age-by-age enrollment status (new enrollment and continuous enrollment in school) and the average bachelor's degree completion[11].

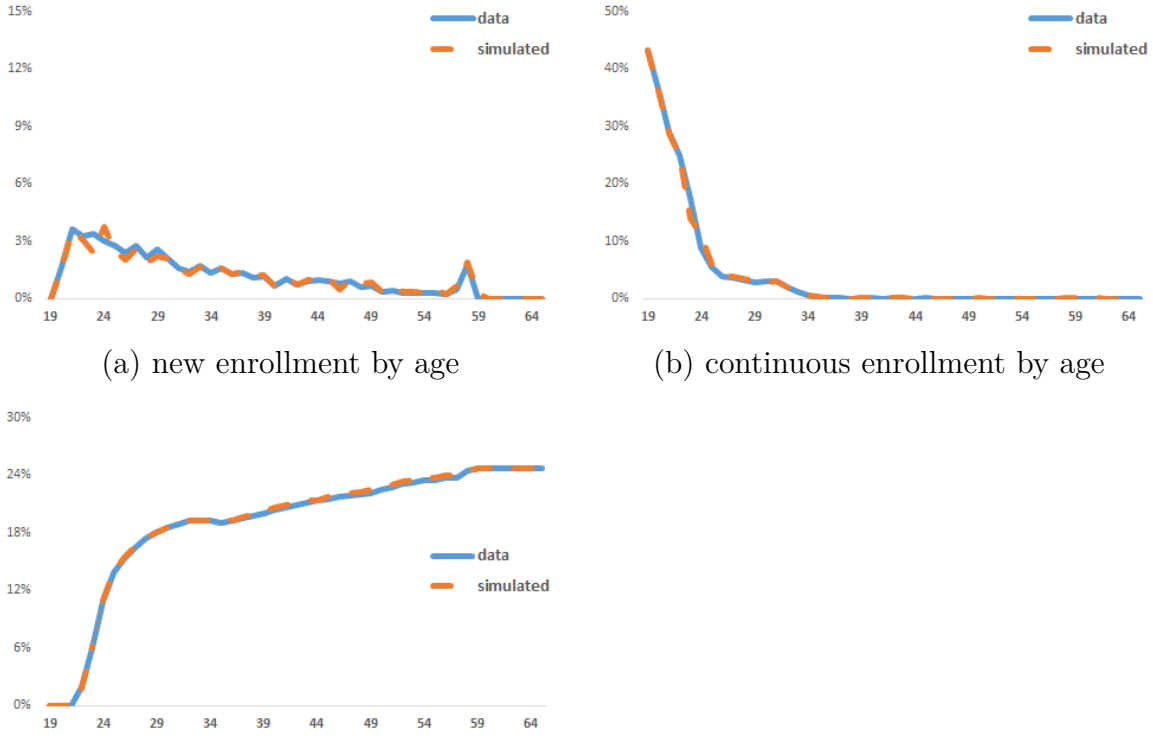
[8]Many macro literature with human capital acquisition only allow for opportunity cost of learning and do not model a direct cost associated with it (e.g. Huggett et al., 2011; Griffy, 2021). Hsieh, Hurst, Jones, and Klenow (2019) argue that a direct cost is important in generating asymmetric human 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 an important channel linking wealth, precautionary savings and risk aversion to schooling decisions. Missing such component may create omitted variable bias in the simulation.

[9]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.

[10]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.

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

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



(a) new enrollment by age

(b) continuous enrollment by age

(c) completed BA by age

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

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

Table 5: Calibration and targeted statistics

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

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

Human capital can move along three trajectories: accumulating on the job (or, loosely speaking, "learning" on the job), learning in school, and depreciating while enjoying full-time leisure. Parameter a determines the curvature of all human capital accumulation. Browning et al. (1999) and Huggett et al. (2011) describe the importance of a in generating the rise of dispersion of income over the lifetime. I set a to match the wage dispersion overtime in my calibration, calculated 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[12]. Models

[12]I follow Huggett et al. (2011) by removing time and cohort effect from the data and deflating all price

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

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

variables to 2009 level.

4.3 Model fit

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

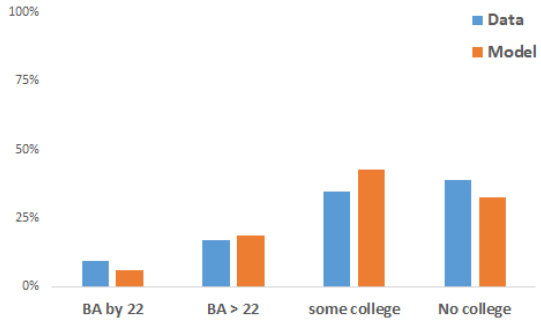
The purpose of this paper intends to examine the risk and value associated with intermittent college. Hence, it is important to compare the heterogeneous lifecycle earnings dynamics between the baseline model and data. Guvenen (2007), Guvenen (2009) and Guvenen and Smith Jr (2014) categorize two patterns of earnings dynamics from the literature, restricted income process (RIP) and heterogeneous income process (HIP). The lifecycle earnings are described by the following process:

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

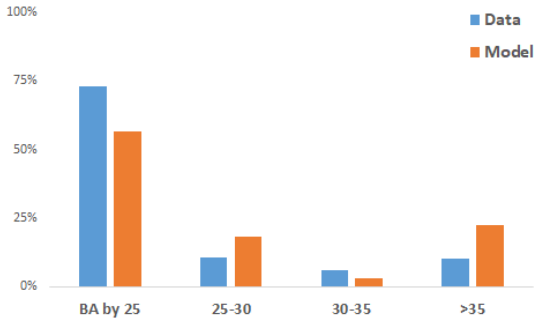
$$z^i_{h,t} = \rho z^i_{h-1,t-1} + \eta^i_{h,t},\ z^i_{0,t} = 0$$

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

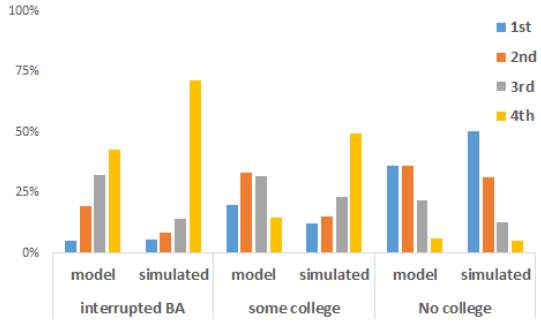
Figure 4: Education and initial conditions: data and model moments



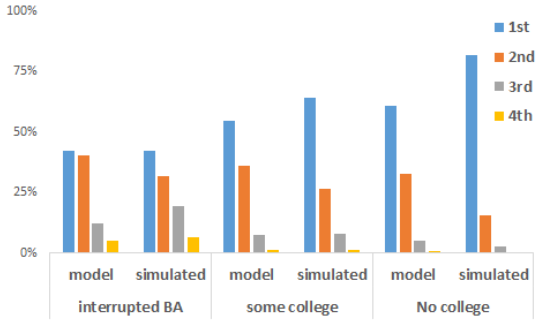
(a) interruption pattern



(b) BA completion pattern



(c) human capital bins



(d) wealth bins

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

ρ and innovation η; $\epsilon^i_{h,t}$ models the transient iid shocks across time and individuals.

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

Table 6: Statistical models of earnings

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

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

5 Main findings

In this section, I present the main findings of this paper: the aggregate and distributional consequences and value of having flexible access to college. First, I examine the role of college by comparing the aggregate variables between the baseline economy and the counterfactuals restricting college access in the general equilibrium setting. Then, I evaluate the heterogeneous impact of having access to college on people with different age 18 conditions.

5.1 Aggregate effect of having flexible access to college

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

Table 7: Aggregate effect of college

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

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

When I remove the flexible access to college, individuals can only have college access right after high school by age 19 and cannot return to college once they leave school. This means that the 19% of individuals who completed college after age 22 in Panel (a), Figure 4 have to either advance their degree attainment age, choose non-stopping but part-time schooling, or give up college after age 22. As a result, such restriction reduces total BA attainment by 28% but increases enrollment by 12%. More people are working, and more asset saves to physical capital, leading to a modicum increase of output, capital share, consumption

share, and employment. In the general equilibrium, additional capital supply reduces the interest rate by 1%, while the wage rate increases by 0.2%. Although with higher output and consumption share, individuals still lose on welfare. The consumption equivalence reduces by 16%, indicating that having flexible access to college creates important consumer welfare, independent from output and consumption measurement.[13]

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

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

5.2 Heterogeneous impact of access to college

Empirical evidence suggests a link of initial conditions to college patterns. In this subsection, I examine the distributional impact of flexible access to college on individuals with different initial conditions in general equilibrium. In particular, I examine the impact of enrollment, degree attainment, and welfare in the measure of consumption equivalence. I split individuals

[13]For the rest of this paper, I measure consumer welfare through consumption equivalence using the average of individual's welfare measure outlined by Mukoyama (2010). A positive consumption equivalence means households prefer the original model, while a negative value means households prefer the counterfactual model. A negative value is interpreted as the percentage of original consumption that the households are willing to give up to keep the counterfactual environment. A positive value is interpreted as the percentage of original consumption that the households need to be compensated to maintain the counterfactual environment.

into four equal valued bins along the initial human capital dimension and four along the initial wealth dimension.

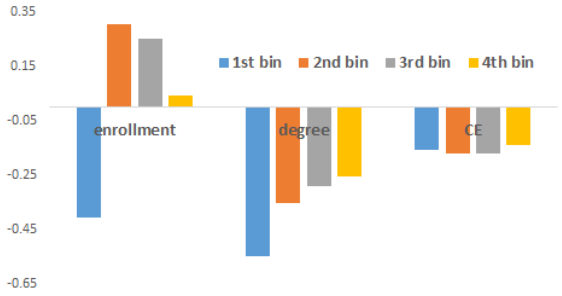
The first row in Figure 5 compares the baseline values to the counterfactual model of removing flexible access to college. Panel (a) examines the changes in enrollment, degree attainment, and consumption equivalence along the initial human capital margins, and Panel (b) examines the changes along the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

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

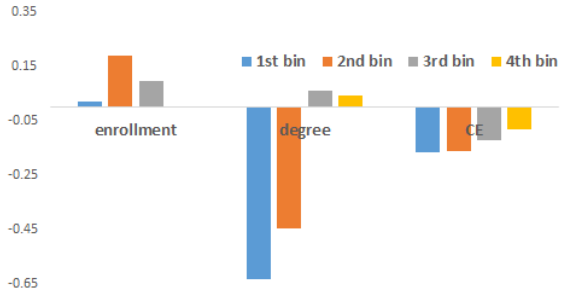
In terms of degree completion, people with lower initial human capital or wealth have higher reductions after removing flexible college access. The pattern is inconsistent with the enrollment response. Individuals in the top two wealth bins have a small increase in degree completion. Ones from the lower two wealth bins incur a large reduction of degree attainment. People from the lowest wealth bins lose nearly 60% of their degree attainment. In terms of the human capital margin, people with higher human capital have less reduction in degree completion.

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

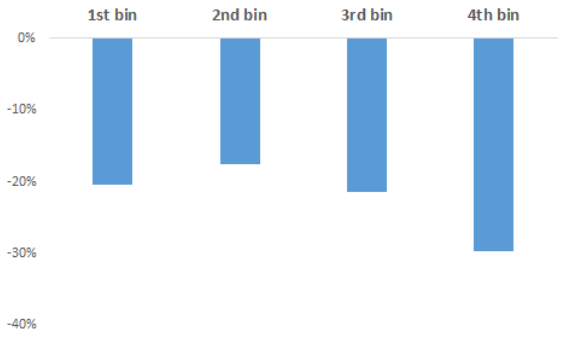
Figure 5: Heterogeneous impact of college and stopout



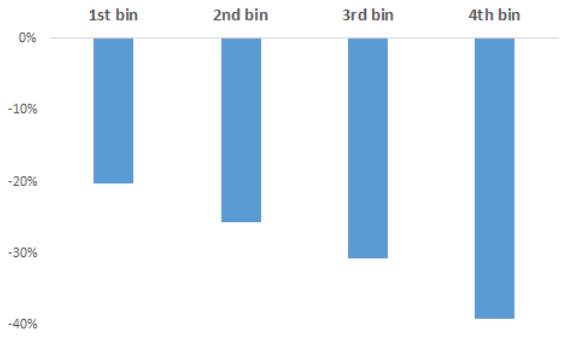
(a) impact of stopout - initial human capital



(b) impact of stopout - initial family wealth



(c) CE of college - initial human capital



(d) CE of college - initial family wealth

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

The bottom row of Figure 5 illustrates the heterogeneous welfare cost when removing college completely from the baseline model. Individuals from the top wealth or human capital bins have the most considerable welfare loss. Ones from lower wealth or human capital bins generally suffer from less severe welfare loss, except the ones from the lowest human capital bin receiving a comparable loss from the third human capital bin. The nearly reverse welfare effect between the top and bottom rows suggests that people with higher initial wealth and human capital conditions value college more, but having flexible access to college matters more to people with lower initial conditions.

Figure 5 further shows that there is a dichotomy between enrollment and degree completion patterns facing flexible access to college. Thus, the welfare value of having flexible access to college matters more to initially less advantageous individuals, although college is overall valued higher by the initially more advantageous individuals.

6 Mechanism

Section 5 presents the main findings on the aggregate and distributional impacts of having college access. This section examines its mechanisms through three channels: price channel, investment value channel, and insurance value channel. First, I explore the price channel by comparing the aggregate results between partial and general equilibrium exercises. Then, I focus on the heterogeneity of initial conditions for the channels on investment and insurance values.

6.1 General equilibrium price channel

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

restricting price change.

Column (1) - (3) in Table 8 present the change of aggregate variables after removing flexible access to college. Individuals can only start college at age 19 and cannot resume college after leaving school. Column (1) fixes the interest and wage rates at the baseline level and compares the aggregate variables to the baseline values. This leads to a near 8% increase in enrollment and a 32% reduction in degree completion. In Column (2), I relax the wage rate to the general equilibrium level when there is no flexible access to college. The wage rate is about 0.24% higher than the baseline level, while the interest rate remains at the baseline level. All values in Column (2) compare to the levels in Column (1). A higher wage rate leads to a higher return to human capital investment, inducing a slight increase in college activities compared to Column (1). However, the feedback to output and consumer welfare is small. Column (3) allows both prices to adjust to the general equilibrium level. The interest 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. Enrollment and degree completion increase (by near 4% and 5% respectively) compared to Column (2). The lower interest rate reduces capital costs to firms. In general equilibrium, output and capital to output ratio both increase by 1%. A lower interest rate leads to a further reduction of consumer welfare. In short, the majority of the increase in enrollment and reduction in degree completion in Table 7, Column (2) come from Column (1) in Table 8. However, the general equilibrium price channel accounts for about half of the welfare reduction when removing flexible access to college.

I conduct a similar comparison in the last three columns in Table 8 to isolate the price channel that leads to the general equilibrium results in Table 7 Column (3) when completely removing college from the baseline model. In Column (4) of Table 8, the college option explains 16% of consumer welfare drop from baseline mode, holding all prices fixed. When relaxing wage rate to the new general equilibrium setting with no college in Column (5) (a 0.27% increase from baseline wage rate), consumer welfare increases by 2% from Column

Table 8: 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)
enrollment/pop.	7.68%	0.16%	3.69%			
BA attainment/pop.	-31.87%	0.42%	4.54%			
employment/pop.	4.15%	-0.07%	-0.05%	-0.23%	-0.07%	-0.76%
K/Y	-1.14%	-0.24%	1.42%	-1.98%	-0.37%	2.81%
Y	-0.84%	0.06%	1.20%	3.09%	0.03%	2.45%
C/Y	0.00%	0.06%	0.14%	0.76%	0.03%	0.76%
consump. equivalence	-8.78%	-0.01%	-7.55%	-16.32%	2.13%	-10.98%

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

(4). Further moving to general equilibrium prices in Column (6) (with 1.4% reduction in interest rate), consumer welfare drops by 11% from Column (5). This accounts for about one-third of the total welfare drop between the general equilibrium without college and the baseline level.

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

6.2 Channels through the values of college

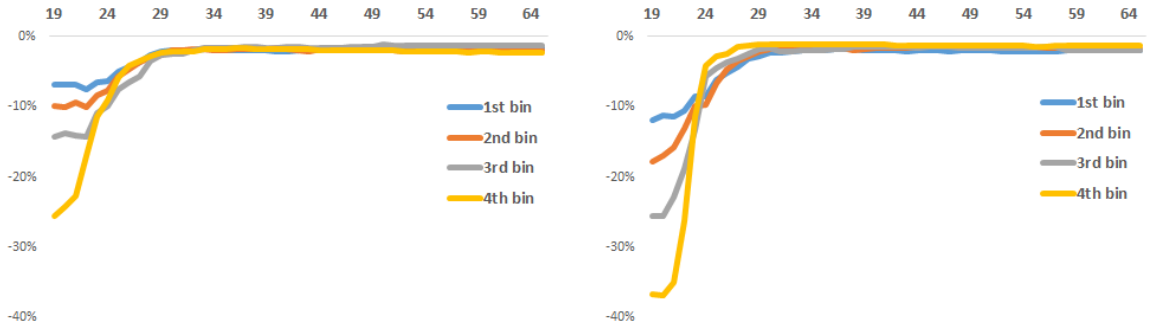
Numerous studies investigate the investment value of school education, a direction initiated by Mincer (1974), Ben-Porath (1967) and Card (1994). The more education one obtains, the higher human capital it leads to, leading to higher labor income. Yet, human capital accumulation resembles physical asset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

6.2.1 Gross value of college

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

Panel (a) presents the gross value of college for people at each initial human capital bin, and Panel (b) presents it for each initial wealth bin. Across all human capital and wealth bins, the value of college diminishes after age 29 but maintains at a relatively constant near-zero level afterward. The value is the highest at the youngest age, hence corresponds to Figure 3 where the majority of college enrollment and completion happens at an age before

Figure 6: Heterogeneous gross value of college by age



(a) by initial human capital

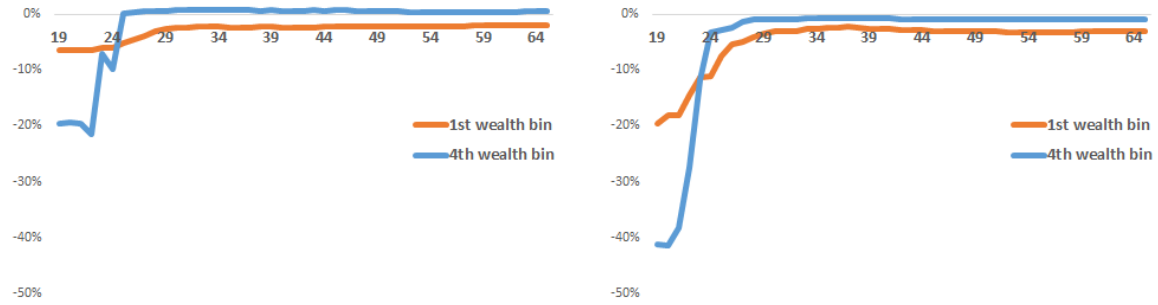
(b) by initial wealth

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

30. Individuals with higher initial human capital or access to wealth have a higher gross value of college at age 19. Their valuation diminishes faster as one grows older. Ones at the lowest human capital or wealth bin have the lowest valuation. However, it is still valued at around 10% of the baseline level of their lifetime consumption, and it decreases slower than the rate at the top bins. This corresponds to the findings in Section 5.2 where ones from the first bins of wealth or human capital suffer more from removing access to flexible schooling.

Figure 7 further controls 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. The college has a consistent positive value for individuals from the first human capital and wealth bins. Individuals value college much more (20% of baseline value) at age 19 if they are from the fourth wealth bin. However, their valuation to college quickly disappears after age 24. The same pattern exists when comparing the gross value of college between the first and fourth wealth bins for the fourth initial human capital bin in Panel (b). The difference between Panel (a) and (b) is that individuals with higher initial human capital have a higher lifetime value of college, controlling for initial wealth. Higher initial

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



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

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

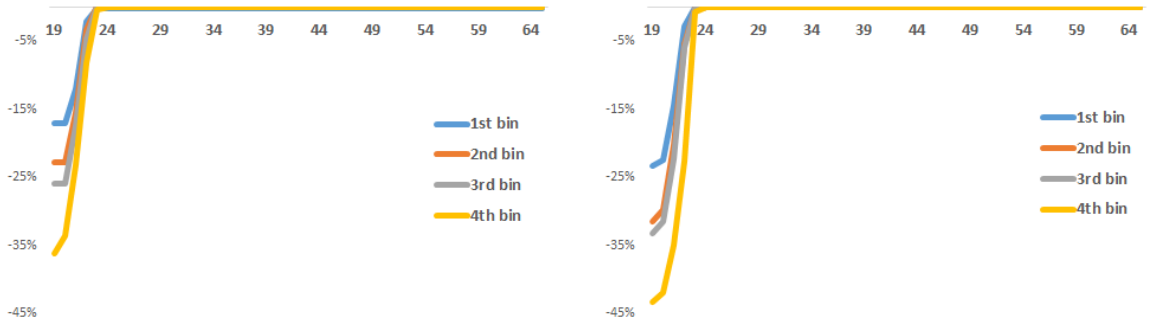
wealth creates higher early age valuation of college and lowers later age valuation of college. Higher initial human capital levels up the valuation of college throughout its lifecycle.

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 risk in the model. The idiosyncratic human capital shock ϵ is the only exogenous risk in the model. After removing ϵ from the baseline model, the remaining value from college comes from the returns to human capital. Since attending school incur differential utility cost, the market return of human capital investment differs from the utility returns (Belley and Lochner, 2007; Yang and Casner, 2021). Therefore, examining the welfare valuation of college needs to consider the utility return rather than monetary returns.

The investment value of college largely mimics the gross value in Figure 6. Individuals with the highest human capital or wealth bins have the highest investment value. This is

Figure 8: Heterogeneous investment value of college by age



(a) by initial human capital

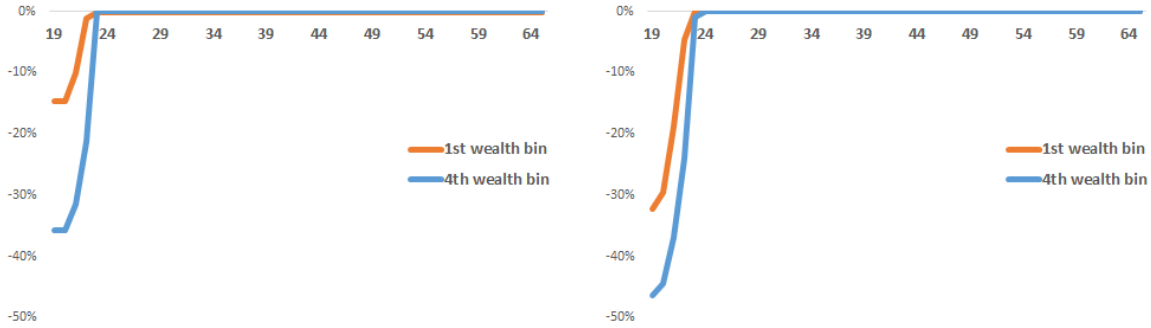
(b) by initial family wealth

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

because human capital production in college is multiplicative. The higher human capital, the easier it reproduces, corresponding to the self-productive and dynamically complementary qualities described by Cunha et al. (2006). The investment value of college diminishes faster than the gross value and nearly vanishes after age 24. This corresponds to the extensive literature on returns to college, where its value motivates early age schooling to accumulate lifetime returns. After a certain age, the lifetime returns to college may be outweighed by its cost (e.g. Becker, 1975). Hence lifecycle models often consider college only in the first model stage with no-repeat afterward (e.g. Heathcote, Storesletten, and Violante, 2010; Kim, 2021).

Figure 9 examines the impact of initial conditions on investment value. Panel (a) shows the difference in investment value by wealth for all from the first initial human capital bin. Ones from the fourth wealth bin have more than double of the investment value at age 19 than those from the first wealth bin. The investment value disappears for all after age 24. Panel (b) shows the valuation for all from the fourth human capital bin. It has a similar pattern as Panel (a), although the difference in investment value between the first and fourth

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



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

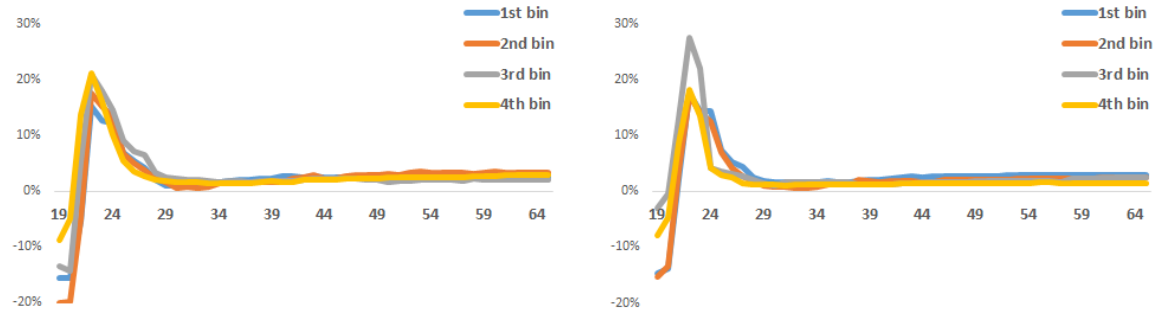
Notes: The plots present the consumption equivalence of removing each year of college in an environment with no exogenous uncertainty, and convert the consumption equivalence from the baseline consumption level. For example, the consumption equivalence of have college at age 19 is measured by comparing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

wealth bins is much smaller in Panel (b). Overall, ones from higher initial wealth and human capital bins have a higher investment value of college. After age 24, the investment value disappears for everyone.

6.2.3 Insurance value of college

The difference between the gross value of college and its investment value in a risk-free environment suggests that risk perceptions alter the value of college, an aspect largely omitted by the literature. Meghir and Pistaferri (2011) discuss that individuals mitigate lifecycle risk through means of self-insurance, either as *ex-ante* precautionary saving or *ex-post* adjustment. Following Meghir and Pistaferri (2011), I explore the insurance value of college by examining the welfare differential of risk between models with and without school. I first calculate the risk valuation with school by measuring the consumption equivalence from baseline to a counterfactual model without risk. I then measure the consumption equivalence of risk between one model without risk and school and one with risk but without school for

Figure 10: Heterogeneous insurance value of college by age



(a) by initial human capital

(b) by initial wealth

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

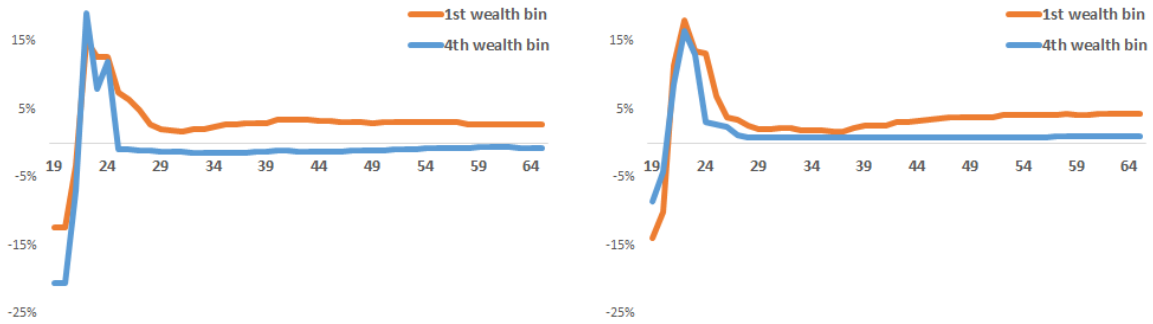
each age. The difference between the risk valuation without school and with school shows the impact of having access to college on risk reduction. A positive value means that a portion of consumer welfare loss from risk is removed by accessing college, showing risk reduction due to college. A negative value represents an amplification of risk by the college.

Figure 10 shows the lifecycle insurance value of college. For both Panel (a) and (b), college amplifies the cost of risk before age 22, negative insurance value. However, college essentially removes the welfare cost of risk between age 22 and 29, positive insurance value. After age 29, the college provides a small but persistent effect in alleviating the welfare cost of risk. For younger people, the lower the human capital or wealth bins, the more substantial the college amplifies risk. For later ages, college reduces risk loss more for ones from higher initial bins.

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

Figure 11 isolates the impact of initial conditions in the insurance value of college. Panel (a) plots the insurance value for the first and fourth wealth bins while limiting the human

Figure 11: Insurance 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 insurance value of college for each initial human capital bin, Panel (a), and for each initial wealth bin, Panel (b). The insurance value is calculated as the difference of consumption equivalence to having risk between models with school and models without school for each age. The negative value means that the individuals face a higher cost of risk due to college, and the positive value means that individuals face a lower cost of risk due to college. Panel (a) examines the insurance valuation for all from the first initial human capital bin, and Panel (b) for all from the fourth initial human capital bin. The red line plots those also in the first wealth bin and the blue line for those in the fourth initial wealth bin.

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

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

6.2.4 Removing welfare aggregation in values of college and college attainment

The lifecycle valuations of college measured in Section 6.2.1, Section 6.2.2 and Section 6.2.3 follow Mukoyama (2010) in the aggregation of welfare to individuals from each initial bin. In this subsection, I examine the contribution of each initial condition to college value and college timing without aggregation in regression analysis and investigate the relationship between investment and insurance values to the college completion patterns.

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

Table 9: Initial conditions and college value

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

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

Table 9 shows that a one standard deviation increase of initial human capital leads to a 0.32 standard deviation increase of gross value, 0.76 standard deviation increase of investment value, and 0.11 standard deviation increase of insurance value of college. The initial wealth condition has a minor positive impact on the gross value and investment value of college but

nearly doubled effect on the insurance value of college (0.21 standard deviation increase). This shows that when considering the policy implication of initial family background, the wealth condition, though more minor, plays a vital role in the insurance consideration of college in a risky environment.

Table 10: Investment and insurance values and college timing

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

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

Similar to Table 9, I conduct regression analysis linking the investment value and insurance value of college for individuals age 19 to the college pattern. Table 10 displays the regression results for dependent variables: college experience, college completion, and age of completion while controlling the investment and insurance values and lifetime consumption. For the last column, BA completion age, I include only simulated observations of all who completed college.

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

In conclusion, initial human capital and family financial conditions play an important role in college valuation. The more substantial college investment and insurance values

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

7 Impact of initial inequality

Table B.1 shows that individuals are unequally distributed on age 18 family wealth and human capital. The distribution is right-skewed, especially along the family wealth dimension. This section examines the welfare consequence of unequally distributed individuals through its relationship to the channels discussed above. I compare the baseline model with unequal initial distribution to one with uniform distribution of individuals on the initial support. This is different from the literature, such as Huggett et al. (2011) and Griffy (2021), where an equal economy is set by reducing the spread of support for the distribution.

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

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

Table 11: Aggregate impact from removing initial inequality

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

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

of individual values. The lower wage rate from uniformly distributed initial human capital reduces enrollment and degree attainment (0.8% and 0.5%). This reduces labor productivity by 0.3%. As a result, consumer welfare drop by 7%. In Column (3), I further relax the interest rate to complete general equilibrium from uniform initial human capital distribution. In this case, the interest rate raises by 1.76% from the baseline level. Compared to Column (2), the rise in interest rate further discourages investment in human capital, lowering enrollment and degree completion. Consumer welfare decrease by 3.9% from Column (2). Altogether, this shows that general equilibrium wage and interest rate adjustment in an economy with uniformly distributed initial human capital generates an 8% lower consumer welfare from the baseline model with the right-skewed initial human capital distribution. Households choose physical capital accumulation over investment in human capital through a college education.

Column (4) - (6) in Table 11 show similar exercises but for uniform initial family wealth condition. Column (4) compared the partial equilibrium results with baseline values for

interest and wage rate. The results follow from Section 6.2. A uniformly distributed initial family wealth moves more individuals to higher initial wealth bins, creating a strong incentive to enroll and complete college, leading to a 3% increase in labor productivity and a 23% increase in consumer welfare. As I move to Column (5), relaxing the wage rate to adjust to the new general equilibrium level (0.003% lower), much of the economy is unchanged. This is because wage adjustment is quite limited. As I further relax interest in adjusting to the new general equilibrium in Column (6), the interest rate increases by 0.03% from the baseline level. This makes physical capital investment more attractive, leading to a small decrease in enrollment and degree completion from the economy with a fixed interest rate. The consumer welfare decreases by 10%. Nevertheless, comparing to the baseline level, consumer welfare still raises by 10.7%. In summary, a more equally distributed initial family wealth creates large and positive general equilibrium welfare gain to consumers.

8 Conclusion

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

Examining the mechanism, I find three channels that flexible access to college impacts the economy: price channel, investment channel, and insurance channel. In general equilibrium,

allowing flexible access to college alters the distribution of individuals on human capital and wealth, raises aggregate consumer welfare. College raises human capital, creating an investment incentive for individuals. The investment value is high for ages before 24 but disappears afterward. The value of college for the remaining lifecycle comes from insurance value, where having access to college at a later age reduces lifecycle welfare loss to risk. Initially wealthier and more prepared individuals have a higher investment value of college, hence more likely to complete college without interruptions. Initially less advantageous individuals find sizable insurance values, especially at a later age. Therefore, flexible access to college benefits them more.

Lastly, an equally distributed initial condition moves otherwise less advantageous individuals to better positions. A uniformly distributed initial human capital condition creates short-run welfare improvement due to increased enrollment and college completion, but long-run negative welfare consequence due to general equilibrium price effect. A uniformly distributed initial wealth condition creates welfare improvement from short run to long run, despite price adjustment, compared to the empirical wealth distribution.

Appendix A NLSY79 and data construction for education pattern

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

Appendix B Initial conditions

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

Appendix C Additional results on college timing

Figure C.1 explores the distributional impact of access to college by age range. I compare the baseline enrollment, degree attainment, and welfare by removing college access after age 25, age 30, and age 35. Panel (a) and (b) show that removing latter access to college pushes at a younger age for all but the ones from the fourth wealth bin. The impact is stronger for lower wealth bins as in Panel (b) and stronger for the second and third human capital bins in Panel (a).

Panel (c) and (d) show the degree completion. In Panel (c), individuals with the lower three human capital bins are less capable of adjusting their degree attainment if no access to college after age 25. As the college access relaxes to a later age, more people can shift later enrollment and previous non-completion to the earlier age. In Panel (d), the lowest wealth bin people suffer from the incapability to adjust their degree attainment once shutting down college after age 25. However, if we allow access to college to age 30, the lowest wealth bin individuals can largely adjust and increase their degree completion.

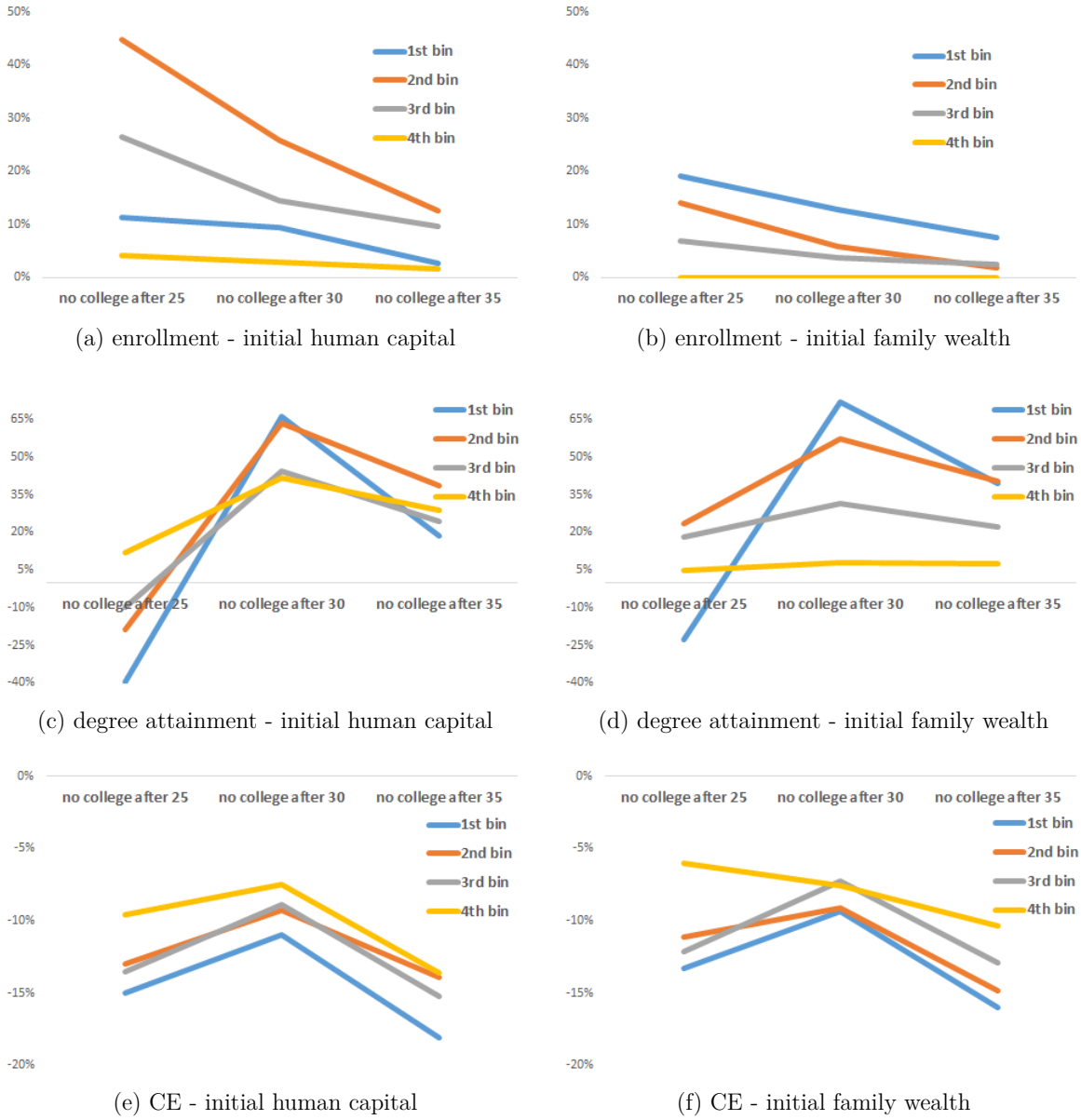
Comparing the top and middle panels of Figure C.1, there are considerable differences between the enrollment and degree completion of college across heterogeneous initial conditions. Hence it shows the importance of differentiating college into intensive margin enrollment behavior and extensive margin degree completion.

Panel (e) and (f) describe the heterogeneous welfare value measured by consumption equivalence. Similar to previous discussions, individuals with lower human capital or wealth bins value the latter access more than higher bins. Contrary to the degree and enrollment

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

Figure C.1: Heterogeneous impact of college timing



(a) enrollment - initial human capital

(b) enrollment - initial family wealth

(c) degree attainment - initial human capital

(d) degree attainment - initial family wealth

(e) CE - initial human capital

(f) CE - initial family wealth

responses, everyone in the model values late (after age 35) access to college the most. This hints at the potential general equilibrium channel affecting college valuation. Different levels of restricting access to college create varying labor and capital supply responses and wage and interest rate change.

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