THE MACROECONOMIC COST OF COLLEGE DROPOUTS*

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Abstract

Forty percent of US college students drop out. I analyze a novel policy-relevant dropout channel: grant uncertainty across academic years that students face at college due to the opaque allocation process of grants. Using a quantitative overlapping generations equilibrium model, I analyze the impact of uncertainty regarding grants, together with uncertain academic ability and productivity shocks, on dropout rates. Grant uncertainty alone explains one-third of dropouts, disproportionately affecting economically disadvantaged high-ability students. Reducing this uncertainty improves social welfare by 2.4% through the complementarity between ability and a college degree, benefiting both graduates and non-graduates by reducing skill premiums and taxation.

Keywords: Inequality, Financial Aid, College Dropouts, Skill Premium, Financial Constraints, General Equilibrium
JEL: E24, H52, H53, I22, I26, I28

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1 Introduction

Forty percent of full-time college students drop out before graduating. While dropout decisions may well constitute an efficient response to students discovering their low academic ability, they may also be inefficient if talented students drop out due to adverse financial shocks. When designing policy, it is crucial to differentiate between these two considerations: while addressing the former may require a complex approach, the latter can be tackled by more straightforward policy instruments with potentially large welfare gains. Many recent contributions on dropouts including Hendricks and Leukhina (2017), Hendricks and Leukhina (2018), Lee, Shin, and Lee (2015), Arcidiacono et al. (2016) and Matsuda (2020) mainly focus on uncertainty in ability and labor market opportunities to explain dropouts.

This paper contributes to the literature by identifying an unexplored aspect of financial uncertainty within college: the uncertainty in grant amounts that students receive throughout their academic years. Through quantitative investigation of this channel, I reassess the role of financial constraints in present-day college participation decisions. In doing so, I uncover a novel policy scope for improving college graduation rates within the grants system, underscoring the significant policy implications of accounting for this aspect of financial uncertainty in the study of dropouts. Using representative administrative data, I show that students lose grants as they progress in college, which increases their probability of dropping out. I incorporate grants uncertainty alongside other channels, including incomplete information about academic ability and labor market productivity, in an overlapping generations model with endogenous college enrollment and dropout decisions. I find that uncertainty in grants can explain 43% of dropouts, indicating its first-order importance in policy. Moreover, within the general equilibrium setting, I show that reducing grant uncertainty can increase quantity and quality of college graduates, resulting in a welfare improvement of 2.4% - 3.4%. The self-financing nature of this policy, driven by the resulting increase in tax base, makes it a cost-effective and compelling instrument for improving college graduation rates.

In the empirical analysis, using the 1979 and 1997 cohorts from the National Longitudinal Survey of Youth (NLSY), I document that family wealth has become a stronger predictor of college participation over the last 20 years. Nowadays, students with lower family wealth are less likely to enroll in college, as shown in Belley and Lochner (2007), and more likely to drop out, even when controlling for ability. This feature contrasts with the limited role family wealth played in college participation margins in the early 1980s. This fact that nowadays being from a disadvantaged family background influences not only the enrollment margin but also the dropout margin highlights that the financial situation of poor students may involve uninsurable volatility across academic years. To explore this possibility, I use representative administrative data from the Beginning Postsecondary Students Longitudinal Study (BPS), which follows first-time students for 6 academic years. I show that up to 30%-45% of first-time, full-time students who qualified for Pell grants in their first academic year and satisfied all academic eligibility criteria to continue receiving them lost the original amount during the following academic year.[1] Scholars and policymakers have posited that the intricacy and inconvenience associated with

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[1] Importantly, I show that the probability of maintaining grants is not correlated with students' GPA, conditional on meeting academic eligibility criteria, suggesting that ability does not explain why a large fraction of students cannot maintain grants.

this government program deter many individuals from participating in it (Dynarski and Scott-Clayton (2006), Bettinger et al. (2012), Dynarski et al. (2021)).[2] Yet, losing grants may have a larger negative impact on poorer students, given that grants constitute the largest fraction of their total college finances, and that they have slim alternative sources to self-insure. I formalize this hypothesis in the reduced form analysis, where I show that losing all or a portion of the grant is associated with an increased probability of dropping out.

Based on these empirical findings, I ask the following questions: what fraction of the observed dropout rates can be explained by the volatility embedded in the current grant system? What remaining fraction arises due to other factors commonly examined in the literature, such as learning about academic ability and labor market opportunities? Is there a policy space to improve college graduation rates? How costly would such policies be for the economy? Which socio-economic group would benefit from such policies and which group would lose?

To address these questions, I incorporate endogenous education decisions within a general equilibrium full life-cycle framework. The framework comprises three distinct stages: college choice, work, and retirement. Newborn individuals make enrollment decisions based on their initial wealth, prior beliefs about their abilities, and idiosyncratic productivity shocks. Once enrolled in college, students reassess the value of college and may potentially drop out. Dropout channels include (1) learning about their abilities through grades, (2) labor market productivity shocks, and (3) observing the grant amounts they qualify for in the upcoming period. A key modeling choice that complements the literature is the variation in grants between academic years. Grants amounts are affected by two channels: (1) GPA and (2) an exogenous stochastic shock, capturing unexplained variations in the grant system across academic years.

The first channel, the GPA-grant relationship, captures the impact of a student's low college GPA on their budget within the current grant system. Therefore, the dropout decision after receiving a low GPA might arise not only from an updated belief about ability, a channel well-explored in the literature, but also from a tightened budget constraint. The second channel, the exogenous stochastic shock, captures the fact that a considerable number of academically-eligible students lose their grants, and may therefore drop out due to borrowing constraints. Thus, the model identifies two new crucial channels that impact college dropout decisions. Overlooking these channels can result in an overestimation of the role of ability and an underestimation of the role of financial constraints, potentially missing the availability of cost-effective and direct policy instruments.

College participation decisions are then integrated within an overlapping generations production economy. Individuals' education choices shape the college wage premium through general equilibrium wage effects as college graduates are imperfect substitutes to both college dropouts and high-school-educated individuals in the representative firm's production function. Given that the college wage premium is a direct source of incentives for pursuing higher education, a general equilibrium framework is essential for an accurate evaluation of the long-run impact of large-scale educational policies.

I calibrate the model to match the key moments of educational attainment in the US, includ-

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[2] Recent research in psychology and economics suggests that implementing strategic and relatively inexpensive adjustments in choice architecture, commonly referred to as "nudges" (Sunstein and Thaler (2008)), can yield substantial and enduring effects on program participation.

ing college enrollment, completion rates, and the skill premiums. To pin down college dropout channels, I proceed as follows. I estimate the uncertainty of grants by quantifying how grants vary across academic years, while controlling for observable eligibility criteria in the data. I obtain GPA thresholds at which students are disqualified from grants from the data. Students' beliefs regarding their abilities are pinned down using empirical estimates from Stinebrickner and Stinebrickner (2014). I base the idiosyncratic component of productivity on data estimates, while I internally calibrate the ability and education contingent labor market fixed effects to match the skill premiums in the data. In validation exercises, the model successfully matches with the empirical estimates regarding the elasticities of college participation in response to subsidy changes, as found in Deming and Dynarski (2009) and Scott-Clayton (2011). Additionally, the model closely matches untargeted moments, such as college participation patterns by family wealth and earnings distributions observed in the data.

Using the calibrated model, I first investigate the effects of adverse shocks in college on various wealth-ability groups. Analyzing dropout behavior shows that having high initial wealth or a high ability prior mitigates the pivotal power of adverse shocks that make dropout decisions optimal. However, high-ability asset-poor individuals remain largely vulnerable to the negative shocks to grant availability, as they cannot self-insure and, consequently, drop out. This challenges the prevailing notion that marginal students are exclusively those with lower ability. Recognizing all dimensions of marginal students is crucial for policy discussions.

To understand what fraction of students drop out due to each reason, I use the model to disentangle the roles of ability, the uncertain nature of grants, and productivity shocks in observed dropout rates. I do so by eliminating one dropout channel at a time while keeping taxation and skill prices at their benchmark values and quantifying the resulting change in college participation margins. I find that eliminating both grants' stochasticity and GPA requirements decreases college dropout rates by 43%, while eliminating one at a time reduces dropout rates by 34% and 5%, respectively. On the other hand, I find that learning about ability explains only 10% of the total dropout rates. The finding that a large fraction of students drop out due to the grant system defines a clear scope for policy intervention.

Lastly, I consider alternative governmental policies aimed at reducing grant uncertainty. I demonstrate that reducing uncertainty in grant allocation leads to improved aggregate productivity in the economy in the long run, as both the quality and quantity of college graduates increases. This improvement in sorting is due to the fact that more poor, high-ability students can now afford to graduate from college. Under these policy reforms, the welfare of newborns improves by 2.4% and 3.4%. It is crucial to emphasize that this increase in welfare is driven not only due to reduced uncertainty individuals face through a stable grant system, but due to increased productivity owing to a higher quality of graduates in the economy. The results show that eliminating uncertainty in the current grant system is cost-effective for the government. The increased cost of a more stable grant system is offset by an increase in the tax bases of consumption, capital gains, labor income, resulting in the reduction of the budget-balancing tax rate. Interestingly, the long-term effects of the policy reforms reveal a shift in dropout patterns from low-income, high-ability individuals to high-income, low-ability individuals, improving sorting in college due to a reduced skill premium, while the overall dropout rates remain almost the same as in the status quo. These findings underscore the significance of examining the underlying ability distribution of dropouts, as it strongly shapes the policy space and its implications.

Related Literature. The paper relates to several areas of literature. Firstly, it is closely related to an expanding body of literature that studies the problem of dropouts, including the works of Lee, Shin, and Lee (2015), Ozdagli and Trachter (2015), Arcidiacono et al. (2016), Hendricks and Leukhina (2017), Hendricks and Leukhina (2018), and Matsuda (2020). Generally, these studies concentrate on the significance of learning about ability as a major factor leading to dropouts. I contribute to this discourse by specifically considering the variability of grants across academic years, which allows financial factors to be taken into account when making decisions about college dropout. Furthermore, apart from Matsuda (2020), I augment these studies by employing a general equilibrium framework, which is essential for policy analysis.

A set of papers, such as those by Caucutt and Kumar (2003), Akyol and Athreya (2005), Hanushek, Leung, and Yilmaz (2004), Castex (2017), and Athreya and Eberly (2021), Blandin and Herrington (2022) model dropout as exogenous risk. This paper contributes to this literature by considering endogenous dropout channels. The sequential papers by Ionescu (2011), Chatterjee and Ionescu (2012), and Matsuda and Mazur (2022) address student loans in the context of endogenous dropout risk, while Garriga and Keightley (2007) models endogenous dropout decisions and quantifies the impact of increased subsidy rates on educational attainment and macroaggregates. Differing from the last four papers, this paper allows for factors beyond ability learning to play a role in dropout decisions, specifically the uncertainty about grants and the relationship between grants and academic performance.

In the macroeconomic literature, Benabou (2002), Bovenberg and Jacobs (2005), Krueger and Ludwig (2013), Krueger and Ludwig (2016), Heathcote, Storesletten, and Violante (2017), and Abbott et al. (2019) study the importance of education policies for inequality and welfare from a macro perspective. However, they do not take the dropout margin into consideration. Another recent important contribution of Colas, Findeisen, and Sachs (2021) studies the optimal design of a need-based grants system in a rich quantitative macro model. I complement their paper by allowing time-varying grants, modeling various dropout channels, and quantify their implications on overall macroeconomic efficiency in the general equilibrium context. I complement their findings by studying endogenous dropout decisions in a general equilibrium setting, taking precollege preparedness as given, and focus on adverse shocks at college.

This paper also relates to the substantial body of empirical work that examines the relationship between family wealth and college success probabilities. This includes studies by Cameron and Heckman (1998), Carneiro and Heckman (2002), Cameron and Taber (2004), Belley and Lochner (2007), Lochner and Monge-Naranjo (2011), and Bailey and Dynarski (2011). This paper adds to this literature by documenting an increasing influence of family wealth on college success, consistent with the findings of Belley and Lochner (2007), Lochner and Monge-Naranjo (2011), and Bailey and Dynarski (2011). I contribute to the initial two papers by incorporating an analysis of graduation rates alongside college attendance. Furthermore, I examine education outcomes at a later age (mid-30s). This allows for a more comprehensive understanding of the relationship between wealth and educational attainment, as well as a more thorough comparison between the NLSY79 and NLSY97.

Finally, this paper relates to important recent contributions that emphasize the complexity of grants, including studies by Dynarski and Scott-Clayton (2006), Bettinger et al. (2012), and

Dynarski et al. (2021). Bettinger et al. (2012) and Dynarski et al. (2021) demonstrate, through the use of experimental designs such as hiring professional assistants for grant applications or guaranteeing grant availability, that increasing certainty in grants ultimately benefits potential students by fostering higher levels of enrollment and persistence. I complement this literature by quantifying grant uncertainty in the administrative data and studying the macroeconomic implications of large-scale governmental policies aimed at reducing grant uncertainty.

The paper is organized as follows. Section 2 analyzes representative, longitudinal samples of the 1979 (NLSY79) and 1997 (NLSY97) cohorts in order to document that financial background matters in ex-ante college completion probabilities. Then, using the Beginning Postsecondary Education data, the analysis illustrates how uncertain are grants between academic years and its association with dropping out. Section 3 describes the model. Section 4 presents the calibration strategy. Section 5 examines the model's behavior and conducts validation exercises. Section 6 investigates how the dropout decisions of distinct wealth-ability groups are shaped and decomposes the relative importance of each channel in explaining observed dropout patterns in the US. Finally, Section 7 quantifies potential governmental policies that target dropout rates and evaluates its impact on macroeconomic variables, welfare, and sorting.

2 Empirical Analysis

Recent policy recommendations argue that government policies should shift the focus on improving college preparedness of children coming from lower-income backgrounds, rather than expand federal student aid for the same income group. These policies are based on influential empirical papers examining the role of borrowing constraints in post-secondary education, such as Cameron and Heckman (1998), Carneiro and Heckman (2002), and Cameron and Taber (2004). However, their conclusions are drawn from an analysis of the National Longitudinal Survey of Youth of 1979, when the cost of education was significantly lower, governmental Pell grants were covering seventy percent of college tuition, and ten weeks of full-time work was enough to earn annual college tuition fees. Consequently, low family income did not seem to be detrimental in college success probabilities at the time.

In this section, I show that financial background has an increasingly important role in predicting college success probabilities, and at present students from economically disadvantaged backgrounds experience uninsured financial shocks at college. Using the most recent NLSY97, I empirically document that family wealth positively affects the probability of college completion, even after controlling for ability and other family characteristics. For completeness, I also examine the NLSY79, confirming the previous findings that in the 80s, family wealth matters less, if at all, in college participation margins. Exploring why poorer students may drop out reveals that their main income source for college is grants – they constitute up to half of their total college budget. I further document that the grant system is characterized by substantial volatility. As a case in point, between 30%-40% of academically eligible students lose maximum Pell grants, excluding dropouts. Losing grants is associated with higher risk of dropping out controlling for academic performance. These results all pose a potential scope for policy intervention, investigated thoroughly in the quantitative part of the model.

2.1 The Role of Family Income on College Dropout Probabilities

To examine the family wealth–college participation relationship, I use two longitudinal datasets, the NLSY79[3] (older cohort) and the NLSY97[4] (younger cohort). Both studies collect data on a wide range of topics, including parental background, ability, and education. The NLSY79 study began in 1979 and follows a sample of individuals who were born between 1957 and 1964. At the time of their last interview used in this paper, 2014, their ages ranged from 49 to 58 years old. The NLSY97 study began in 1997 and follows a sample of individuals who were born between 1980 and 1984. At the time of the last interview used in this study, 2017, respondents were between 32 and 35 years old.

For this analysis, I employ the methodology implemented in Carneiro and Heckman (2002). Specifically, I divide each sample into three groups by their ability terciles,[5] and for each group, I regress a college participation margin (enrollment/dropout) on the family income[6] quartile dummies, together with ex-ante family characteristics such as parental education, family structure, and type of household residence. This is formally specified in equation 1, where Y_i represents the outcome variable as an indicator of college enrollment or dropout decision of an individual i. The independent variable, X_i, is a set of dummy variables representing the family income quartiles, and the control variable, Z_i, is a set of ex-ante family characteristics. In such a specification, the sign and size of the coefficients of the family income dummies would inform the extent to which belonging to a lower income group affects college outcomes relative to the highest income group (i.e., the omitted category). The regression equation is:

$$Y_i = \alpha + \beta X_i + \beta^f Z_i + \epsilon_i. \tag{1}$$

For both datasets, I use representative respondents. I drop respondents with missing values of valid AFQT and family income as of the first survey date (or at the age of 17). I use parental education, place of residence, single-parent upbringing, and the number of siblings as control variables of family background. In all regressions, I control for gender and race. To conserve space, I provide a more detailed description of the control variables used across those two surveys in appendix A.2.

Tables 1 and 2 present the results of this strategy, where the estimated gaps by family wealth quartiles are measured relative to the top quartile, and adjusted for previously mentioned controls. Specifically, panel A in Table 1 reports the gaps in college enrollment, and panel B reports the gaps in college dropout rates for the NLSY79 sample. Table 2 reports the same for the NLSY97, while taking into account the quality of the college. Specifically, panel A (B)

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[3] The NLSY79 sample consists of 12686 individuals born between 1957 and 1964, out of whom 6111 belong to a representative, cross-sectional sample, designed to represent the civilian segment of people living in the US in 1979.5295 respondents are oversampled minorities such as Hispanic or Latino, Black, and economically disadvantaged non-Black/non-Hispanic. The remaining 1280 respondents were drawn to represent the population serving in one of the four branches of the US military. In my analysis, I solely concentrate on a cross-sectional sample.

[4] Similarly, the NLSY97 surveys 8984 individuals, born between 1981 and 1984, out of whom 6748 are a representative, cross-sectional sample.

[5] The ability of individuals is assessed through their AFQT test scores, as detailed in Appendix A.1. Moreover, the robustness of the results is confirmed by alternative measures, such as the PIAT (or Peabody Individual Achievement Test) test scores.

[6] While the NLSY97 provides information on both family income and family wealth, I use family wealth as it allows for a more rigorous characterization of the family's financial condition.

presents the estimates for enrollment at (dropout from) a 4-year college, and panel C (D) presents respectively enrollment at (dropout from) any college, i.e., without distinguishing between 2 and 4-year colleges.

Comparing the two tables, it can be observed that the estimated effects of family income are significant for the younger cohort but generally insignificant for the older cohort. For the NLSY79 sample shown in Table 1, family income plays a small and statistically insignificant role in determining college attendance and completion for the highest ability-lowest family income group. The estimated probability gap of dropping out for this group is 0.13 percentage points higher compared with their richest counterparts. Nevertheless, a joint F-test – in the last row of each panel – shows that the overall effects are insignificant, as the null hypothesis that all gaps are equal to zero cannot be rejected. This finding is consistent with Carneiro and Heckman (2002), who show that controlling for family background characteristics leaves family income redundant in explaining college participation margins.

Table 1: NLSY79 representative sample. Gaps in enrollment and completion of 4-year degrees (measured from the highest income quartile) conditional on parental education, number of siblings, urban, gender and race dummies.

	AFQT Tercile 1	AFQT Tercile 2	AFQT Tercile 3	All
		Panel A _ College Enrollment		
q1	-0.0025	0.0236	0.03740	-0.0842^{***}
Std.Err.	(0.0501)	(0.0443)	(0.0310)	(0.0238)
q2	-0.0141	-0.0843^{**}	-0.0100	-0.0976^{***}
Std.Err.	(0.0490)	(0.0397)	(.0.0260)	(0.0218)
q3	-0.0269	-0.0127	-0.0127	-0.0424^{**}
Std.Err.	(0.0494)	(0.0365)	(0.0221)	(0.0202)
All Gaps = 0	$F(3,1180)=0.1034$	$F(3,1377)=0.5258$	$F(3,1487)=0.959$	$F(2,2876)=16.4260^{***}$
		Panel B _ College Dropout, Bachelor degree		
q1	0.0543	0.0810	0.1329^{***}	0.1363^{***}
Std.Err.	(0.0846)	(0.0575)	(0.0483)	(0.0329)
q2	0.0552	0.0026	0.0620	$0.0666**$
Std.Err.	(0.0836)	(0.0531)	(0.0402)	(0.0298)
q3	0.0171	0.0277	0.0409	0.0504^{*}
Std.Err.	(0.0829)	(0.0464)	(0.0338)	(0.0261)
All Gaps = 0	$F(3,339)=0.3148$	$F(3,768)=0.7448$	$F(3,1269)=6.3666^{**}$	$F(3,2396)=12.5304^{***}$

Note: Ability is measured by Armed Force Qualification Test (AFQT) scores. Within each ability tercile, I regress college enrollment (dropout) on family background and dummies of family wealth quartiles. All gaps are measured relative to the highest family wealth quartile within each ability tercile. q1(q2,q3) denotes gaps in enrollment (dropout) between quartiles 4 and 1 (2,3). Each of the first three columns in these Tables represents a different AFQT tercile. The last column with the title "All" shows the gaps in college enrollment (dropout) for the entire population, without dividing it into different AFQT terciles. The last line of each panel presents a joint F-test that all gaps are equal to zero. $*$, $**$, $***$ denote statistical significance at the 10, 5, and 1 percent, respectively. The methodology is taken from Carneiro and Heckman (2002).

In contrast to the older cohort, the role of financial background is instead more pronounced in the younger cohort. In the bottom ability – bottom family wealth group, individuals have a 16 percentage point lower probability of enrollment at a 4-year college relative to the bottom ability – highest wealth quartile family group. For individuals with abilities in the middle and highest terciles, these gaps amount to 26 and 17 percentage points, respectively. Not surprisingly, at the same time, it can be observed that the higher is the income group the lower the gap of college participation margins are relative to the default category.

Table 2: NLSY97 gaps in enrollment across family wealth, dropout, 4-year or 2-year and 4-year colleges, conditioning on parental education, number of siblings, urban.

	AFQT Tercile 1	AFQT Tercile 2	AFQT Tercile 3	All
Panel A _ College Enrollment, Bachelor degree				
q1	-0.1604^{***}	-0.2676^{***}	-0.1728^{***}	-0.2845^{***}
Std.Err.	(0.0459)	(0.04918)	(0.0405)	(0.0267)
q2	-0.1668^{***}	-0.2239^{***}	-0.0359	-0.2162^{***}
Std.Err.	(0.0448)	(0.0437)	(0.0332)	(0.0241)
q3	-0.1518^{***}	-0.1154^{***}	-0.0469^{*}	-0.1227^{***}
Std.Err.	(0.0479)	(0.0410)	(0.0276)	(0.0227)
All Gaps = 0	$F(3,951) = 14.8261^{***}$	$F(3,1031) = 29.4676^{***}$	$F(3,1338) = 11.0536^{***}$	$F(3,3144) = 105.5945^{***}$
Panel B _ College Dropouts, Bachelor degree				
q1	0.1178	0.4016^{***}	0.1251^{**}	0.2550^{***}
Std.Err.	(0.1182)	(0.0716)	(0.0543)	(0.0396)
q2	0.1569	0.2630^{***}	0.0850^{**}	0.1662^{***}
Std.Err.	(0.1138)	(0.0618)	(0.0410)	(0.0333)
q3	-0.0691	0.1876^{***}	0.0382	0.0912^{***}
Std.Err.	(0.1192)	(0.0530)	(0.0333)	(0.0282)
All Gaps = 0	$F(3,175) = 0.4683$	$F(3,521)^{***} = 32.4386$	$F(3,916)^{***} = 6.6494^{***}$	$F(3,1636) = 42.0546^{***}$
Panel C _ College Enrollment, 2 year & 4 year				
q1	-0.1819^{***}	-0.1973^{***}	-0.0711^{**}	-0.2213^{***}
Std.Err	(0.0572)	(0.0429)	(0.0287)	(0.0250)
q2	-0.1370^{**}	-0.1417^{***}	-0.0202	-0.1471^{***}
Std.Err.	(0.0558)	(0.0381)	(0.0235)	(0.0225)
q3	-0.1661^{***}	-0.0974^{***}	-0.0162	-0.0909^{***}
Std.Err.	(0.0596)	(0.0358)	(0.0194)	(0.0212)
All Gaps = 0	$F(3,951) = 9.796^{***}$	$F(3,1031) = 20.0448^{***}$	$F(3,1138) = 3.9061^{***}$	$F(3,3114) = 65.7215^{***}$
Panel D _ College Dropout, 2 year & 4 year				
q1	0.1900^{**}	0.3243^{***}	0.1249^{**}	0.2410^{***}
Std.Err.	(0.0820)	(0.0580)	(0.0488)	(0.0331)
q2	0.2129^{***}	0.2409^{***}	0.0698^{*}	0.1851^{***}
Std.Err.	(0.0780)	(0.0504)	(0.0388)	(0.0288)
q3	0.0756	0.1527^{***}	0.0260	0.0890^{***}
Std.Err.	(0.0844)	(0.0463)	(0.0317)	(0.0257)
All Gaps = 0	$F(3,393) = 5.0246^{**}$	$F(3,774) = 32.1769^{***}$	$F(3,1045) = 5.9862^{**}$	$F(3,2236) = 105.5945^{***}$

Note: Ability is measured by Armed Force Qualification Test (AFQT) scores. Within each ability tercile, I regress college enrollment (dropout) on family background and dummies of family wealth quartile. All gaps are measured relative to the highest family wealth quartile within each ability tercile. q1(q2,q3) denotes gaps in enrollment (dropout) between quartiles 4 and 1 (2,3). Each of the first three columns in these Tables represents a different AFQT tercile. The last column with the title "All" shows the gaps in college enrollment (dropout) for the entire population, without dividing it into different AFQT terciles. The last line of each panel presents a joint F-test that all gaps are equal to zero. *, **, *** denote statistical significance at the 10, 5, and 1 percent, respectively. The methodology is taken from Carneiro and Heckman (2002).

Next, in panel B, Table 2, I examine dropping out probabilities for a bachelor's degree. The table shows that individuals from the middle ability tercile are affected largely by their family income: they are 40% less likely to stay enrolled in college than their rich counterparts. As for the highest ability group, their dropping out probability is still 12% more as compared to their rich counterparts. It is worth noting that significant wealth effects on college dropout probabilities cannot be observed among poor and low ability students (second column of panel B, Table 2). This can be explained by the fact that only a few students enroll at a bachelor's degree from the first ability tercile (67, 48, 34, and 38 individuals respectively from the lowest to the highest family wealth quartiles),[7] and therefore, the estimates for their dropping out probabilities (conditional on enrollment) are imprecise.

When examining participation in any college, including both 2-year and 4-year institutions, a consistent qualitative relationship between family wealth and college outcomes is observed. This is evident from panel C and panel D in Table 2. Specifically, family wealth plays a significant role in determining whether students attend college, although the effect may be less pronounced for 2-year colleges due to their lower costs. Overall, the data suggest that family wealth remains a key factor in determining college participation, regardless of the type of institution attended.

In conclusion, the analysis of NLSY79 and NLSY97 databases indicates that family income's significance in post-secondary education success has significantly increased over the years, even after accounting for ability. Family income's role is mitigated for the highest ability tercile group across all college participation levels, suggesting that ability is a strong asset for college success. However, high ability alone cannot offset the negative effects of a low financial background on college success probabilities, as seen in the early 1980s. Today, low-income students face decreased college success probabilities, including enrollment and graduation, due to their low-level wealth background.

2.2 College Financing in NLSY97

To understand why family wealth remains a significant predictor of college completion probabilities in NLSY97, conditional on enrollment, I next explore how students in this sample finance their education. In particular, I am interested in how poor students' financing options compare with those of their wealthy counterparts.

The NLSY97 survey groups the sources students use to finance their education into the following seven categories: family transfers for education purposes, family loans, financial assistance received from institutional sources such as grants or scholarships (henceforth grants), subsidized or other types of loans, work-study, employer assistance, and out-of-pocket payments.[8]

To get a better idea of which sources poor students rely on the most, Figure 1 presents the relative proportion of each source for each family wealth quintile. The amounts are broken down by main sources: out of pocket payments, loans, grants and family aid.[9] For poor students, family contributions constitute only 9% of their college funding, with the bulk of their financial support coming from grants (52%) and loans (31%). This means that an overwhelming 91% of college funding for these students stems from what I term 'external sources,' defined as sources that require specific steps for qualification, maintenance, or earning. In contrast, students from wealthier families primarily finance their college education through parental transfers (54%), followed by grants (25%), and loans (13%).

Moreover, the relative importance of grants to students' total finances for college across family wealth is reaffirmed by representative administrative data from the Beginning Postsecondary Student data, provided by the National Center for Education Statistics. Table 3 displays the

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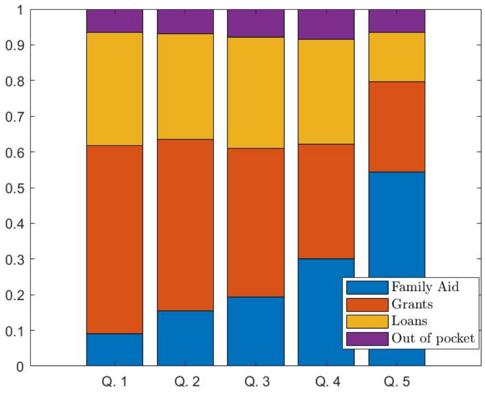
[7] In the bottom ability tercile, the number of individuals from the lowest to the highest family quartiles are respectively 155, 120, 69, and 61.

[8] I express the students tuition expenditure across years in terms of 2000 US dollars, using the chain-weighted (implicit) price deflator for personal consumption expenditure, published by the BEA. Further details about the sources and the data cleaning procedures can be found in appendix A.1.

[9] For simplicity in illustration, I exclude other sources as they constitute only a small fraction of total finances.

Figure 1: Sources of finances by family wealth – NLSY97



Note: I divide students according to their family wealth quintiles. For each group, I calculate annualized average amounts they get from different sources to finance college, including family transfers, grants, loans, and out of pocket payments. For the poorest (richest) quintiles, family transfers account for 8% (50%) of the total finances they have for college. Grants constitute 52% (25%) of the total finances for the poorest (richest) quintile students.

distribution of grants in relation to total college finances for different family wealth quintiles. It indicates that grants constitute approximately 49% and 42% of the total college finances for individuals in the lowest and second family wealth quintiles, respectively. Conversely, grants contribute to merely 19% of the total income distribution for those in the top quintile. These findings are consistent with the earlier analysis using the NLSY97 cohort data, further establishing that grants serve as the main financial resource for students from economically disadvantaged backgrounds.

2.3 Grants Uncertainty

In light of the previous findings that (1) poor students are more likely to drop out of college, even controlling for their ex-ante family characteristics and ability, and (2) that grants constitute a larger fraction of their college income, I now turn to examine how likely it is for college entrants to maintain the amount of grants they are qualified for during the first year of their college degree. This is a crucial consideration, as poor students heavily rely on grants to finance their education. Therefore, if these subsidies prove challenging for students to maintain, it may disproportionately impact their college persistence decisions.

To do so, I examine the Beginning Postsecondary Student (BPS) data from the National Center for Education Statistics, which specifically surveys first-time students enrolled in post-secondary education institutions. The BPS follows respondents for a total of six years, interviewing students at the end of their first, third, and sixth year of college. Importantly, this survey is integrated with individual-level data from official records, including college entrance exam scores (from the ACT and College Board), financial aid information (from the FAFSA), and aid disbursement information (from the National Student Loan Data System). Finally, the BPS also provides detailed information on enrollment patterns and degree attainments.

Using this data, I can evaluate the actual proportion of students who not only qualify for and

Table 3: Total grants, merit-based and need-based grants as a share of total cost by ability and wealth

Ability Quintiles	Total Grants
Q 1	35
Q 2	31
Q 3	32
Q 4	34
Q 5	35

Wealth Quintiles	Total Grants
Q 1	49
Q 2	42
Q 3	23
Q 4	20
Q 5	19

Note: Ability quintiles are measured by SAT grades, and Family wealth quintiles are measured by Expected Family Contribution (EFC). Total Grants, merit-based grants, and need-based grants are normalized by a student budget in each respective subgroup. Source: Data from the Biginning Postsecondary Education data, the National Center of Education Statistics.

receive a grant during their first academic year but also maintain it throughout their studies. By working with non-restricted BPS data, I can track need-based subsidies exclusively, such as Pell grants, which are part of the federal financial aid system. In the following section, I will also outline the patterns of merit-based grants.

I examine the 2003-2004 cohort, restricting the sample to first-time, full-time students under age 22 who enrolled directly in a 4-year college.[10] Specifically, I investigate what fraction of students maintains the grants across years – both unconditionally and controlling for eligibility requirements, such as academic progress and labor income.[11] In this respect, it is important to specify that students meet the satisfactory academic progress when (1) they have a GPA higher than 2.00, and (2) accumulate a full-time number of credits (equal or more than 24 credit hours within the corresponding academic year). On top of that, I observe how much an individual earns in each academic year, which further affects grant eligibility.

Panel (a) in Table 4 describes the share of students maintaining the grants for their second academic year, i.e. in 2004-2005. The fraction refers to the recipients of the maximum Pell grants, computed according to the initial number of recipients during the first year. In the first column, unconditional shares are presented. The second column shows the share of academically-eligible students who maintained the maximum Pell grants. Finally, the third column shows the fraction of students maintaining the grants by restricting the sample only to those who are academically-eligible and also meet earnings requirements. According to column (1), approximately 57% of students maintained the maximum Pell grant from the first to second academic year, while around 16% lost it. This share increases to 65% if I control for academic progress requirements, and to 67% if I further control also for earnings. This suggests that

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[10] For calibration purposes, I examine a more recent cohort, specifically the 2011-2012 cohort, and the results remain robust across cohorts.

[11] Detailed requirements for getting and maintaining the Pell grants are outlined in appendix C.

Table 4: Percentage of 2003-2004 students who received full Pell grants again in their second and third year by proportion of Pell grants

Grants transition from 2003-2004 into 2004-2005

	Unconditional	Controlling for academic progress	Controlling for academic progress and earnings
No Pell	16.02	9.37	8.67
Partial Pell	27.31	26.89	25.87
Full Pell	56.67	64.80	65.45

Grants transition from 2003-2004 into 2005-2006

	Unconditional	Controlling for academic progress	Controlling for academic progress and earnings
No Pell	25.81	8.76	8.43
Partial Pell	30.49	29.69	30.39
Full Pell	43.70	61.55	61.17

Note. Selected sample: Degree program in 2003-04 is Bachelor; students younger than 22; Recieved Pell Grants (More than \$4,000); Controlling for academic requirements to maintain the grants: (1) Grade point more than 2.00; (2) Total credit hours more than 24. Meeting financial requirements: (1) Job 2004 - Earnings (include work study) less than \$6,400.
Source: US Department of Education, National Center for Education Statistics, 2003-04 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:04/09).

academic progress requirements seem to be binding for a non-negligible share of students, while earnings do not play an essential role in explaining the loss of the Pell grants.

Panel (b) repeats the analysis by looking at the status of the grant in the third year. Only 44% managed to successfully maintain the grant after two years, while 25% lost it completely. As seen in the 2004-2005 academic year, also in this case, controlling for academic progress plays a crucial role in maintaining the grant. Among only those meeting the academic requirements, 65% maintained the grants, while 9% lost them. Finally, column (4) of panel (b) shows that the proportions are robust to controlling for students' earnings as part of the Pell grant eligibility criteria.

Examining the representative BPS data indicates that maintaining the grants is not a straightforward process for students. Controlling for academic progress requirements and financial background requirements only partially explains why access to grants declines over the years. It can also be that Expected Family Contributions (EFC) change between academic years, causing some to lose their grants. However, since 30% of students have a zero EFC, and EFC is truncated below zero, indicating financial hardship, it is unlikely that changes in EFC can explain a significant portion of the remaining residuals.[12] Hence, I argue that the reason why students lose their grants lies in the opaque process associated with the reapplication.

To reapply for Pell grants each academic year, students are required to fill out the Free Application for Federal Student Aid (FAFSA), a thorough survey with 121 different questions that covers the financial status of both the student and their family. The grant authorities use this application to calculate the Expected Family Contribution (EFC), which is often difficult to predict. It is important to note that the income and asset thresholds at which Pell grants start to diminish are not provided to applicants. After submitting the FAFSA, it takes up

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[12] This aligns with existing literature that suggests parental wealth and income are relatively stable across years.

to one to two months for the application to be reviewed and accepted. During this time, students should respond promptly to any emails to avoid delays. Additionally, 30 percent of initial applicants are selected for a verification step, which requires them to provide additional financial documents. If the verification is completed successfully, the student may qualify for the grant. The extensive bureaucracy associated with the continuation of Pell grants may be the reason why many academically advanced students lose them after only one or two years, as noted in Table 4.

Merit-based grants are also not guaranteed between academic years. Though, the BPS data does not provide information how the merit-based grants evolve, a couple of micro-empirical papers show that they dwindle over the years even more rapidly than the Pell grants, and approximately half of students eventually lose them. To illustrate, Carruthers and Özek (2016), by exploiting the Tennessee Education Lottery Scholarship, show that out of 40,000 students with HOPE scholarships, 42% eventually lost them. Moreover, they find that losing financial aid has a negative effect on students' post-secondary education engagement, especially at the extensive margin, which I examine for Pell grants in the next section. Looking at graduates from a high school in Georgia in 1995, Henry, Rubenstein, and Bugler (2004) also document that 66% of all HOPE recipients lost their scholarship due to GPA checkpoints, and that losing the scholarship eliminated positive effects of the grants on graduation from four-year institutions, thus suggesting that losing merit-based scholarships might compromise the initial gains of subsidies on college participation margins. Using administrative data, Scott-Clayton (2011) exploits the effects of the PROMISE scholarship in West Virginia on college completion margins. The scholarship is a high-value award, worth an average of approximately $10,000 over four years for those who initially qualify. She shows that approximately 25% of students lose the scholarship for a second year, and only 50% retain the scholarship for four years.

2.4 Losing Grants and Academic Outcomes

Hereby, I empirically investigate how losing all or partial grant affects the decision to drop out of college. I restrict the sample to those who got maximum Pell grants in their first academic year. They are first-time, full-time students enrolled in Bachelor's degree programs. This dataset comes from the Beginning Education Postsecondary Longitudinal Data. The regression is specified in equation 2:

$$\mathrm{Y}_{it} = \beta_1 \mathrm{Grants}_{it,Pell\in[0,\$1{,}500]} + \beta_2 \mathrm{Grants}_{it,\mathrm{Pell}\in(\$1{,}500,\$3{,}000]} + \beta_3 \Theta_{it-1} + \beta_4 \mathrm{X}_t + \epsilon, \qquad (2)$$

The dependent variable Y_{it} represents the outcome for an individual i in their t-th academic year following college entry. Specifically, it equals one if the individual is "Not enrolled at the end of period t."[13] The variables of interest are the loss of full grants in period t. To capture the extent of the loss, I define two brackets. The first bracket represents the lowest amount of grants, indicating that an individual has lost more than two-thirds of their initial Pell grants. The second dummy variable indicates that an individual loses more than one-third and less than two-thirds

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[13] Although not being enrolled full-time does not necessarily indicate that students have dropped out, the robustness of the results is maintained when considering graduation within a few years.

of their initial grants. The first bracket corresponds to a grant amount between \$0 and \$1,500, while the second bracket ranges from \$1,501 to \$3,000. The reference category represents the highest bracket, which corresponds to grant amounts between \$3,001 and \$4,050. Since the reference category is full grants, β_0 and β_1 show how the probabilities of college detachment are influenced by the loss of grants.

The control variable vector Θ_{it} comprises lagged academic performance, including GPA, and credit accumulation, which have direct and indirect impacts on grant eligibility and college discontinuation decisions. Using lagged academic progress variables, such as $t-1$ period grades, is a useful approach to mitigating reverse causality bias. Specifically, a student who plans to drop out in period t may not study at all in that period, resulting in poor grades.[14] Additionally, the inclusion of the variable X_{it} allows for controlling individuals who never enroll in Year t. Thus, the regression captures the impact of losing a grant in Year t on a student's decision to drop out in Year t, conditional on them being enrolled in college for at least a month.

The results are summarized in Table 5. Losing grants has statistically significant effects on the probabilities of college discontinuation. Those who lost two-thirds of their grants from Year 1 to Year 2 are 21% more likely to discontinue college in year 2 compared to those who maintained the full amount. The loss of only one-third of the grants also has a statistically significant impact on college discontinuation, increasing the likelihood of dropping out by 24% compared to those who were able to retain the maximum amount of grants. It is worth noting that the control variable X_{it} indicating "Not enrolled in Year t" works against finding an effect of grant loss on college exit. Some of those people might not have entered college in period t because of a withdrawn grant, and they are not accounted for in β_1. As expected, it can be seen that controlling for GPA and credit accumulation has a significant effect on college termination decisions.

Next, I proceed to analyze the scenario where individuals lose their grants in their third year. In this case, the control variables include GPA and credits for the second year, as well as a dummy variable indicating "Not enrolled in year 3." The results are summarized in column 2 of Table 5, and they exhibit qualitatively equivalent effects to those documented for the second year. The loss of grants in Year 3 leads to a 30% increase in the probability of college dropout, significant at the 1% level, while a reduction of one-third of the original grant amount is associated with a 10% higher probability of dropping out.

The evidence provided above, that a significant proportion of students lose their grants either due to GPA requirements or an opaque reallocation process, and that losing grants is linked to a higher likelihood of dropping out, is highly informative for my model. Based on this evidence, I assume that grants vary over the college years. First, I consider grants to be dependent on academic performance. Then, in order to account for students who lose their grants for reasons beyond academics, I incorporate stochastic shocks into the grant allocation system. These shocks are modeled using the transition probability of grants between academic years, which has been quantified from data. By leveraging this probability, I can accurately model the size and distribution of these shocks, which helps to capture the unpredictability of

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[14] It is also possible that such a student may exhibit poor academic performance in the period prior to that, i.e., $t-1$, knowing that they will drop out in period t. However, given the fixed cost associated with entering college in period t in terms of time and money, it is unlikely that this concern should be considered a primary factor.

Table 5: BPS students who received full Pell grants in their first year

Dependent: College discontinuation in Year t		
	t=2	t=3
$\text{Pell}_t \in [0, \$1,500]$	0.209***	0.305***
	(0.069)	(0.053)
$\text{Pell}_t \in (\$1,500, \$3,000]$	0.240***	0.102*
	(0.059)	(0.054)
GPA in $t-1$	-0.039**	-0.083***
	(0.0305)	(0.031)
Credits in $t-1$	-0.0076*	0.0001
	(0.0031)	(0.0603)
Not enrolled in year t	0.6558***	0.4589***
	(0.0806)	(0.067)
Earnings in year $t-1$	-0.0394***	–
	(0.0305)	–
Intercept	0.312***	0.2895***
	(0.0774)	(0.0766)

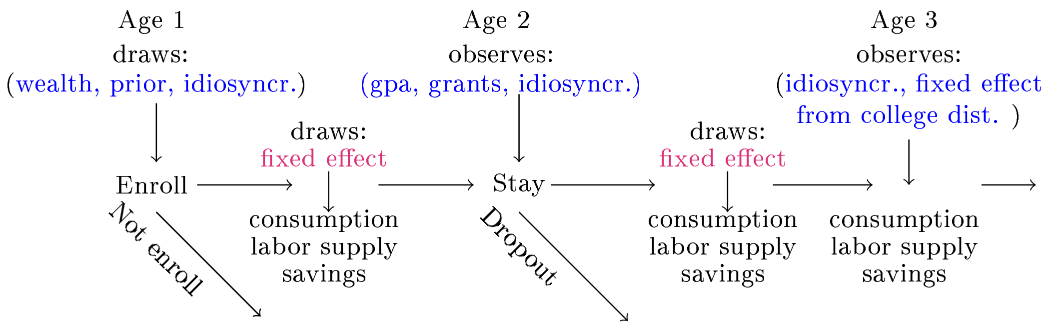
Note: Linear regression analysis of college discontinuation in academic year t on losing grants in year t, academic progress in year $t-1$ (GPA and credit accumulation), earnings in year $t-1$, enrollment at least one month in year t. The reference category includes the maximum Pell grant bracket for the Pell grant amount during period t.
Data: the U.S. Department of Education, National Center for Education Statistics, $2003-04$ Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:04/09).

grant loss and its impact on college discontinuation decisions.

3 The Model Economy

I consider an overlapping generations general equilibrium model. The model economy consists of individuals that are heterogeneous with respect to age, wealth, learning ability, education, and labor productivity, firms that produce a final good by hiring labor and capital on competitive spot markets, and a government that operates a tax system and a pension system. The key innovation of the model is the two-period college stage. Individuals make two education-related decisions: first, whether to enroll in college, and, second, whether to continue or to drop out of college. An individual's enrollment decision is based on her prior beliefs about ability and initial wealth. Once in college, a student can drop out, basing her decision on an ability signal (captured by college GPA scores), her labor market productivity, and, a novel dropout channel, the grants available to her. In particular, I model the second-period grant as a function of academic performance measured by the GPA as well as stochastic shocks. These features complement the existing macro literature, which usually models grants as a constant share of the tuition costs over time. As demonstrated in the empirical analysis, grants vary from year to year and have a tendency to decrease over time, thus potentially affecting individuals' willingness to continue college. Furthermore, I model the working and retirement stages to account for the long-term gains of college attendance in life-time earnings and risk. These stages are key in assessing welfare consequences in the long-run and the transitional paths of the general equilibrium.

Figure 2: Timeline of schooling decisions



3.1 Demographics

Time is discrete, indexed by t, and it goes forever. At any point in time, the economy is populated by J overlapping generations indexed by $j = 1, 2, \cdots, J$, where J denotes the maximum age. Individuals survive from age j to $j+1$ with probability ϕ_{j+1}. For simplicity, I assume that the survival rate before retirement is equal to one; agents face a death hazard once they retire, i.e., $\phi_j \in [0, 1)$ for $j \geq j_r$, where j_r denotes the retirement age. Let N_t denote the initial size of the cohort that enters the economy in period t; N_t grows at a constant rate n, i.e., $N_t = (1+n)N_{t-1}$. The relative share of each age cohort in the population is constant over time since the population growth rate is constant, and the age-specific survival rates are time-invariant. To ease aggregation later on, I define m_j as the population size of the age cohort j relative to the youngest cohort alive in the current period:

$$m_j := \frac{N_{t-j+1}\left(\prod_{i=0}^{j-1}\psi_i\right)}{N_t}.$$

Note that ψ_i captures the mortality risk in age i, discuss further below.

3.2 Timeline

In this section, I provide an overview of an individual's life-cycle, with emphasis on the two-period college stage depicted in Figure 2, before describing the main elements of the model.

Individuals enter the economy as high school graduates at age 1. They draw a prior on academic ability and an education-contingent initial wealth endowment,[15] based on which each individual decides whether to enroll into college or not. After enrollment decisions, they observe their productivity in the labor market and correspondingly make consumption-leisure-savings decisions. College lasts two periods. At the beginning of age 2, halfway through college, individuals reflect on their academic abilities, grant amounts, and labor productivity. In light of the incoming information, students update their beliefs on their ability and reassess the value of college. Based on their assessments, they either continue with a college education or drop out.

After the college continuation decision, individuals observe the remaining uncertainty on the labor market and make consumption-leisure-savings decisions accordingly. Those who remain in college are able to graduate. As of period 3, all individuals have finalized their education and

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[15] Initial wealth is an exogenous way of modeling parental transfers discussed below in details.

earn their education-specific (high school graduate, dropout, or college graduate) wages.

Finally, after working for 24 periods, the individuals retire (i.e., at the age of 66) and live on capital income and pension benefits. Following their retirement, individuals face mortality risk, and they die with certainty at period 40 (at the age of 98 years).

The rest of this section is organized as follows. First, I describe the belief system embedded in the model. Second, I describe the resource cost of college. I then illustrate the household's life-cycle decisions in detail.

3.3 Beliefs about ability

An individual enters the economy with a normally distributed prior about her true (yet unobserved) ability e_i. The mean of the prior is given by $\mu_{e0,i} = e_i + \alpha_e + \epsilon_{e0,i}$. The parameter α_e is a general optimistic bias that one has about true ability, common to all individuals.[16] Optimism is often named as a major determinant in college dropout decisions. Therefore, incorporating this element, allows the model to generate conservative dropout rates with respect to other dropping out channels that are novel to the literature. The noise $\epsilon_{e0,i}$ is distributed normally, $\mathbb{N}(0, \sigma^2_{e0})$. This implies that an individual prior has mean $\mu_{e0,i}$ and standard deviation σ_{e0}.

Individuals get their GPAs at the end of the first period of college. A GPA is contingent on heterogeneity, luck, and effort toward college. The first is captured by true ability, e_i, the second by the noise associated with grades, ψ_i, and the third is captured by one minus the time spent working in the labor market in period 1, $1 - l_{1,i}$. The assumption that working while in college may be detrimental to academic performance aligns with the large literature that isolates the causal impact of working hours on education attainment, including Scott-Clayton and Minaya (2016), Stinebrickner and Stinebrickner (2003), Wenz and Yu (2010), Darolia (2014), Bozick (2007). The GPA of an individual i is thus given by:

$$GPA_i = e_i + \lambda_l \max(l_{-1,i} - \underline{l}, 0) + \psi_i, \tag{3}$$

where $\underline{l}$ denotes the threshold amount of working hours that does not harm one's GPA,[17] and $\lambda_l < 0$ captures how strongly working in the labor market affects academic performance. The stochastic part of the GPA, ψ_i, is distributed normally with mean zero, and standard deviation $\sigma_{\psi,i}$. An individual who enrolls in college extracts a signal through GPA in the following manner:

$$\hat{S}_i = GPA_i - \lambda_l \max(l_{-1,i} - \underline{l}_i, 0). \tag{4}$$

Given the signal, she updates her beliefs in a Bayesian fashion given by equations (5) and (6). Since I assume that both the prior and the signal are normally distributed, the posterior is also normally distributed, with mean $\mu_{e1,i}$ and variance $\sigma_{e1,i}$.

$$\mu_{e1,i} = \frac{\sigma^2_{\psi,i}}{\sigma^2_{e0,i} + \sigma^2_{\psi,i}} \mu_{e0,i} + \frac{\sigma^2_{e0,i}}{\sigma^2_{e0,i} + \sigma^2_{\psi,i}} \hat{S}, \tag{5}$$

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[16] Failing to include the optimism parameter would underestimate the role of beliefs in dropout decisions.

[17] That captures the empirical evidence that working for a few hours a week $(15 - 20)$ does not affect negatively on GPA accumulation (Bozick (2007)).

$$\sigma^2_{e_1,i} = \frac{\sigma^2_{\psi,i}}{\sigma^2_{e_0,i} + \sigma^2_{\psi,i}} \sigma^2_{e_0,i}. \tag{6}$$

I assume that the variance of the prior, $\sigma^2_{e_0,i}$, is the same across all individuals, i.e., given the latter, $\mu_{e_0,i}$ is a sufficient statistic for capturing the distribution of the prior beliefs across individuals. In the following, I suppress the subscript i wherever it does not cause confusion.

3.4 Resource Cost of College

Governmental subsidies

In each period of college attendance, there is a resource cost that is incurred and represented by a portion, ι, of the skilled labor wage rate, $w_{t,c}$. Denote the fraction of that cost borne by the government in the first period in college by $z_1(a_c, \mu_{e_0})$. Note that $z_1(\cdot)$ is a function of parental transfers for college purposes, a_c, and an ability prior, μ_{e_0}. In particular, I model merit-based and need-based grants with separable functions, as they exhibit different uncertainty between academic years, i.e., $z_1(a_c, \mu_{e_0}) = z_1^{\text{need}}(a_c) + z_1^{\text{merit}}(\mu_{e_0})$.[18] Note that the government observes the mean of the individual prior, as it is assumed to be shaped by high school grades. The direct cost of attending college in the first period for an individual is therefore $\big(1 - z_1(a_c, \mu_{e_0})\big)\iota w_{t,c}$.

In the second period, students might not get the same grant amount as they did in the first year. This is because in the second period, the grants depend on their academic performance, and the stochastic shocks to their grants, ζ. The stochastic shock is motivated by the empirical analysis in section 2, where I show that even controlling for a set of eligibility criteria, students grants' are still characterized by significant volatility. The second-period grant is summarized as follows:

$$z_2\big(a_c, \zeta, GPA(l_{-1}, \hat{S})\big) = z_1^{\text{need}}(a_c)\mathbb{1}_{GPA \geq \overline{GPA}_{\text{need}}}\zeta + z_1^{\text{merit}}(\mu_{e_0})\mathbb{1}_{GPA \geq \overline{GPA}_{\text{merit}}}\zeta, \tag{7}$$

where $\overline{GPA}_{need}$ ($\overline{GPA}_{merit}$) is the GPA threshold below which students are disqualified from need-based (merit-based) grants.

Parental Transfers

I use heterogeneity in initial wealth to capture family wealth effects on college attendance. Individuals draw a college-contingent wealth from an exogenous initial wealth distribution, which captures the gradient of parental contributions for college purposes in the data. Moreover, by continuing college, they will receive the same amount for the second period of college. Modeling per-period college contingent parental transfers is particularly crucial to analyze dropouts, and it deviates from the macro education literature, which usually models parental contributions as once-and-for-all transfers before college enrollment decisions. Such modeling is problematic when focusing on dropout behavior. To begin with, if all the money is transferred at the age of 18, it underestimates the financial constraints students face during their college years. In addition, it creates a moral hazard problem: by front-loading the transfer, individuals may enroll in college

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[18] The specific functional form of each type of grant is explained in the calibration section of the paper.

only to receive the transfer and then drop out strategically.[19] However, modeling multi-period endogenous transfers is computationally infeasible. Therefore, I exogenously approximate the parental transfer distribution from the data so that it closely aligns with parental contribution by wealth quintiles. Once individuals receive an initial transfer, they continue to receive the same amount in each subsequent college period, provided they remain enrolled.

Hereby, I address two potential problems which might arise due to not modeling endogenous transfers. First, parents could adjust their transfers if students face financial shocks. However, this concern should not be present in this framework. In the data, the bottom 40% have zero to very little family contribution, and it is not likely that such poor students' parents would be able to hedge against grant shocks.[20] The second potential problem associated with having no endogenous transfers in the model is that parents might crowd out their transfers as a response to the change in subsidy rates. Since the policy experiments of this paper do not change the level of per-period grant, then, this concern is also not of the first order.

3.5 Labor Productivity

The set-up of the productivity process is standard in the overlapping generations literature and closely follows Karahan and Ozkan (2013) and Krueger and Ludwig (2016). Labor productivity for an individual i at age j with education status s is denoted by:

$$h_{j,i} = \epsilon_j \cdot \exp\left(\theta_i + \eta_i\right), \qquad \text{where} \qquad \eta_i \in \mathcal{H}_s, \qquad \theta_i \in \Theta_s, \qquad s = \{h, d, c\}.$$

The three elements are: (1) a deterministic, life-cycle productivity profile, ϵ_j, (2) a productivity fixed effect, θ_i, and (3) a stochastic component, η_i. The distribution of the stochastic component η_i is education-specific $\mathcal{H}_s$, where subscript s indexes for education levels are: $s = h$ for high school graduates, $s = d$ for college dropouts, and $s = c$ for college graduates. The idiosyncratic shock, η_i, is drawn every time an individual's education status changes, and follows an education-specific Markov process $\pi_s(\eta'|\eta)$ after college. Specifically, at age 1, all individuals draw from the distribution for high school graduates $\mathcal{H}_n$; at age 2, only those who have enrolled in college redraw η_i, from the distribution for college dropouts $\mathcal{H}_d$; at age 3, those who graduated redraw η_i, from the distribution for college graduates $\mathcal{H}_c$;

The distribution of the fixed effect component θ_i is Θ_s, which depends on both education, s, and one's true and yet unknown ability, everyone draws θ_i at age 1, and only those with an education status change redraw during college. In order to ease the state space, the fixed effects have two draws $\theta_s = \{\exp(-\sigma_{\theta_s}), \exp(\sigma_{\theta_s})\}$. The relationship between ability and labor productivity is formalized as follows:

$$\pi\big(\theta_s = \exp(\sigma_{\theta_s})\big) = \omega_s e, \tag{8}$$

where $\omega_h < \omega_d < \omega_c$, i.e., given ability e the higher the education status the higher the probability of drawing higher θ_i. Such a modeling of fixed effects closely follows Krueger and Ludwig (2016) and allows to drop ability as a state variable after college graduation, thereby easing the state

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[19] To address this issue, for instance, Colas, Findeisen, and Sachs (2021) incorporate a pecuniary dropout cost to discourage such strategic behavior among college-age individuals.

[20] Their main sources of income are grants, loans, and work.

space. Without loss of generality, ω_c is set to 1.[21] Once the education level is finalized (i.e. an individual becomes a college dropout or a college graduate), θ_i remains fixed for the rest of the lifespan.

3.6 Government

Before defining the individual's problem, it is useful to introduce how the government operates the fiscal system in the first place. The government collects taxes on household consumption, capital income, and labor income, so as to finance public expenditure G_t, and education subsidies. Consumption and capital income are taxed with flat rates, τ_c and τ_k, respectively. Following Heathcote, Storesletten, and Violante (2010), I consider a potentially progressive labor income tax function:

$$\tau_l(y) = 1 - \lambda y^{-\lambda_m}, \tag{9}$$

where $\tau_l(y)$ is the tax rate at income level y, $\lambda_m > 0$ is a measure of the progressivity of the tax schedule and λ is a parameter that governs the average tax rate (for a given λ_m).

The pension system operates on a pay-as-you-go basis: it collects contributions from the current workers and distributes the revenues directly to the current pensioners. In period t, current workers contribute a fraction, τ_p, of their labor income to the pension funds, whereas current retirees receive a pension benefit that is proportional to their average life-time income: $pen_t(s,\theta) = \kappa_s w_{t,s} \bar{L}_t(s,\theta)$, where $\bar{L}_t(s,\theta)$ denotes the average labor supply, in terms of efficiency units, of working-age cohorts with the characteristics (s,θ), $\theta \in \Theta_s$. The budget constraint of the pension system is then given by:

$$\sum_{s\in\{h,d,c\}} \tau_p w_{t,s} L_{t,s} = \sum_{s\in\{h,d,c\}} \sum_{\theta\in\Theta_s} \sum_{j=j_r}^{J} pen_t(s,\theta) m_j(s,\theta), \tag{10}$$

where $m_j(s,\theta)$ is the relative size of age cohort j that falls into the skill category s and has a fixed productivity component θ.

Finally, the government collects accidental bequests in the economy and individuals draw on this pool to determine their parental wealth. This assumption allows for parental transfers in the economy without the need for direct modeling of intergenerational transfers. The description of the government budget constraint is given in equation (26), in section 3.9.

3.7 The Individual's Problem

Next I describe the life-cycle problem of an individual.

Decisions at age $j = 1$

Before making consumption-leisure-savings decisions, an individual observes an idiosyncratic productivity shock, η, draws a prior belief μ_{e_0} about her innate ability, and receives an education-contingent initial wealth $\{a_c, a_h\}$, where a_c captures per-period parental contribution for college-

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[21] Note that those who enrolled in college draw $\theta_i \in \Theta_n$ irrespective of ability. This assumption serves to eliminate learning about one's academic ability through the labor market.

bound individuals, and a_h parental transfers if individuals do not go to college. The enrollment decision is given by:

$$\mathbb{1}(1,a,\eta,\mu_{e0}) = \begin{cases} 1, & W_c^1(a_c,\eta,\mu_{e0}) > W_h^1(a_h,\eta,\mu_{e0}), \\ 0, & \text{otherwise.} \end{cases}$$

The value functions $W_c^1(a_c,\eta,\mu_{e0})$ and $W_h^1(a_h,\eta,\mu_{e0})$ denote the expected present values of life-time utilities, respectively, of going to college or not. It follows that the indicator function, $\mathbb{1}(1,a,\eta,\mu_{e0})$, is equal to 1 when individuals find it optimal to attend college. The two value functions are formally defined as follows:

$$W_c^1(a_c,\eta,\mu_{e0}) = \mathbb{E}_{\theta'\in\Theta_h} V_c^1\big(a_c,\theta',\eta,\mu_{e0}\big),$$

$$W_h^1(a_h,\eta,\mu_{e0}) = \mathbb{E}_{\theta'\in\Theta_h|\mu_{e0}} V_h^1\big(a_h,\theta',\eta\big),$$

where $V_c^1\big(a_c,\theta,\eta,\mu_{e0}\big)$ and $V_h^1\big(a_h,\theta,\eta\big)$ are the expected present values of the life-time utilities of an individual who decides to enroll in or stay out of college, respectively. Note that the non-college value function, $V_h^1\big(a_h,\theta,\eta\big)$, does not take an ability prior as a state variable, because beliefs become redundant after drawing the fixed effect. Furthermore, note that for enrolled individuals, the first period fixed effect is independent of ability. This assumption is necessary to avoid learning about ability in the labor market.

After the enrollment decision at age 1, having drawn the fixed effect, θ, individuals solve a standard consumption-leisure-savings problem. For those who decide not to enroll, their recursive problem reduces to the standard consumption-leisure-savings problem defined subsequently in this section (equation 12). Formulated recursively, the college-bound individuals' Bellman equation is as follows:

$$\begin{aligned} V_c^1(a_c,\theta,\eta,\mu_{e0}) = \max_{a',c,l} \Bigg\{ & u(c, 1-\xi(\mu_{e0})-l) + \beta \int_{\hat{S}}\int_{\zeta}\int_{\eta'\in\mathcal{H}_d} \\ & \max\Bigg(W_c^2\big(a'(a_c),\eta',z_2(a,\zeta,GPA(l,\hat{S})),\mu_{e1}(\mu_{e0},\hat{S})\big), \\ & W_d^2\big(a'(a_h),\eta',\mu_{e1}(\mu_{e0},\hat{S})\big)\Bigg) d\eta d\zeta d\hat{S} \Bigg\}, \end{aligned} \tag{11}$$

s.t.

$$(1+\tau_c)c + a' + (1-z_1(a,\mu_{e0}))\iota w_{t,c} = (1+(1-\tau_k)r_t)a_c + (1-\tau_p)y - y\tau_l(y) + T,$$

$$a' \geq -\underline{\mathrm{A}}_1,$$

$$\mu_{e_1} = \frac{\sigma_\psi^2 \mu_{e0} + \sigma_{e0}^2 \hat{S}}{\sigma_{e0,i}^2 + \sigma_\psi^2},$$

$$\sigma_{e_1} = \frac{\sigma_{e0}^2 \sigma_\psi^2}{\sigma_{e0}^2 + \sigma_\psi^2}.$$

The expectations are taken with respect to the distribution of the ability signals, $\hat{S}$, shocks to college subsidies, ζ, as well as the future idiosyncratic labor market shocks, η'. The continuation value for college-bound individuals is the maximum expected utility between two scenarios: (a) stay in college, $W_c^2\big(a'(a_c), \eta', z_2(a_c, \zeta, GPA(l, \hat{S})), \mu_{e_1}(\mu_{e_0}, \hat{S})\big)$, or (b) dropping out, $W_d^2\big(a', \eta', \mu_{e_1}(\mu_{e_0}, \hat{S})\big)$.[22] Note that a' depends on the parental transfers.[23] Therefore, students internalize the fact that their parents will only contribute financially if they stay in college. The GPA is formed by $\big(l, \hat{S}\big)$ and grants depend on $\big(a, \zeta, GPA(l, \hat{S})\big)$, as defined in equations (3) and (7), respectively. Finally, note that y defined as $y_1 = w_c h_{1,c}(\theta, \eta) l(1, a_c, \theta, \eta, \mu_{e_0})$ is earnings.

Decisions at age $j = 2$

At the beginning of period 2, students make a dropout decision based on their GPAs, the stochastic part of the grants, ζ, and an idiosyncratic part of the labor productivity process, η, now drawn from a dropout wage distribution. The GPA affects posterior beliefs about one's true ability, while simultaneously affecting grant allocation. Therefore, a high GPA enhances the value of college through the following channels (1) lowering the instantaneous utility cost of staying in college (2) increasing expected college returns, and (3) decreasing the probability of losing grants (through GPA requirements). The stochastic shock ζ affects the affordability of college (and, therefore, average returns of college). When $\zeta < 1$, the budget constraint is tightened, and when $\zeta > 1$, the college becomes more affordable and, as a consequence, incentivizes more college attendance. Finally, the idiosyncratic wage shock, η, affects an individual's budget constraint as well as the outside option of college: high η may induce students to drop out as the opportunity cost of college increases, but at the same time, it might motivate students to stay in college as college becomes more affordable. Therefore, the impact of η on college attendance cannot be isolated, and it depends on the other component of state space.

With the realized state vector $(GPA(l, \hat{S}), \zeta, \eta)$, an individual compares the value of college to the value of dropping out and optimally decides whether or not to stay in college. Formally, the decision is summarized as follows:

$$\mathbb{1}\big(2, a, \eta, z_2, \mu_{e_1}\big) = \begin{cases} 1, & \text{if } W_c^2\big(a'(a_c), \eta', z_2, \mu_{e_1}\big) > W_d^2\big(a'(a_h), \eta', \mu_{e_1}\big), \\ 0, & \text{otherwise,} \end{cases}$$

where

$$W_c^2\big(a'(a_c), \eta', z_2, \mu_{e_1}\big) = \mathbb{E}_{\theta' \in \Theta_d | \mu_{e_1}} V_c^2\big(\theta', \eta, z_2, \mu_{e_1}\big),$$
$$W_d^2\big(a'(a_h), \eta', \mu_{e_1}\big) = \mathbb{E}_{\theta' \in \Theta_d | \mu_{e_1}} V_d^2\big(a, \theta', \eta\big).$$

$W_c^2\big(a'(a_c), \eta', z_2, \mu_{e_1}\big)$ and $W_d^2\big(a'(a_h), \eta', \mu_{e_1}\big)$ denote the expected present values of the lifetime utilities of staying in college and dropping out, respectively. The probabilities are taken with respect to the fixed labor productivity shocks, $\theta \in \Theta_d$. It leads the indicator function, $\mathbb{1}\big(2, a, \eta, z_2, \mu_{e_1}\big)$, to take the value of 1 if the individual decides to remain in college.

After the dropout decision, individuals make consumption-leisure-savings decisions. This

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[22] Note that once an individual decides to drop out, the signal, $\hat{S}$, and the subsidies shock, ζ, become redundant.

[23] While students make decisions about their savings, they take into account the expectation that if they continue their education, they will receive parental transfers in the next period, denoted as a_c, reflecting the recurring nature of parental financial support for college-related expenses. Conversely, if they choose to drop out, they will forgo such transfers.

problem is formulated as follows for college-bound individuals:

$$V_c^2(a,\theta,\eta,z_2,\mu_{e_1}) = \max_{a',c,l}\left\{u(c,1-\xi(\mu_{e_1})-l)+\beta\int_{\eta'\in\mathcal{H}_c}\mathbb{E}_{\theta'\in\Theta_c|\mu_{e_1}}V_c(3,a',\theta',\eta')d\eta\right\},$$

s.t.

$$(1+\tau_c)c+a'+(1-z_2(a,\zeta,GPA(l_{-1},\hat{S})))\iota w_{t,c} = (1+(1-\tau_k)r_t)(a+a_c)+(1-\tau_p)y-y\tau_l(y)+T,$$

$$z_2\big(a_c,\zeta,GPA(l_{-1},\hat{S})\big) = \big(z_1^{\text{need}}(a_c,\mu_{e_0})\mathbb{1}_{GPA\geq\overline{GPA}_{\text{need}}}+z_1^{\text{merit}}(a_c,\mu_{e_0})\mathbb{1}_{GPA\geq\overline{GPA}_{\text{merit}}}\big)\zeta,$$

$$a' \geq -\underline{A}_2.$$

For those individuals who decide to drop out, beliefs about their ability become redundant. Their recursive problem reduces to the standard consumption-leisure-savings problem defined in equation (12).

Decisions at age $j >= 3$

College graduates draw their wage components from the college wage distribution. From age $j=3$ onward,[24] the problem of an individual with an education level $s=\{h,d,c\}$ is as follows:

$$V_s(j,a,\theta,\eta) = \max_{a',c,l}\{u(c,1-l)+\beta\int_{\eta'|\eta}V_s(j+1,a',\theta,\eta')d\eta\}, \tag{12}$$

s.t.

$$(1+\tau_c)c+a' = (1+(1-\tau_k)r_t)a+(1-\tau_p)y-y\tau_l(y)+T,$$

$$a' \geq -\underline{A}_j. \tag{13}$$

Decisions at age $j >= j_r$

Upon retirement, individuals' labor productivity drops to zero, and, therefore, they live on capital income and pension benefits. The associated Bellman equation is given by:

$$V(j,a,\theta,0) = \max_{a',c}\left\{u(c,1)+\beta\varphi_{j+1}V(j+1,a',\theta,0)\right\}, \tag{14}$$

s. t.

$$(1+\tau_c)c+a' = (1+(1-\tau_k)r_t)a+pen_t(s,\theta)+T.$$

Individuals after retirement face mortality risk φ_{j+1} in each period. They die with probability 1 at age $j=J$.

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[24] For high school graduates, who never enroll, the optimization problem reduces to equation (12) from age $j=1$, and for college dropouts their problem reduces to equation (12) from age $j=2$ onward.

3.8 Firms and Production

Firms hire labor and capital on competitive spot markets to produce a final good. The final output is produced according to the standard Cobb-Douglas production function:

$$Y_t = AK_t^{\alpha}L_t^{1-\alpha},$$

where A denotes total factor productivity, and α is a parameter that governs the elasticity of output with respect to capital.

I assume that workers come in two skill types: those with a college degree are referred to as skilled labor, the others (college dropouts and high school graduates) are referred to as unskilled labor. The two skills are imperfectly substitutable to each other, with the substitution parameter ϑ. Aggregate labor, therefore, can be formulated as follows:

$$L_t = \Big(\upsilon(L_{t,h} + L_{t,d})^{\vartheta} + (1-\upsilon)L_{t,c}^{\vartheta}\Big)^{1/\vartheta}, \tag{15}$$

where $L_{t,s}$ denotes aggregate labor in terms of efficiency units in the different educational groups, s. The parameter υ is calibrated to match the college wage premium in the data.

The assumption that there are only two skill types is based on the proportion of firms that require a "High school degree," "Associate's degree," "Some college, no degree," or "Bachelor's degree and higher" in their job postings. According to Torpey and Watson (2014), only 5% of all jobs require the "Some college, no degree" category of education. This suggests that most individuals with some college education are employed in positions that only require a high school diplomas.[25]

Finally, assuming perfect competition and constant returns to scale of the production function, the size distribution of firms is indeterminate. Therefore, I will assume the existence of a representative firm without loss of generality. This representative firm takes the wage rates of skilled labor, $w_{t,c}$, unskilled labor, $w_{t,h}$, and the interest rate, r_t, as given.

3.9 Competitive Equilibrium

To define a general equilibrium of the model economy, it is useful to introduce some additional notation. In particular, I define the distribution of individuals on the state space. Let $\mathcal{J} = \{1, 2, ..., J\}$, $\mathcal{E} = [0, 1]$, $s = \{h,\ d,\ c\}$, $\mathcal{A} = \mathbb{R}$, $\Theta = \mathbb{R}$ and $\mathcal{H} = \mathbb{R}$ denote the state space for age j, ability e, education level s, wealth a, fixed productivity effect θ and the stochastic productivity component η. And let Σ represent the Borel σ-algebra defined on the product space $\mathbb{X} = \mathcal{E} \times \mathcal{J} \times \mathcal{S} \times \mathcal{A} \times \mathcal{F} \times \mathcal{H}$. Then, for any $X \in \mathbb{X}$, a measure $\phi(X)$ can be properly defined. For ease of notation, let $X(j, s) \in \mathbb{X}$ be the state space of an individual of age j and with education status s, defined by the recursive representation of the individual's problems above.

With this preparation, I now define the stationary recursive competitive equilibrium as follows. A stationary recursive competitive equilibrium is a collection of: (i) decision rules of individuals $\Big\{\ \mathbb{1}(1, a_s, \mu_{e_0}, \eta),\ \mathbb{1}\big(2, a, z, \mu_{e_1}, \eta\big),\ c(X(j, s)), l(X(j, s)), a'(X(j, s))\Big\}$; (ii) aggregate capital and labor inputs, $\big\{K, L_h, L_d, L_c\big\}$, on the part of firms; (iii) value functions $\big\{V\big(X(j, s)\big)\big\}$;

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[25] Another 6% percent of jobs requires postsecondary non-degree awards, which I have not considered in the model.

(iv) government policies $\{\tau_c, \tau_k, \tau_p, \tau_l(y), pen(s,\theta_s), \kappa_s, z_1, z_2, T\}$; (v) prices $\big\{r, w_h, w_c\big\}$; (vi) education system characterized by $\{\iota, \xi(\mu_{e_0}), \xi(\mu_{e_1})\}$; and (vii) a vector of measures ϕ, such that:

1. The decision rules of individuals solve their respective life-cycle problems, and $V\big(X(j,s)\big\}$ are the associated value functions.

2. Aggregate capital and labor inputs, $\{K, L_h, L_d, L_c\}$, solve the representative firm's profit maximization problem, which is fully characterized by the following first order conditions:

$$r = \alpha A k^{\alpha-1} - \delta, \tag{16}$$

$$w = (1-\alpha)Ak^{\alpha}, \tag{17}$$

$$w_c = (1-\alpha)(1-\upsilon)k^{\alpha}\left(\frac{L}{L_c}\right)^{1-\zeta} = w\left(\frac{L}{L_c}\right)^{1-\zeta}, \tag{18}$$

and

$$w_h = (1-\alpha)k^{\alpha}(\upsilon)\left(\frac{L}{L_h+L_d}\right)^{1-\zeta} = w(1-\upsilon)\left(\frac{L}{L_h+L_d}\right)^{1-\zeta}, \tag{19}$$

where $k = \frac{K}{L}$, $w = (1-\alpha)k^{\alpha}$, and the college wage premium is therefore given by:

$$\frac{w_c}{w_h} = \frac{1-\upsilon}{\upsilon}\left(\frac{L_h+L_d}{L_c}\right)^{1-\zeta}. \tag{20}$$

3. The labor market for each skill type clears:

$$L_s = \sum_{s=\{h,d,c\}}\sum_{j=1}^{j_r-1}\int_{X(j,s)} h_{s,j}(\theta,\eta)l\big(X(j,s)\big)d\phi\big(X(j,s)\big), \tag{21}$$

4. The capital market clears:

$$K = \sum_{s=\{h,d,c\}}\sum_{j=1}^{J}\int_{X(j,s)} a'(X(j,s))d\phi\big(X(j,s)\big) + A_{init},$$

where A_{init} is the aggregate wealth transfer to the newly arrived generation:

$$A_{init} = \sum_{s=\{h,d,c\}}\int_{X(1,s)} af(s,a)\,d\phi(X(1,s)) + \sum_{s=\{h,d,c\}}\int_{X(2,s)} af(s,a)\,d\phi(X(2,s)), \tag{22}$$

where $\phi(j,s)$ denotes the measure of individuals at age $j=\{1,2\}$ with college decision s and $f(s,a)$ is the distribution from which initial wealth is drawn.

5. The good market clears:

$$Y = C + G + E + I, \tag{23}$$

$$C = \sum_{s=\{h,d,c\}}\sum_{j=1}^{J}\int_{X(j,s)} c\big(X(j,s)\big)d\phi\big(X(j,s)\big), \tag{24}$$

$$E_t = \int_{X(1,c)} \iota w_c d\phi(X(1,c)) + \int_{X(2,c)} \iota w_c d\phi(X(2,c)), \tag{25}$$

where G represents government spending, and I is gross investment.

6. The government budget constraint holds:

$$\tau_c C + \tau_k r A + T_l + (1+r)A_b = G + A_{init} + Z + T, \tag{26}$$

where T_l denotes labor income tax revenues, as given by:

$$T_l = \sum_{s=\{h,d,c\}} \sum_{j=1}^{j_r-1} \int_{X(j,s)} \tau_l(y_s) y_s d\phi(X(j,s)), \tag{27}$$

with $y_s = (1-\tau_s)w_{t,s}h_{s,j}(\theta,\eta)l(j,a,\theta,\eta)$.[26] A_b denotes accidental bequest:

$$A_b = \sum_{s\in\{h,d,c\}} \sum_{j=j_r}^{J} \int_{X(j,s)} a'(X(j,s)) \frac{1-\varphi_{j+1}}{\varphi_{j+1}} d\phi(X(j,s)). \tag{28}$$

Z is the aggregate education subsidies:

$$Z_t = \int_{X(1,c)} z_1(\cdot)\iota w_c d\phi(X(1,c)) + \int_{X(2,c)} z_2(\cdot)\iota w_c d\phi(X(2,c)). \tag{29}$$

7. The pension budget constraint (10) holds.

8. Individual behaviors are consistent with aggregate behavior: measure ϕ is a fixed point of $\phi(X) = \Pi(X,\phi)$, for any $X \in \mathbb{X}$, where $\Pi(X,\cdot)$ signifies the transition function generated by the decision rules of individuals, the process of exogenous states, and the survival probabilities.

9. All aggregate per capita variables increase by the population growth rate, n_p.

4 Calibration

This section discusses the model calibration. A majority of the parameters are either estimated directly from the data or calibrated internally by matching certain aggregate moments in the US data. The remaining parameters are taken from the literature.

Demographics–A period in the model corresponds to two years. New generations enter the economy at the age of 18 and it takes two model periods (four years) to complete college. Individuals retire at the age of 66, and the maximum age is 96. Moreover, the population grows at a constant rate of $n = 1\%$ annually, which is consistent with the long-term population growth rate in the U.S. Likewise, survival probabilities $\{\varphi_j\}$ are computed from the actuarial life Tables for the US.

Preferences– I consider a fairly standard utility function:

$$u(c, 1-l) = \frac{\left[c^{\nu}(1-l)^{1-\nu}\right]^{1-\frac{1}{\gamma}}}{1-\frac{1}{\gamma}}, \tag{30}$$

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[26] Note that I slightly abuse notation in that for college-bound individuals the state space also incorporates prior, posterior of ability and a shock to the grants.

where ν is a taste parameter for consumption and $\frac{1}{\gamma}$ denotes a risk aversion parameter. The two parameters ν and γ determine together (i) the average labor supply, (ii) the intertemporal elasticity of substitution of consumption, and (iii) the Frisch elasticity of labor supply. ν is chosen such that individuals, on average, work one-third of their time endowment. Parameter γ is set to 0.25 so that the risk aversion, $\frac{-cu_{cc}}{u_c} = \frac{1}{\gamma}\nu + 1 - \nu$, is set to ≈ 2, a standard value in the literature.

Technology–The aggregate production function is a Cobb-Douglas form. The capital share α is set to 0.33. Total factor productivity A is normalized to 1. The elasticity of substitution between skilled and unskilled labor is borrowed from Card (2009) and set to 3.33. This estimate is in line with the estimate in Abbott et al. (2019) and those in literature. The discount factor is internally calibrated to target at a capital-output ratio of around 3 as in Krueger and Ludwig (2016). Finally, υ is calibrated internally to match the college wage premium of about 80%, reported in Table 4. The college wage premium is defined as the ratio of the (age-composition-adjusted) average wage between those with a college degree and those with only a high school degree.

Utility Cost of College–Utility cost is one of the critical factors that generate differentiated college attainment rates by ability quintiles.[27] I parameterize the utility cost of attending college as follows: $\xi_1(\mu_{e_{0,i}}) = \exp(b_0 - b_1\mu_{e_{0,i}})$ and $\xi_2(\mu_{e_{1,i}}) = \exp(b_0 - b_1\mu_{e_{1,i}})$. It is important to note that these parameters, b_0 and b_1, are kept constant across college periods. This assumption is crucial. If the coefficients vary across years, they directly influence dropout rates. This influence could obscure the effect of learning about one's ability on the decision to stay in college. I calibrate these parameters internally, calibrating the constant to match the overall enrollment rate in the data while calibrating the slope parameter to match the enrollment rates by ability. The calibrated values are reported in Table 13, and the results are shown in Figure 3.

Resource Cost of College–To determine the resource cost of college, denoted by ιw_c, I utilize data from the Digest of Education Statistics, which reports that the average annual education cost per student for a four-year college degree was \$24,000 in 2016 dollars for the 2011-2012 academic year.[28] This amount is a good approximation of the average cost of college attendance in nonprofit universities, which 95% of undergraduate students attend.[29] To inform the parameter ι, I calibrate it in the benchmark by matching the average cost of education to the GDP during the same years. The resulting calibration is reported in Table 12.

Borrowing Limits–The Beginning Postsecondary Education dataset provides information about the loan size in relation to the student budget.[30] Based on the data, I allow students to borrow 40% of the student budget in each academic period.[31] Borrowing constraints for $j \geq 3$

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[27] The other three factors are the expected earnings in non-college labor market, the expected earnings in college market, and the time to work at college – all functions of true ability.

[28] Source: https://nces.ed.gov/fastfacts/display.asp?id=76.

[29] The share of the students in public, private for nonprofit, and private for-profit is respectively 0.78, 0.17, and 0.05. Since private for-profit universities have a minimal share of undergraduate students, I drop them from the analysis. Excluding private for-profit universities helps to prevent overinflation of the price of education in the model, as they are the most expensive.

[30] The BPS data presents college finances as a share of the student budget, which is a valuable metric for assessing the relative significance of various funding sources for college.

[31] It is worth highlighting that the loan modeling derived from the Beginning Postsecondary Education dataset (BPS) introduces a more flexible borrowing constraint than the federal loan limit commonly employed in macro literature Colas, Findeisen, and Sachs (2021), Abbott et al. (2019), Krueger and Ludwig (2016). This more

are set such that borrowers repay at least a minimum amount, P, in each period, and that the loan is fully paid back in 10 years after their graduation.

Initial Wealth–To model the distribution of initial wealth for college students, I rely on the Beginning Postsecondary Education dataset, which provides detailed information about expected parental contribution for enrolled students. To approximate this distribution, I use the modified generalized Pareto distribution and calibrate its parameters internally to match parental contribution moments for the third and fifth quintiles of family wealth. It should be noted that the focus of this study is on initial transfers for early college purposes only, and thus, individuals who do not attend college receive zero initial wealth.

Table 6 presents the average parental transfers for college costs in each wealth quintile, which are consistent with the data. The model slightly overestimates the role of parental contribution for the bottom two quintiles, as it is internally matched, and very poor people opt not to go to college in the model. As a result, the bottom two quintiles have more wealth than in the data, leading to a conservative result on how grants uncertainty affects the bottom quintile families.

Table 6: Initial wealth as a share of the student budget. Model vs. Data

	Initial transfers				
Wealth Quintiles	Q1	Q2	Q3	Q4	Q5
Data	0.00	0.08	0.31	0.60	0.89
Model	0.05	0.17	0.31	0.53	0.86

At the same time, the proportion of college cost financed by parental contributions does not vary significantly based on ability gradient.[32] Therefore, I will not include an external correlation between wealth and ability in the default calibration of the model, as the focus is on the relative importance of each source of college finances. My goal is to examine the individual impacts of each financial source on college costs.

Working Hours in the GPA Function–To account for the negative impact of working full-time on grades, an important parameter is the working impact on GPA, which is captured by equation (3). This parameter is determined using empirical estimates, which vary in the literature. For a benchmark calibration, I rely on Stinebrickner and Stinebrickner (2008), who estimate the impact of studying time on GPA using a compelling identification strategy.

Their findings suggest that studying for one additional hour per day increases GPA by an average of 0.36 points, implying that working for eight hours per day reduces semester GPA by 2.52 (8×0.36). As the time in the model is measured yearly, and only 32 out of 52 weeks are considered as study weeks, increasing work by one hour would reduce GPA by $\frac{32}{52}2.52$. Using a full-time worker hours of 0.35 and a normalized GPA between 0 and 1, I obtain λ_l in equation (3) as -1.11. Additionally, based on studies such as Bozick (2007), I assume that working below

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flexible loan size, based on the administrative data, ensures to avoid an overestimation of the impact of financial adverse shocks during college. I also omit the separate modeling of Parental PLUS loans, as students cannot independently take out such loans, and as the observed loan limits in BPS include Parental PLUS loans.

[32] Table 7 provides more detailed information on the relationship between parental transfers and student budget by ability quintiles. Specifically, for each ability quintile, the ratio of parental transfers to student budget remains roughly the same, though the absolute values of parental transfers vary slightly by ability gradient.

$\underline{l} = 0.1$ (i.e., working 15 hours a week) does not harm GPA.[33]

Government Policy–I set the ratio of government spending to GDP at 17%. The consumption tax rate is estimated to be 7.3% based on the US National Income and Product Accounts data set. The capital income tax rate is taken from Chari and Kehoe (2006). Pension benefits are set to be 35% of the average income within each skill group, consistent with the current social security configuration. The payroll tax rate τ_p is set to balance the pension budget. To parameterize the progressive labor income tax, I rely on the estimate of $\lambda_m = 0.18$ for the measure of progressivity from Ferriere et al. (2023), which is a commonly used value in the literature. The flat part of the labor income tax function, λ, is then set to balance the government budget.

Calibration of the Dropout Channels

In the following subsections, I outline the calibration of the dropout channels: grants system, ability beliefs, and productivity shocks. I pin down grants volatility, ability beliefs, and idiosyncratic labor market shocks from the data, while internally calibrating the ability-dependent fixed effect of productivity shocks to match graduation rates based on individual abilities.

Grants in the First Period of College

To calibrate the grants, I use data from the Beginning Postsecondary Data of the National Center for Education Statistics cohort of 2011-2012. The summary statistics of the distribution of total grants in the first academic year based on ability and wealth are provided in Table 7. Note that the grants are presented as a share of student budget.[34]

Table 7: Total grants as a share of total cost by ability and wealth

Data	Total grants (need-based plus merit-based grants)				
Quintiles	Q1	Q2	Q3	Q4	Q5
By ability	0.35	0.31	0.32	0.34	0.35
By wealth	0.49	0.42	0.23	0.20	0.19

Note: Ability quintiles are measured by SAT grades, and family wealth quintiles are measured by Expected Family Contribution (EFC). Total grants are normalized by a student budget in each respective subgroup. Wealth quintiles are measured by expected family contributions.
Data from the Biginning Postsecondary Education data, the National Center of Education Statistics, cohort 2011-2012.

The table shows that grants are not significantly differentiated based on ability quintiles, with an average of 32% of the total cost. At the same time, grants are strongly differentiated by wealth, with 49% for the lowest income quintile and about 19% for the top income quintile. Table 8 decomposes the total grants by its type: merit-based and need-based, confirming that merit based grants are not strongly differentiated by ability quintiles, whereas need-based grants strongly decrease in parental wealth.

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[33] Counterfactual experiments suggest that this particular margin holds limited quantitative significance in explaining the dropout phenomenon within the model. This is attributed to the fact that students internalize the negative consequences of excessive work on their GPA, thereby influencing their eligibility for grants.

[34] The BPS data presents college finances as a share of the student budget, which is a valuable metric for assessing the relative significance of various funding sources for college.

Table 8: Merit-based and need-based grants as a share of student budget by ability and wealth quintiles. Model vs. Data

merit-based grants					
Ability Quintiles	Q1	Q2	Q3	Q4	Q5
Data	0.14	0.16	0.13	0.12	0.14
Model	0.13	0.13	0.13	0.13	0.14

need-based grants					
Wealth Quintiles	Q1	Q2	Q3	Q4	Q5
Data	0.38	0.25	0.10	0.06	0.04
Model	0.40	0.26	0.12	0.05	0.03

Note: the distribution of wealth and ability quintiles are based on among already enrolled students both in the model and in the data. In both cases, the grants are presented as a percentage share of a student budget in each respective subgroup.

Based on the above observations, I model merit and need types separately. I assume that the merit-based grants increase only slightly with ability and have an average value of 13%. The need-based grant function follows a step function so that it matches its data counterpart by family wealth quintiles. Table 8 presents the calibration results alongside their data counterparts. As a validation exercise, in Table 9, I provide the joint distribution of the grants by the wealth and ability distributions in the model and the data. The model successfully generates the comparable shares of college cost financed by grants in each ability-wealth quintile category.

Table 9: Grants distribution by ability-wealth quintile category. Model vs. Data

(a) Grants distribution in the model

	Ability	Q1	Q2	Q3	Q4	Q5
Wealth Q1		0.53	0.56	0.57	0.58	0.60
Q2		0. 41	0.43	0.45	0.45	0.48
Q3		0.28	0.31	0.32	0.33	0.35
Q4		0.24	0.26	0.28	0.28	0.31
Q5		0.20	0.22	0.24	0.24	0.27

(b) Grants distribution in the data

	Ability	Q1	Q2	Q3	Q4	Q5
Wealth Q1		0.48	0.50	0.53	0.58	0.55
Q2		0.40	42	0.42	0.42	0.50
Q3		0.27	0.30	0.31	0.31	0.45
Q4		0.22	0.27	0.30	0.30	0.32
Q5		0.24	0.26	0.25	25	0.32

Note: Note that the distribution of wealth and ability quintiles are based on among already enrolled students both in the model and in the data. The grants are normalized by a student budget in each respective subgroup.

Grants in the Second Period of College

The second-period grant function, equation (7), has two main components to calibrate. First, the GPA thresholds, $\overline{GPA}_{\text{need}}$ and $\overline{GPA}_{\text{merit}}$, below which students lose their respective grants. Second, the stochastic process, ζ.

The need-based GPA threshold is chosen by considering the Satisfactory Academic Progress (SAP) requirements embedded in the current Pell grants, which is 2.00. The merit-based GPA threshold, $\overline{GPA}_{\text{merit}}$, is usually set at a higher level. I choose a threshold of 3.00, which is a lower bound of the eligibility requirement, to maintain merit-based grants in the data. In the BPS dataset, I find that 9 percent of students fail to meet the 2.00 GPA threshold, and 29.9 percent of students fail to meet the 3.00 GPA threshold. Therefore, in the model, I internally calibrate the corresponding thresholds such that the shares of students failing to meet these requirements match the data.

Table 10: Grants transition by initial amount between academic years

Grants in Year 3 Grants in Year 1	bracket 1	bracket 2	bracket 3	bracket 4	bracket 5	$\frac{\text{need-based grants}}{\text{student budget}}$
bracket 1	0.71	0.08	0.07	0.03	0.12	0.38
bracket 2	0.31	0.31	0.11	0.05	0.22	0.25
bracket 3	0.14	0.09	0.23	0.09	0.45	0.10
bracket 4	0.12	0.16	0.09	0.10	0.52	0.06
bracket 5	0.03	0.01	0.01	0.01	0.94	0.04

Note: Controlling for academic eligibility criteria, earnings, and college enrollment.

Next, I approximate grant uncertainty in the model. In order to do so, I exploit the residual variation in the Pell grants between academic periods conditional on its size after controlling for all observable eligibility criteria.[35] The uncertainty observed in Pell grants, which account for approximately 50% of need-based grants in the US, can be extended to other types of grants as they depend on the same application system.

Table 10 summarizes grant transitions between model period 1 (year 1 in the data) and model period 2 (year 3 in the data). I approximate the size of need-based grants by five brackets to avoid carrying continuous parental wealth as a state variable between academic periods.[36] Without loss of generality, bracket 1 represents the maximum need-based grant students can get, and is set to 38% of the student budget, in line with the BPS data. Bracket 5 is virtually equal to zero. The size of the grants in each bracket is presented in the last column of Table 10. The table shows that the grants in different brackets have different degrees of uncertainty associated with them. As a rule of thumb, the higher the initial amount of the grants, the higher the probability of maintaining it. Using this transition matrix, I recover the stochastic shock, ζ_{ij}, presented by matrix (31) and the probability distribution, $\pi_{\zeta_{ij}}$, presented by matrix (32). The subscript i indicates which grant bracket an individual belongs in the first period and the subscript j indicates which grant bracket she moves in the next period as a result of receiving a shock ζ_{ij}. This happens with a probability $\pi_{\zeta_{ij}}$. If $i = j$ then the individual gets the same grant in both periods.

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[35] The available data, as discussed in the empirical part, does not include information on variations in parental wealth between academic years. However, considering that 30 percent of students who hold Pell grants have a zero expected family contribution (EFC), and EFC is truncated below zero, indicating that students are even more economically disadvantaged than what zero EFC represents (see Kelchen (2015)), it is unlikely that changes in parental wealth significantly contribute to the loss of grants among economically disadvantaged students in subsequent academic years. Existing literature supports this view by suggesting that parental wealth tends to persist between academic years (Hendricks and Leukhina (2017)).

[36] Again, this assumption saves virtual memory computationally, which is highly valuable given the eight state variables during the college years.

$$\zeta = \begin{pmatrix} 1.00 & 0.67 & 0.25 & 0.16 & 0 \\ 1.48 & 1.00 & 0.37 & 0.24 & 0 \\ 3.95 & 2.67 & 1.00 & 0.65 & 0 \\ 6.06 & 4.09 & 1.53 & 1.00 & 0 \\ 0 & 0 & 0 & 0 & 1.00 \end{pmatrix} \quad (31) \qquad \pi_\zeta = \begin{pmatrix} 0.71 & 0.08 & 0.07 & 0.03 & 0.12 \\ 0.31 & 0.31 & 0.11 & 0.05 & 0.22 \\ 0.14 & 0.09 & 0.23 & 0.09 & 0.45 \\ 0.12 & 0.16 & 0.09 & 0.10 & 0.52 \\ 0.03 & 0.01 & 0.01 & 0.01 & 0.94 \end{pmatrix} \quad (32)$$

Learning Ability and Beliefs

Without loss of generality, I normalize newborns' true ability between 0 and 1, and I assume that it is distributed uniformly across the population. Each individual forms beliefs about their ability based on some signals, described below.

Newborns have a prior about their true ability via their high school grades. These grades are exogenous to the model, with mean μ_{e_0} and variance σ_{e_0}. Generally, high school grades are higher than college grades, which in turn leads students to be overly optimistic about their ability. This has been shown by Stinebrickner and Stinebrickner (2014), who use a longitudinal survey of students' beliefs at Berea College. They show that on average, students expect their college grades to match their school grades. The optimism parameter, α_e, is therefore defined as the difference between the mean belief about future college GPA (which equals to the mean of high school-grades before enrollment), 3.21, and the mean of realized college GPA after the first half of college, 2.97. That leads to: $\alpha_e = \frac{(3.21-2.97)}{4} = 0.06$. Here, the denominator rescales the optimism into the support of the model GPA, which is normalized between 0 and 1.

As for the standard deviation of the prior, I impose a restriction that $\sigma_{e_0} = \sigma_{\mu_{e_0}}$.[37] The latter is the approximate standard deviation of the distribution describing beliefs about grades averaged over the college enrollees. The parameter is measured in Stinebrickner and Stinebrickner (2014). Following them, $\sigma_{e_0} = \sigma_{\mu_{e_0}} = \frac{0.52}{4} = 0.13$.

Table 11: Parameters of prior-posterior distributions

parameters	Definition	Value
$\sigma^2_{e_0} = \sigma_{\mu_{e_0}}$	variance of the prior	0.52
α_e	optimism parameter	0.24
$1+\sigma^2_{\mu_{e_0}}/\sigma^2_{\psi_i}$	signal-noise ratio	1.34

After parameterizing the prior distribution, the next step is to determine the signal-noise ratio, that is, to recover the value of σ_ψ. To estimate this parameter, I refer to the weights assigned by students to their prior beliefs relative to the observed signals after each academic year, as documented by Stinebrickner and Stinebrickner (2014). By using the estimated weights and equation 5, I can derive the value of σ_ψ. In the benchmark calibration, I select the estimated weights for the first year, as it corresponds to the point of highest belief revision. This approach allows me to attain the upper bound of dropout rates in relation to the learning ability channel, thereby obtaining a conservative calibration for the model in relation to alternative dropout

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[37] This assumption is essential due to the lack of available or informative survey data regarding the distribution of an individual's prior by various student characteristics such as wealth and ability.

channels such as grants uncertainty.Table 11 summarizes the calibrated parameters for the prior and posterior distributions.

Labor Productivity

I proceed to calibrate the wage process as follows. I bring into the model the estimates of deterministic-age profile, and AR(1) process exogenously from the data. I calibrate the fixed effects internally to match key moments of wage distributions for different skills, and college participation moments in the data.

Specifically, I assume a deterministic process, ϵ_j is normalized to one after college graduation and increases by a factor of two until the age of 50. The overall patterns closely follow wage profiles observed in the data (see Ludwig, Schelkle, and Vogel (2012)).

Using the estimates from Abbott et al. (2019), I exogenously calibrate the AR(1) process for both the non-skilled group (high school and dropouts) and the skilled group. Furthermore, I calibrate the fixed effect of high-school graduates based on the initial dispersion of earnings among this group.

The remaining four parameters of the fixed effects in the wage process (ω_h, ω_d, σ_{θ_d}, and σ_{θ_c} in equation (8)) are internally calibrated to match key moments in the data, including the dropout wage premium, college wage premium, dropout rate, and graduation rates by ability quintiles. So, the four parameters are overidentified. The resulting lifecycle profiles are presented in Figure 8 in Appendix F.[38]

5 Model Fit

5.1 Targeted moments

I next discuss how the model matches the data moments. The targeted moments and their model counterparts are presented in Figure 3, Table 6, and Table 14. The figure shows that the model fits college participation margins by ability quite well. Both the enrollment and the graduation rates are increasing in ability. The economic mechanism that underpins these observations is as follows. The riskiness of college is decreasing in ability, and returns to college are increasing in ability. Specifically, high-ability students (1) are less likely to receive bad ability signals that are pivotal to a loss of grants; (2) are less likely to have such posterior beliefs that make a college degree suboptimal; (3) have lower time cost and therefore more time to work and finance college through labor earnings when experiencing adverse financial shocks; and (4) expect higher returns to a college degree due to the complementarity assumption between ability and education level. These channels lead to declining dropout rates and increasing graduation rates with respect to ability.

Table 14 shows that the model matches the wage premiums, overall enrollment and dropout

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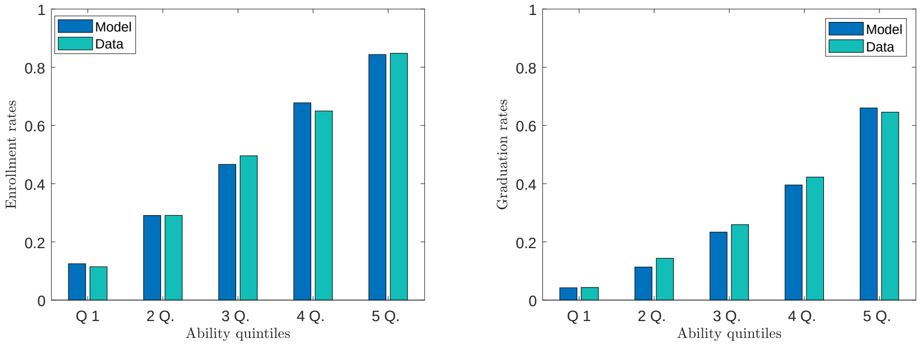
[38] It should be noted that all other dropout channels are exogenously calibrated. In an alternative version of the paper, the wage process is calibrated exogenously, while grants' stochasticity is calibrated internally. The results are robust both quantitatively and qualitatively. Specifically, the policy-relevant channel - grants' stochasticity - explains the dropout rates with the same magnitude, allowing the policy impact and welfare results to remain unchanged. However, there is a slight difference in the relative weights of ability beliefs and productivity in explaining dropout rates, with ability belief playing a slightly larger role.

Table 12: Externally calibrated parameters

Parameter	Description	Value
Demographics		
n	Population growth rate (annually)	1%
φ	Survival probabilities Actuarial Life Tables	
j_r	Retirement age (age 66)	25
J	Maximum age (94)	40
Preferences		
γ	Risk aversion parameter	0.25
ν	Parameter for leisure (hours worked)	0.374
Technology		
α	Capital share of output	0.33
A	Total factor productivity	1
δ	Depreciation rate (annually)	0.05
ϑ	Elasticity of substitution (Card (2009))	0.69
Labor productivity		
σ_{θ_n}	Fixed effect for non-college	0.059
ρ_c	Persistence parameter, college	0.933
η_c	Stochastic shock, college	0.033
$\rho_{n,d}$	Persistence parameter, dropout & high school	0.906
$\eta_{n,d}$	Stochastic shock, dropout & high school	0.032
Edu. costs and subsidies		
z_1	Subsidy rate in period 1	section **??**
z_2	Subsidy rate in period 2	section **??**
Φ_1	Student loan parameter (the Office of the Federal Student Aid)	0.396
Φ_2	Student loan parameter (the Office of the Federal Student Aid)	0.791
λ_l	GPA function (Stinebrickner and Stinebrickner (2008))	-1.11
Government policy		
g_y	Government spending to GDP ratio	17%
τ_c	Consumption tax	7.3%
τ_k	Capital income tax	28.3%
κ_s	Pension benefits	35%
m	Progressivity	0.1

rates well. The average college wage premium is 80% both in the model and in the data. The average wage premium of dropouts is 20%, which is in line with its empirical counterpart. Additionally, the model matches the capital-output ratio as well as the average percent of total time endowment devoted to the labor market.

Figure 3: Targeted moments. The fraction of enrollment and graduates in each ability quintile. Model vs. Data (NLSY97)



(a) Enrollment rates **(b)** Graduation rates

Table 13: Internally calibrated parameters

Parameter	Description	Value	Target
Discount factor			
β	Discount factor	0.99	K/Y
Production function			
υ	MP of skill levels	0.94	College wage premium
Utility cost of attending college			
b_0	const. in $\xi(\cdot)$	0.45	Total enrollment
b_1	slope par. in $\xi(\cdot)$	-0.16	Enrollment rates by ability quintiles
Edu. costs			
ι	Cost parameter ($\frac{\iota w_{t,c}}{\hat{Y}}$)	0.196	College tuition as a share of GDP
GPA thresholds			
$\overline{GPA}_{need}$		0.1	% with less than GPA 2 in the data
$\overline{GPA}_{merit}$		0.3	% with less than GPA 3 in the data
Generalized Pareto Dist.			
p_k	shape parameter	0.08	Average family contribution
p_σ	scale parameter	0.94	Average family contribution
Labor productivity			
ω_h	scale parameter	0.28	(Section 4)
ω_d	scale parameter	0.84	Dropout wage premium
σ_{θ_d}	fixed effect, dropout	0.072	Total dropout
σ_{θ_c}	fixed effect, graduates	0.084	Graduation rates by ability
Budget-balancing government policies			
τ_p	Payroll tax	0.07	Pension-budget clearing
$1-\lambda$	flat part of the earnings tax	0.19	G budget clearing

Table 14: Targeted moments: Model vs. Data

Description	Model	Data	Source
Capital-Output Ratio	3	3	Fernandez-Villaverde and Krueger (2011)
College wage premium	1.8	1.8	Lee, Shin, and Lee (2015)
Dropout wage premium	1.2	1.2	Lee, Shin, and Lee (2015)
Tuition to GDP ratio	0.5	0.5	NCES
Total Enrollment	49.4	49.4	NLSY97
Total Dropout	36.2	36.3	NLSY97
Average working time	0.3	0.3	PSID
Student budget to GDP per capita	0.5	0.5	NCES
Initial wealth			Table 6
Enrollment rates by ability			Figure 3
Graduation rates by ability			Figure 3

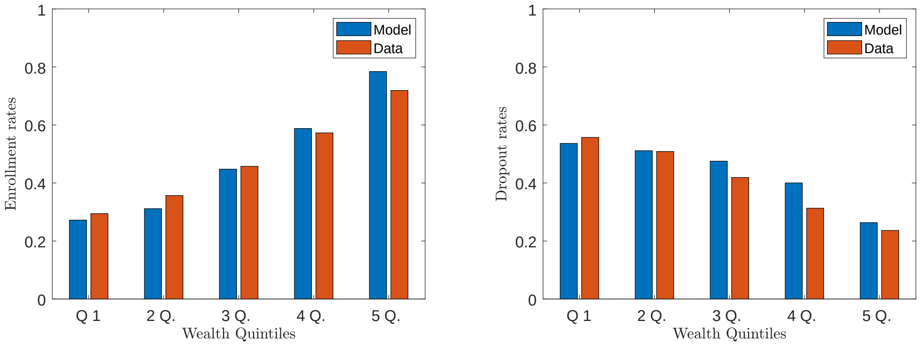
5.2 Untargeted moments

To evaluate how the model performs, I analyze untargeted moments in several directions. Firstly, I examine how well the model captures college participation margins by wealth. Afterwards, I use the micro-empirical literature estimates to validate the model's elasticities to a change in subsidy rates. This is important because I utilize the grant system as a policy tool in the policy analysis section, and examining these elasticities is crucial to validate the model. Finally, I examine the extent to which the model captures the earnings distribution of the economy.

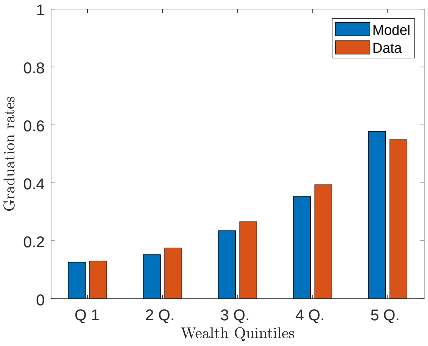
5.2.1 College participation margins by ability and wealth quintiles

Figure 4 exhibits a set of non-targeted moments in the model: the enrollment (panel a), dropping out (panel b), and graduation rates (panel c) by initial wealth. The figure shows that the model successfully matches these college participation patterns. It is observed that enrollment and graduation rates are increasing in initial wealth. These patterns are driven by the following factors. First, the wealthier the individuals are, the more affordable education becomes. Second, initial wealth compensates for the instantaneous loss of utility from attending college through consumption. Third, the assets enable them to self-insure against adverse financial shocks at college. All of these end up increasing enrollment and graduation profiles while reducing dropout patterns with respect to wealth.

Figure 4: Untargeted moments. The fraction of college entrants, dropouts and graduates in each wealth quintile. Model vs. Data (NLSY97)



(a) Enrollment Rates **(b)** Dropout Rates



(c) Graduation Rates

5.2.2 Enrollment and graduation elasticities w.r.t. an increase in subsidies

In this section, I examine the responsiveness of college enrollment and graduation rates in the model regarding subsidies. To understand the effect of changes in the price of education on participation, micro-empirical studies have conducted small-scale natural experiments to quantify college participation elasticities. While some studies have focused on the enrollment margin, fewer have examined the impact on the completion margin. Thus, I will explore the effects on both margins separately in order to gain a more comprehensive understanding of the relationship between subsidies and college outcomes in the model, and to compare these outcomes to those estimates.

Table 15: Responsiveness to an increase in subsidies. Model vs. Empirical Estimates

Increase in subsidies by $2900		
	Scott-Clayton (2011)	model PE
Δ in enrollment	–	3.6pp
Δ in graduation	7.5pp	5.0pp
Increase in subsidies by $1000		
	Deming and Dynarski (2009)	model PE
Δ in enrollment	3 – 6pp	4.0pp
Δ in graduation	–	2.8pp

Note: I use the estimated model to simulate the experiment of increasing grants and compare their effects on college enrollment and graduation in the model to its empirical estimates. First, I analyze the impact of an increase in merit-based grants on college completion in the spirit of the study of Scott-Clayton (2011). Second, I analyze the impact of an increase in grants by $1000 in the spirit of Deming and Dynarski (2009). I then compare the elasticities to those of the empirical estimates.

Using administrative data, Scott-Clayton (2011) quantifies the impact of the introduction of the PROMISE scholarship in West Virginia in 2002 on the college completion margin by exploiting discontinuities in (1) the eligibility formula and (2) the timing of the implementation. The scholarship is worth $2,900 annually on average. It is granted to college entrants with a high school GPA higher than 3.00, a requirement that was met by 40% of college enrollees. To maintain this reward, students were required to earn a GPA above 3.00. The requirement was met by 50% of the students at the end of the fourth year. Scott-Clayton (2011) finds that such an increase in subsidies increased graduation rates by 7pp.

To implement the same exercise in the model, I increase the size of the merit-based grants by $2,900 to those students whose ability prior belongs to the top 40% of the distribution. I allow students to keep the grants in the second half of college if their realized GPA belongs to the top 50% of the grade distribution among those who received the merit-based grant in the first year. I check the model's responsiveness in the partial equilibrium framework, keeping skill prices and the tax system as in the benchmark economy. The results are summarized in Table 15. According to my findings this increases college completion by 5 percentage points, which is comparable to 7.51 percentage points found in Scott-Clayton (2011).

As the next step, I test the enrollment margin. As Scott-Clayton (2011) does not examine this margin, I compare the responsiveness of this margin with the large empirical literature summarized by Deming and Dynarski (2009). Their findings propose that a $1, 000 reduction in the cost of attending college leads to 3 to 6 percentage points increase in enrollment. Therefore, in the next experiment, I increase subsidies by $1, 000 and quantify the impact on college enrollment rates in the next experiment. I find that the model's enrollment rates as a response to this change in subsidies increases by 4pp, completion rates by 2.8pp, well in the range of threir findings. The results are summarized in Table 15.

5.2.3 Earnings inequality: Model vs. data

In this section, I quantify how far the model goes to generate realistic wage dispersion. This is particularly important as the general equilibrium wages are one of the main drivers of the elasticities of college participation margins in the model. I report different measures of earnings inequality, including wage ratios, Gini coefficients for wage income. I then compare them to pre-tax earnings inequality observed in the data. Table 16 summarizes the results.

The benchmark model generates a Gini coefficient in line with the data. At the same time, the model slightly overshoots overall earnings inequality when measured by the wage ratio between the 90th percentile and 10th percentile of the wage income distribution. Overall, however, the model matches earnings inequality in the data reasonably well.

Table 16: Earnings inequality: Model vs. Data

	Model	Data
Gini	0.4	0.4
P90/P10	6.4	5.2
P90/P50	2.3	2.4
P50/P10	2.9	2.2

6 Model mechanism

6.1 Initial wealth, ability, and the decision to Drop Out

In this section, I explore how family wealth and initial ability interact with the decisions to drop out of college. As discussed in section 3, dropping out can be driven by (1) ability signals, (2) shocks to grants, and (3) shocks to labor productivity. The policy functions of dropping out decisions are summarized in Figures 5a, 5b and 5c, respectively.[39] Each figure plots the dropout decisions of an individual with the 10th (top), 50th (middle), and 90th (bottom) percentiles of the initial wealth distribution. The horizontal axis refers to an ability prior, with the vertical axis denoting the college dropout/continuation decisions. The red and blue lines plot the policy functions of dropping out under positive and negative shocks, respectively. The blue shaded area characterizes the region in the ability prior where individuals find it optimal to enroll in college in the first place.

The black shaded area, on the other hand, is the region where students' college dropout decisions depend on the type of the shock they receive, i.e., if they receive a favorable shock, they will remain in college, otherwise they drop out. Note that the black shaded area is conditional on the college enrollment decision. Outside of the black area, individuals decisions to stay in college or to drop out is not contingent on the shocks. To the left of the black shaded area, the individuals either never enrolled or they are determined to drop out after the first period irrespective of the type of the shock. To the right of the black shaded area, the individuals are determined to complete college, irrespective of the shocks. Consider Figure 5a, for instance. A median wealth individual (second panel) with an ability prior of 0.7 is shown in the black region. This implies she will stay in college if and only if she experiences a high shock (a high ability signal) and leave college if she gets a low shock (a low ability signal). On the other hand, an

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[39] When studying each shock, I hold the other shocks fixed. By doing so, I isolate the dropout decisions that are solely driven by the shock under study.

individual with an ability prior of 0.2 within the same wealth group (middle panel, Figure 5a) is not inside the black region. Her education decision is independent of the shock only because she was never a student.[40]

Figure 5a illustrates how ability signals affect the dropout decisions. As discussed above, low ability signals influence the value of college in three ways. They lead to (1) lower GPA, and therefore, increase the utility cost from staying in college, (2) lower expected return on college graduation by lowering the (subjective) probability of drawing a high fixed effect after college graduation, and (3) a higher probability of losing the grant.[41] The following observations can be made. First, students from poor backgrounds enroll in college only if their ability prior is high, more than 0.6 in my normalization. This is shown by the shaded area on panel (a), Figure 5a. Second, their decisions to stay in college are altered by negative ability signals – they drop out if they get a low realization of the shock.

Next, I discuss the drop out decisions of median wealth students in the presence of ability signals, which is shown on the middle panel of 5a. It shows that they attend college with a wider ability prior, priors being higher than the bottom 50% percent. When those students get a low grade, they then decide to drop out. Their reevaluation of college stems from, first, the high realized instantaneous utility cost from staying in college (which is a decreasing function in grades), second, the lower expected return to a college degree (due to lower beliefs about ability), and, third, the fact that they owing be eligible for grants going forward. In the next section, I quantify the fractions of students dropping out of college owing to each of these factors.

Furthermore, I examine the behavior of wealthy individuals in response to low and high ability signals, presented in the bottom panel of Figure 5a. First, they enroll in college at any ability priors (the blue shaded area lies along all priors, masked by the gray area). This indicates that the wealthy are quite comfortable exercising the college option regardless of the high monetary and utility costs. However, they remain sensitive to ability signals. Wealthy students with a low ability prior who then earn low grades do not find staying in college optimal. They have a high instant-utility cost from remaining in college, lower expected returns to a college degree, and, to top it off, they can also lose grants due to GPA requirements. These factors, in combination, make dropping out value outweigh the return to a college degree.

Next, I turn to investigate the impact of grant shocks on college continuation decisions. As shown in equation 7, uncertainty about grants in the current system changes from one year to another due to (i) poor academic performance, and (ii) stochastic shocks. Figure 5b solely shows how the stochastic component of subsidies, ζ, interacts with the college retention decisions. As expected, poor students are particularly sensitive to the adverse financial shocks. The students who have an ability prior between 0.6 and 0.8 will leave college if they get a negative shock to the grants but stay in college otherwise. The dark shaded, i.e., the support of the ability prior at which students leave college if they get a low realization of the shock, extends almost until the very end of the ability support. This means that low-income students cannot afford to attend college without financial assistance, unless they are among the top 20% of the ability distribution. High academic ability lessens the negative effects of a shock in three ways: first,

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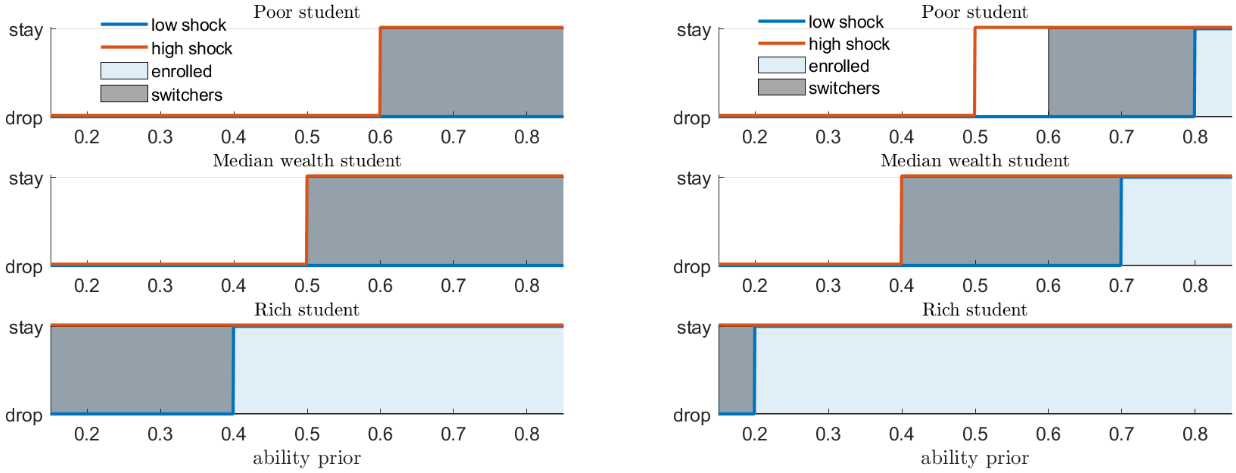
[40] If she were enrolled, she would also be part of the black region: she would stay in college if she received a high shock (red line), and leave college if she got a low shock (blue line).

[41] Note, if GPA falls below the threshold – $\overline{GPA}_{need}$ or/and $\overline{GPA}_{merit}$, individuals lose their grants.

students with high ability have a lower opportunity cost of staying in college, leaving them more time to work. Second, they earn more while in college due to their higher productivity in the labor market, which is dependent on ability. Third, they receive higher financial gains post-graduation, as the premium for a college degree is also dependent on ability.

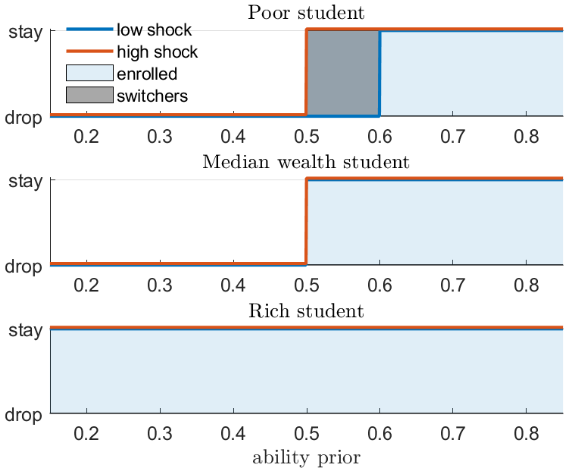
Figure 5: Dropout decisions by ability prior and initial wealth



(a) Signals

(b) Shocks to grants

(c) Idiosyncratic productivity shocks



Note: the y-axis plots the college dropout decision, and the x-axis plots the ability prior support, normalized between 0 and 1. The blue shaded area marks the ability priors in which the individuals find it optimal to enroll in college in the first period. The red (blue) line denotes the dropout decision under the high (low) realizations of the shock (ability signals in panel (a), grants in panel (b), and idiosyncratic productivity in panel (c)) at the beginning of the second college period. The gray shaded area marks the support of the ability prior in which students are sensitive to the shocks, i.e., where they drop out if they get a low shock and stay if they get a high shock. A comparison of the panels highlights that a poor student is more sensitive to the negative shocks of ability signals and grants than a rich student.

The middle panel of Figure 5b exhibits the dropout decisions of the median wealth students. The panel characterizes a large range of ability priors at which students with median ability cannot afford college if they get a low realization of the grant shocks. If they lose the grants and their prior is not greater than 0.7, they optimally leave college and engage in full-time work. Therefore, individuals with high ability are able to survive in college regardless of financial shocks, unlike those with median ability who cannot afford to graduate without grants. The dark shaded area in the middle panel extends over median ability levels, implying that students of median wealth and high ability are able to insure themselves against adverse shocks for the same reasons as those who are poor and have high ability. The bottom panel of Figure 5b shows that wealthy students are unaffected by adverse financial shocks as long as their ability prior is greater than 0.2. Their ability to easily hedge against the loss of need-based grants can be attributed to their initial wealth, which provides them with financial resources to fall back on. Furthermore, need-based grants awarded to wealthier students tend to be a smaller proportion of the total cost of college than those awarded to students with lower income. Therefore, need-based grants may not create the same financial burden for wealthier students as they do for those who rely more heavily on financial aid.

Figure 5c examines the impact of productivity shocks (η) on the decision to stay in college. Productivity shocks have an ambiguous effect on education decisions. They can motivate some students to stay in college by making education more affordable, while at the same time motivating others to leave college by increasing its opportunity cost. For the state space shown in the figure, it can be observed that the first effect dominates for poor students with ability priors of 0.5 and 0.6. They stay in college in the presence of good productivity shocks, as these make college more affordable. Additionally, it is observed on the figure that median wealth and rich individuals are not affected by the productivity shocks given this particular state. It is worth noting that there is another channel related to the wage process that incentivizes some students to drop out, which is the dropout wage premium incorporated in the expected fixed effect derived from the dropout wage distribution.

This analysis highlights that the placement of uncertainty, within or outside the college context, has a distinct impact on individuals dropout decision. When uncertainty arises from factors external to college, such as shocks to the labor market, its impact on college attendance is ambiguous and context-dependent. However, when an adverse shock stems from within the college system itself, it tends to have an unambiguous negative effect. Therefore, differentiating the sources of uncertainties within the college is important for understanding dropout behavior, indicating to consider this aspect of financial uncertainty at college.

To conclude, this section highlights that both having a high initial wealth level and a high ability prior mitigates the pivotal power of low shocks in college that make college suboptimal. However, talented poor, and median wealth students largely remain sensitive to the negative financial shocks and unlucky ability signals. This is a potential source of inefficiency, taking into account that ability and education are complements in productivity. In order to gain a better understanding of the magnitude of these shocks and their overall impact on the economy, I will explore distributions in the next section and quantify the percentage of talented students who leave college due to these adverse shocks.

6.2 Decomposing the channels of dropping out

In this section, I explore how the benchmark dropout rates change after eliminating one dropping out channel at a time. This is an important step to analyze the potential scope for policy intervention. As a case in point, if productivity and learning about ability drive a significant amount of dropout decisions, then there is relatively little scope for policy intervention. On the other hand, if grants volatility strongly impacts on dropout decisions, then policy makers can use grants as an instrument to target dropout rates. Throughout these experiments, I consider partial equilibrium outcomes (i.e., keeping prices and the tax system as in the benchmark economy). This is a useful in isolating the effects of each dropping out channel from its interactions with the general equilibrium forces.[42]

The first three experiments delve into the grant system. In the first and second experiments, I study what happens when grants face no stochasticity, $\zeta = 1$, and, what happens when maintaining grants is not GPA-contingent. In the fourth experiment, I study the two in combination, i.e., when the grants stay constant over the two college periods. The fourth experiment assumes that students know their true ability, thus implying that students can predict their grades, utility cost, and face less uncertainty in their post-college labor market outcomes. In the fifth experiment, I isolate the impact of labor productivity shocks on dropout decisions. To achieve this, I recompute the model, eliminating all other types of uncertainties. In practice, this means integrating all previous studies: students possess comprehensive knowledge of their inherent abilities, there are no unexpected changes to scholarships during college education, and scholarships are not dependent on GPA. In this setting, all remaining dropout decisions are prompted by favorable idiosyncratic productivity shocks, η, or the dropout wage premium.

Table 17 summarizes the results. The first four rows report the college participation frequencies in the benchmark and the counterfactual experiments, and the last two rows report the average working hours and labor productivity. Labor productivity is defined as the average product of wages and the efficiency units of labor. Note here that the change in labor productivity is solely steered by the change in the efficiency units since wages are set to the benchmark value.

Results from experiments 1 and 2 are presented in columns 2 and 3 of Table 17, respectively. It is observed that eliminating the stochastic part of the grants and the GPA requirements reduces the dropout rates by 33.7% and 4.5%, respectively. As opposed to the experiment of the GPA requirements, average efficiency units of labor increase significantly in the stochastic shock experiment. The difference comes from ability sorting. Removing the uncertain component of scholarships leads to a rise in graduation rates for high-ability individuals, while easing GPA requirements, as anticipated, largely increases graduation rates for individuals with low to medium abilities.[43]

In the third experiment, I find that keeping grants constant across the college periods has the largest effect on college enrollment, and graduation rates. The fifth column of Table 17 shows

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[42] For instance, when incorporating general equilibrium effects, it becomes impossible to disentangle the specific role of the dropout channel in driving the changes in dropout rates. This is because the dropout rates are also influenced by general equilibrium dynamics, such as changes in skill prices and taxation.

[43] I discuss ability sorting in details in section 7, where policy experiments are analyzed taking into account the general equilibrium forces.

that the aggregate dropout rates fall by 40.9% (about 15pp) and now constitute only 21.4% of total enrollees. As a result, 45 percent of students graduate. I observe that experiment 3 has a stronger impact on the enrollment as well as on the graduation rates than the combination of experiments 1 and 2. This is because there are a set of individuals at risk of losing their grants either by a stochastic shock to their grants, and/or the GPA requirements. Therefore, eliminating only one reason (like in experiments 1 and 2) puts them at risk of losing their grants because of the other. Only when one eliminates both simultaneously do the individuals find it significantly less risky to enroll. Consequently, under this experiment, about 8pp more people enroll in college in comparison to the benchmark economy. Once enrolled, they maintain their grants, and, therefore, find it optimal to graduate. As a result, the graduation rates increase by 13.5pp. This has a strong positive impact on the overall economy. With the increase in the graduation rates, aggregate labor productivity increases by 4%. This result underpins the strong linkage between skilled workers and aggregate productivity in the economy. Note that this exercise defines a clear scope for policy intervention. Given the skill premium and tax system as in the statues quo, if the uncertainty embedded in the current grant system was eliminated, 8pp more students enroll and 14pp more students graduate.

In the fourth experiment, under the complete information scenario, the enrollment rate decreases. There is a set of low ability individuals who do not enroll into college since they are aware of their low academic ability, the high utility cost of attending college, and the low pay-off of a college degree. On the other hand, the high ability individuals want to enroll in college as they know they are academically talented. These countervailing factors result in the number of college entrants remaining virtually the same. However, since the optimism parameter is also set to be zero with the noise in signals, overall less students enroll. The reduced uncertainty leads the number of college dropouts to decrease by as much as -10.1% (about 3.6pp). Note that, less students, and less graduates reduce efficiency units of labor by -0.1%.

The last experiment, where students do not face any uncertainty (combination of policy 3 and 4) in college but do experience labor productivity shocks, reduces dropout rates by 49.6% and sets it to 18.2%. The students who still drop out find their outside options more attractive even in the absence of ability uncertainty and grant volatility. Despite the absence of ability uncertainty and grant volatility, some students still choose to drop out. This is because they receive a favorable idiosyncratic wage shock, η, which makes the value of the outside option of college more attractive than staying in college. Typically, these students have low to median ability and do not anticipate high post-college earnings due to the complementarity between ability and the college wage premium. Under this experiment, students do not have optimism, so they are more averse to enrolling in college. At the same time, they face a more stable grant system. These two effects result in the overall enrollment rates remaining relatively unchanged. The average efficiency units increase in response to the increase in the quantity and quality of graduates.

Before concluding, it is worth discussing why ability learning alone does not explain the largest share of dropouts. Looking at the data, considerable differences can be observed in enrollment rates by ability (see Table 24). Only 11% enroll from the lowest ability quintile, while the same fraction is 86% from the highest quintile. This marked difference in the enrollment rates by ability implies that students have a decent prior on their ability when they

Table 17: College participation rates: Experiments vs. Benchmark

	Benchmark	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5
		No stochastic shock	No GPA requir.	Constant grants	known ability	residual dropout
Δ in dropout rates	0	-33.7	-4.5	-40.9	-10.1	-49.6
Dropout rates	36.1	24	34.5	21.4	32.5	18.2
Enrollment rates	49.4	55.2	49.5	57.3	44.7	51.2
Graduation rates	31.5	42	32.4	45	30.2	41.8
Δ, Efficiency units,$\hat{L}$	0	4	0.4	4.9	-0.8	3.8
Δ, Hours, $\hat{H}$	0	0	0	-0.1	0.1	0
Δ, Flat tax rate, τ_w	0	-2.9	-0.1	-3.9	-0.2	-3.4

Note: Counterfactual experiments are implemented in the partial equilibrium, i.e., keeping skill prices and tax system as in the benchmark economy.

consider enrollment. Furthermore, when looking at the NLSY97 data, it is evident that low-ability students, as measured by AFQT test scores, make up only a small proportion of enrolled undergraduates. Individuals from the lowest two quintiles of ability comprise just 16% of enrolled students. Therefore, it is clear that low-ability students alone cannot account for the high dropout rates observed in the data. If students were to face more uncertainty, the model would struggle to capture the stark disparity in enrollment rates across ability quintiles, as observed in the data (see Figure 4). This suggests that factors beyond ability learning play a significant role in dropout decisions.

To sum up, this section shows that the college students' financial situation plays a significant role in the decisions to drop out. Therefore, there is scope for an intervention if a government aims to reduce dropout rates caused by financial difficulties. I use this finding in the next section to study potential policies and evaluate their impact on skill allocation, sorting, macroeconomic equilibrium aggregates, and, finally, welfare gains in the long run.

7 Policy

In this section, I examine governmental policies aimed at the current grant system in a general equilibrium setting. The use of a general equilibrium framework in this analysis is crucial as it enables the examination of the effects of large-scale education policies on the reallocation of skills and the equilibrium skill prices, providing a comprehensive understanding of the long-run dynamics of the economy in response to these policies.

I implement three governmental policies, assuming that each policy lasts forever, and the government balances its budget by the level of the labor income tax schedule, λ, defined in equation 9. In the first policy, the government eliminates the stochastic element in the grant system, leaving the GPA requirements intact. This means that under policy 1, students only lose grants if their GPA drops below the threshold. This eliminates the need for reapplication each academic year and instead, students automatically maintain the grants as long as their GPA requirements are met (which can be checked through their academic transcripts). Under the second policy, the government eliminates the GPA requirements, leaving the stochastic part of the grants as it is in the benchmark economy. This implies that students maintain the grants regardless of their grades; however, they might lose them due to an exogenous shock.

Removing the GPA requirements may help students who were too optimistic and initially had high signals to leave college, but it also may lead to high ability students losing grants due to unlucky grades and increasing their own precarity in college. Finally, in policy 3, the government makes grants constant between academic years in both ζ and GPA. Eliminating both sources of uncertainty together would have amplified effects on the college participation margins, because some individuals would have lost grants due to either channel in the benchmark economy.

The rest of the section is structured as follows. In section 7.1, I analyze the changes in college enrollment and dropout rates compared to the benchmark economy. Section 7.2 focuses on the effects of the policies on the sorting of students by ability and wealth within college. In section 7.3, I quantify the impact of the policies on macroeconomic aggregates. Lastly, in section 7.4, I examine the welfare implications of these policies.

7.1 College participation rates in the long-run

Table 18 illustrates the impact of three governmental policies on college participation in a general equilibrium setting. The policies aim to improve the grant system by eliminating the stochastic element and GPA requirements. The results show that these policies lead to higher enrollment and graduation rates, but the magnitude of these effects is less pronounced in the long run compared to the partial equilibrium analysis in section 6.2. The increased enrollment and graduation rates range from 2 to 3 percentage points. The difference in short-term and long-term outcomes is driven by the dynamics of skill prices and taxation in the long run. The reduced uncertainty makes college investment more attractive, leading to more students enrolling and fewer students dropping out. The share of college graduates increases over time, which leads to a gradual decrease in the equilibrium skill premium (by around -2%). This, in turn, increases the option value of dropouts and further decreases the riskiness of college, resulting in moderately higher enrollment and graduation rates while keeping the dropout rates virtually unchanged in the long run.[44] The divergence of the short-run and long-run dynamics emphasizes the importance of explicitly accounting for general equilibrium effects while studying large-scale education policies. While the long-run impact on overall dropout rates may not be strong quantitatively, it has a significant effect on the qualitative aspects of dropouts, resulting in a shift in dropout frequencies from high-ability, low-income students to low-ability, high-income students. Understanding the changing ability composition of dropouts is of intrinsic importance when considering its implications on aggregate productivity, as we will further explore below.

Table 18: College participation rates under the benchmark and policies.

	Benchmark	No stochastic shock Policy 1	No GPA requirements Policy 2	Constant grants Policy 3
Enrollment rates	49.4	52.5	49.3	54
Graduation rates	31.5	33.6	31.8	34.4
Dropout rates	36.1	36	35.4	36.3
Wage premium	0	-1.7	-0.7	-2.8

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[44] These results align with the empirical findings of Dynarski et al. (2021), who by means of experimental settings show that promising constant amount of grants across academic years results in higher enrollment rates.

Policy 3, which combines policies 1 and 2, leads to outcomes that are similar to policy 1 but with a larger quantitative impact. In the benchmark economy, there exists a group of individuals who face the risk of losing grants due to both stochastic shocks and GPA requirements. As a result, some of them choose not to enroll in college, and others who do enroll may drop out after experiencing adverse shocks. However, under policy 3, this group of individuals no longer faces grant uncertainty, making college more attractive to them. Consequently, more students decide to enroll in college. Furthermore, policy 3 reduces the college wage premium by up to 2.8%, thereby further decreasing the risk associated with college. These mechanisms amplify enrollment rates by 4.6 percentage points and graduation rates by 2.9 percentage points, resulting in a slight increase in overall dropout rates by 0.2 percentage points. The college and dropout wages are examined in greater detail below.

One model limitation regarding policies 2 and 3 is that if the grant system is unconditional on GPA, students might decrease college effort, a dimension not integrated into the model. In the model, this effect would be captured by an increase in labor supply, specifically by students working more during college. However, quantitatively this channel is found to have a small impact. At the same time, as seen in Table 18, policy 1, which eliminates only the stochastic part of the grants, already leads to a significant increase in graduation rates that can be achieved in the long run, accounting for up to 70% of the total increase that can be achieved under policy 3. Therefore, policy 1 is already a powerful policy that significantly raises graduation rates compared to policy 3.

7.2 Sorting into college by ability and wealth

Next, I examine how the reforms affect ability and wealth sorting at college. For that purpose, Figure 6 (Figure 7) plots the change in percentage points of college participation margins by ability (wealth) under policies relative to the benchmark. Panels (a) and (b) capture the percentage point deviations in college enrollment and graduation rates, respectively. Policy 1 is captured with blue bars, policy 2 with yellow bars, and policy 3 with red bars.

Figure 6 illustrates that both policy 1 and policy 3 have a substantial impact on sorting, resulting in increased enrollment and graduation rates among higher ability individuals. As expected, policy 2 works in the opposite direction. A comparison of these policies reveals that the key to improving sorting is to remove grants stochasticity. This change benefits low-income students with high abilities, enabling them to graduate successfully, as discussed in section 6.1. Interestingly, the impact of these policies on low-ability students is relatively smaller. There are two reasons for this. First, this group is already susceptible to other types of adverse shocks in college, such as low ability signals and stringent GPA requirements. As a result, the influence of stochastic shocks in explaining their dropout rates is diminished. Second, a larger proportion of this ability group consists of wealthy students, as discussed in section 6, who are less affected by financial shocks to begin with.

Policy 2, which eliminates the GPA requirements, does not significantly change sorting patterns based on ability. Lower-ability levels have a lower risk of losing their grants, leading to a higher chance of graduating, but the overall effect is small. Interestingly, there is a slight decrease in the number of graduates from the top ability quintile. This can be attributed to the

Figure 6: Relative changes in college participation rates compared to the benchmark by ability

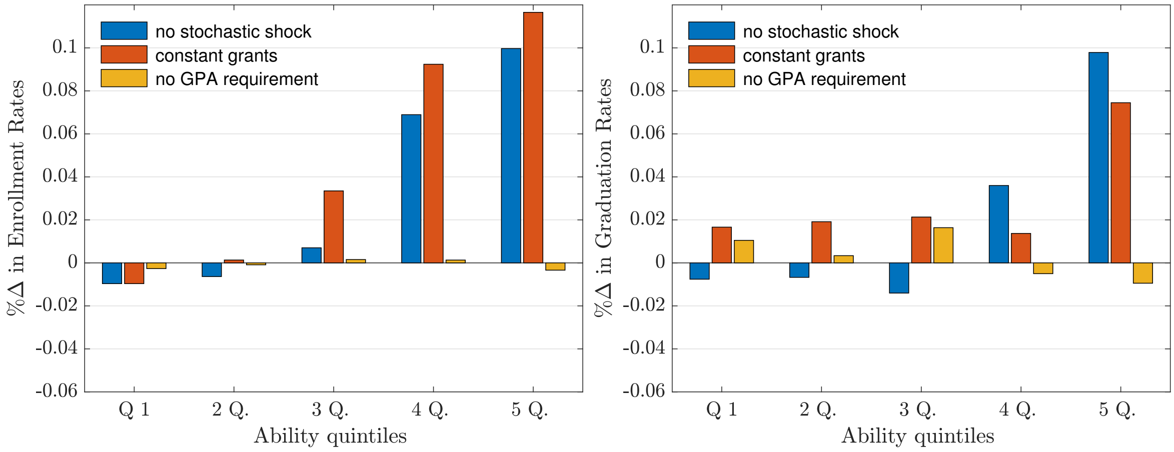
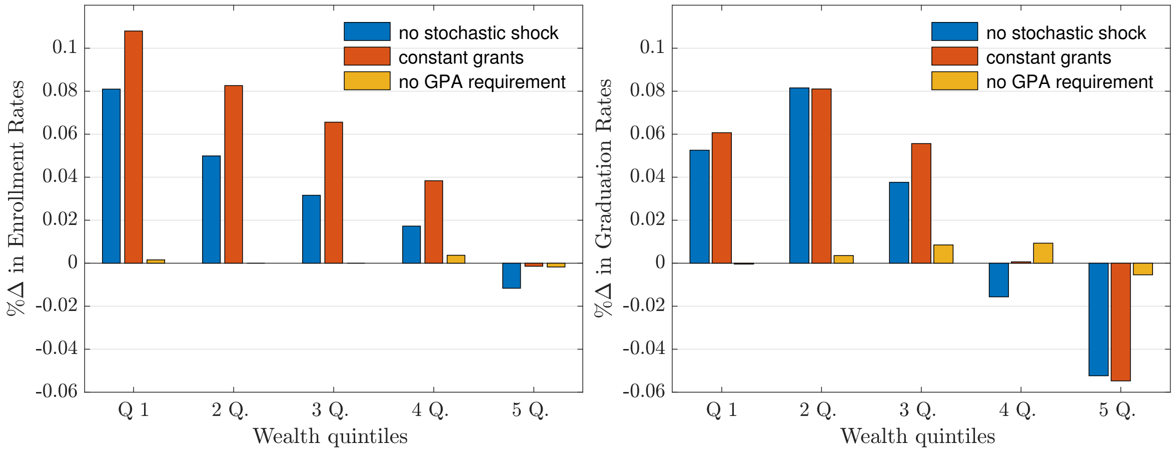


Figure 7: Relative changes in college participation rates compared to the benchmark by wealth



fact that none of these students were at risk of losing their grants due to GPA requirements in either scenario. However, they now face a higher opportunity cost of college due to a decrease in the wage gap between attending college and dropping out.

Next, I explore the sorting patterns based on wealth. The analysis shows that removing grant uncertainty primarily assists low income students. As previously discussed, these students are most at risk of dropping out due to financial uncertainty. Moreover, a noticeable decrease in the graduation rate is observed among the wealthiest quintile. This decrease in the graduation rate is primarily driven by lower ability students, who choose not to graduate due to the decline in the college wage premium. Thus, these policies not only enhance sorting in college by enabling more talented individuals to graduate but also facilitate the exit of less talented individuals from college.

7.3 Macroeconomic variables

Here I examine the impact of each policy on the economy in terms of equilibrium aggregates. Table 19 reports the relative changes in key macroeconomic variables under the experiments relative to the benchmark. In this regard, several observations can be made. Under each policy, average labor productivity increases, while average hours worked falls or stays about the same.

Importantly, under policy 1 and policy 3, productivity increases by 2.1% and 2.9% respectively. Better sorting in college improves productivity due to the complementarity between ability and college earnings.

Table 19: Relative changes in macroaggregates under the policies compared to the benchmark

	No stochastic shock Policy 1	No GPA requirements Policy 2	Constant grants Policy 3
Efficiency units, Labor	2.1	0.2	2.9
Hours	-0.1	0	-0.2
Output	2.2	0.2	2.9
Capital	0.2	0	0.3
Consumption	2.1	0.2	2.8
G edu	18.6	1.8	25.1
G edu/GDP	16.1	1.6	21.6
Interest rate	-0.3	-0.1	-0.6
Flat tax rate	-0.9	0	-1.1

Coupled with the increase in labor productivity, aggregate output and consumption significantly increase under all policies. The magnitude of these changes closely follows the relative changes in labor productivity across the policies. The increase in average consumption is 2.1%, 0.2%, and 2.8% under policies 1, 2, and 3, respectively. Policy 2 lags behind in terms of ability sorting, which affects its impact on output. Additionally, it is worth noting that the sum of the increase in output across the first two policies is less than the increase under policy 3 (which is a combination of policies 1 and 2). The effect on output is magnified under the latter policy as it specifically promotes higher enrollment rates and, as a consequence, graduation rates.[45]

Next, I analyze the monetary cost for the government to implement each policy compared to the benchmark. To gain some intuition, it is important to note that the increase in output directly influences the cost per student in all economies, assuming that tuition is a fraction of average output. As a result, the government needs to allocate more funds in absolute terms: (1) per student, (2) for a larger number of students, and (3) for an extended duration.

Table 19 shows the percentage change of (1) the absolute cost of education subsidies and (2) education subsidies to GDP ratio. Government spending on education increases by 18.6%, 1.8%, and 25.1% under policy 1, 2, and 3, respectively relative to the benchmark economy. The changing cost for the government is compensated by an increase in output. The ratio increases less than the absolute cost of education for the government (16.1% vs. 18.6% under policy 1, 1.6% vs. 1.8% under policy 2, and 21.6% vs. 25.1% under policy 3). Thus, neglecting the increase in output while accounting for the increased government spending would lead to an overestimation of the cost of the policies.[46]

Now I examine whether the increase in the cost of subsidies constitutes a burden on tax-

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[45] As discussed in section 6.2, this effect comes from the fact that eliminating both policies together reduces college riskiness for large share of individuals, and therefore they want to exercise a college option.

[46] Note that I made an assumption that the cost is tied to the aggregate output in the economy. If the absolute cost of education remained the same as in the benchmark, then, in the long run, the price of education would become a significantly lower share of aggregate output, and consequently, for the government the policies would be even cheaper.

Table 20: Wage premiums and efficiency units by education level and by skill type

	No stochastic shock Policy 1	No GPA requirements Policy 2	Constant grants Policy 3
College premium	-1.7	-0.7	-2.8
Dropout premium	4.9	1.1	8.7
Efficiency units, graduates	3	-0.1	2.4
Efficiency units, dropouts	2	1	4.9
Efficiency units, high-school	-2.6	-0.2	-3.1

payers. Table 19 shows that the equilibrium labor income tax rate τ_w decreases rather than increases under policies 1 and 3 – the policies that foster aggregate productivity the most. This is attributed to the increased tax bases in consumption, capital income, labor earnings, and pension contribution, which allows the equilibrium labor tax rate to decrease. In contrast, under policy 2, the equilibrium tax rate stays virtually the same. The results suggest that eliminating the uncertainty embedded in the current grant system is a self-financing policy in the long run, in the sense that the increased subsidies decrease rather than increase the equilibrium tax rates.

Finally, it is important to discuss the wage premiums. The general equilibrium results are largely influenced by a change in the skill prices and this is the primary factor contributing to the disparity between partial equilibrium and general equilibrium results (Table 17 vs. Table 18). The change in college and dropout wage premiums relative to the benchmark economy are summarized in Table 20. The college (dropout) wage premium is defined as the average earnings of a college graduate (dropout) at age 50 relative to the average earnings of the same age high school graduate. Several observations can be gathered here. First, it can be observed that the college wage premium decreases under each policy. The decrease is around 1.7%, 0.7%, and 2.8% under these policies. The decrease in the college premiums follows from the fact that there is a larger share of skilled workers under the reforms relative to the benchmark. The reduction in the college wage premium is closely accompanied by an increase in the dropout wage premium. It increases by 4.9%, 1.1%, and 8.7%, respectively, under policies 1, 2, and 3. The economic mechanism behind this is that the ability composition of college dropouts improves relative to the benchmark economy (as policies increase enrollment at high ability groups), and, as a result, the average labor productivity of this group improves due to ability-dependent labor market outcomes. Therefore, the dropout earnings are higher relative to the benchmark because of the complementarity between education and the fixed effect.

7.4 Welfare

In this section, I examine how increased enrollment, dropout and graduation rates, increased productivity, and the decreased gap in skill prices affect the overall welfare of the economy in the long run.

I explore welfare effects in three distinct ways. First, I examine a welfare measure in terms of consumption equivalence, denoted by ω_{CEV}, showing what percent of consumption should be given to an individual in the benchmark economy to make her indifferent between being born in the pre-reform and the post-reform economy. Second, I decompose the welfare gains into three components: inequality, uncertainty and level effects in the fashion of Floden (2001) and Domeij and Heathcote (2004). Level effects exhibit whether a reform generates additional resources in the economy, i.e., at least one individual can be made better off under the policy, while the others keep the same utility. The uncertainty effects measure the proportion of welfare improvement that results from a reduction in an individual's consumption variability. Inequality effects are measured by comparing how equally consumption is distributed across different groups.[47] Third, I ask how the individual welfare gains change for various wealth-ability groups, i.e., exploring conditional welfare gains. This is useful exercise to see which particular groups lose or win from these policy reforms.

Table 21 summarizes the first set of results. The policies improve utilitarian welfare over the benchmark economy. The welfare gains for newborns are 2.4%, 0.1%, and 3.4%, for policies 1, 2, and 3, respectively. The substantial welfare gains under policies 1 and 3 are consequences of the positive co-movements in the macroaggregates discussed above. An increase in skilled labor fosters labor productivity. That in turn drives the equilibrium output to rise significantly and, therefore, increases average consumption. At the same time, the gap in skilled prices decreases pre-tax income inequality for ex-ante identical individuals. These dynamics result in large utilitarian welfare gains.

Table 21: Welfare gains under policies relative to the benchmark

	No stochastic shock Policy 1	No GPA requirements Policy 2	Constant grants Policy 3
Welfare	2.4	0.1	3.4
Decomposition of welfare gains			
Welfare Levels, ω_{level}	2.1	0.2	2.8
Welfare Uncertainty, $\omega_{uncertainty}$	0.5	-0.2	1
Welfare Inequality, $\omega_{inequality}$	-0.7	0	-0.8

The separation of welfare effects shows that the level effect makes a significant contribution to these large welfare gains, as observed in the second row of Table 21. The level gains are 2.1%, 0.2%, and 2.8% for policies 1, 2, and 3, respectively. These results come from the fact that all policies yield a substantial increase in aggregate output and consumption.

Regarding the uncertainty effect, the policies yield welfare improvements in terms of uncertainty of 0.5%, -0.2%, and 1%. Two opposing factors influence these outcomes. Firstly, the removal of uncertainty has positive effects. Secondly, reducing uncertainty leads to increased college participation, resulting in greater uncertainty in wage streams during the early stages of the lifecycle when insurance is most challenging. It can be observed that the first effect prevails under policy 1 and policy 3, leading to positive gains of 0.5% and 1% respectively. However, for policy 2, the second effect outweighs the first, resulting in a negative uncertainty effect. Finally, the last row of Table 21 displays the impact of these policies on welfare inequality. The policies can influence inequality in two directions. The decreased gap in wage premiums should promote more equal welfare. On the other hand, inequality might increase as the policies improve sorting based on skills and ability, which are complementary. It is observed that the second effect

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[47] The details about the decomposition of the welfare gains are delegated to appendix G.

dominates under policies 1 and 3, while these two effects cancel out under policy 2, resulting in virtually zero impact on inequality in welfare.

Table 22: Conditional welfare gains under policies by ability and wealth

	low ability	median ability	high ability
Policy 1 – No Stochastic Shock			
Poor	1.6	1.6	2.7
Median	1.6	1.5	11
Rich	1.6	0.1	0.6
Policy 2 – No GPA Requirements			
Poor	0.1	0.1	0.1
Median	0.1	0.1	0
Rich	0.1	-0.1	-0.2
Policy 3 – Constant Grants			
Poor	1.9	1.9	6.6
Median	1.9	4.3	10.8
Rich	1.9	1	0.3

Next, I look at who wins or loses at an individual level. Table 22 provides conditional welfare gains for newborns of various wealth-ability groups. Specifically, I consider students at the 10th, 50th, and 90th percentiles of wealth and ability distributions, resulting in a total of nine different types. Table 22 reports the conditional welfare gains for policies 1 (panel (a)), 2 (panel (b)), and 3 (panel (c)).

First, examining panel (a) in Table 22 indicates that eliminating the stochastic part of the grant system leads all groups but one to win unconditionally on whether they go to college or not. For example, poor and median wealth individuals with low ability, and poor individuals with median ability do not go to college in either case. However, they face welfare gains of about 1.6% in terms of consumption equivalence. In the long term, the benefits are solely due to the rise in their relative wages and the reduction in average labor taxes. The college-bound individuals win as they face less adverse shocks in college, and the reduced uncertainty promotes their utility gains.

As for the case of the elimination of the GPA requirement (policy 2), panel (b) in Table 22 shows that only two groups, rich - median ability and rich - high ability individuals, lose (by 0.1pp and 0.2pp, respectively). This is because these groups would go to college and graduate in either case. The GPA requirement was not a major concern for them in the benchmark as they have quite a high prior, and the chance of losing grants is minor even in the presence of lower grades. While all other types gain, this group faces a decreased college wage premium (by around 0.7%) as compared to the benchmark case, and this is the driving force of their welfare losses. All other types gain.

Finally, as for the last policy, panel (c) in Table 22 shows that all groups but the top ability–top wealth group are better off relative to the benchmark economy. College-bound individuals win as the policy greatly reduces adverse shocks at college. Non-college individuals win as their wage rate increases. All individuals also enjoy the fact that the budget-balancing tax rate is reduced.

7.5 Hiring Professional Assistance for Grant Reapplication

Next, I will explore a scenario where the grant reapplication requirement remains intact, but students are provided with professional assistants to simplify the application process. This analysis aims to determine the cost-effectiveness of using professional assistance as an alternative policy to reduce grant uncertainty, as discussed in Bettinger et al. (2012). By comparing the cost per student of hiring an assistant with the potential gains in annual earnings per student and the resulting increase in labor taxes, I can evaluate the effectiveness of this intervention.

Assuming the assistance provided by professional assistants is perfect, implementing this intervention would be as effective as removing the entire reapplication requirements at college. This assumption allows me to work with the same policy functions students have under policy 1. Despite the possibility of partial uncertainty still existing in grant applications under this experiment, further analysis, as discussed below, is necessary to evaluate the feasibility and potential impact of this intervention. Appendix H demonstrates that the even improving partial uncertainty can generate significant welfare gains, underscoring its effectiveness.

To estimate the cost of hiring professional assistants, I refer to a study conducted by Bettinger et al. (2012). According to their research, the total cost per applicant for this intervention, including expenses associated with software adoption and call centers, amounts to approximately $87.50. Taking into account the fact that not everyone graduates, the cost per graduate is then calculated to be $137.4 per student.

To evaluate the potential benefits of this intervention, the focus is on the projected increase in average annual earnings for college graduates. On average, this intervention is expected to result in increased earnings of 1.7% per year, equating to a roughly $744 raise. Considering a minimum income tax rate of 20%, the cost per student per year is significantly lower than the benefit the government would receive from the expanded labor income tax base. The analysis suggests that reducing grant uncertainty by employing professional assistants for students could yield substantial benefits in comparison to the cost per student.

By focusing solely on college graduates, the estimated benefits provided may be considered conservative, as they serve as an illustrative example rather than an exhaustive analysis of potential outcomes. However, when accounting for the relative earnings gain of high school students and dropouts, as discussed earlier, as well as the potential increase in tax revenue from sources such as consumption and capital gains, it becomes reasonable to anticipate significantly greater financial gains for the government associated with implementing the policy. This further strengthens the justification for supporting the provision of professional assistants to mitigate grant uncertainty.

Whether through the removal of reapplication requirements or the provision of professional assistance during the application process, these interventions aim to alleviate barriers and enhance access to financial aid. Reducing uncertainties associated with grants has the potential to enhance educational opportunities and outcomes for a broader range of college-age individuals, leading to substantial welfare gains through cost-effective policy tools.

8 Conclusions

This paper examines the reasons why 40% of college students do not complete their Bachelor's degree. I begin with an empirical investigation which reveals three key findings. Firstly, being financially disadvantaged increases the likelihood of dropping out before graduation. Secondly, grants are uncertain from one academic year to the next. Thirdly, losing grants is strongly linked to dropping out of college education. Based on these findings, I develop a quantitative model that incorporates the uncertain nature of grants, as well as other commonly explored factors in the literature, such as beliefs about academic ability and productivity shocks.

I first use the model to identify the students who are most affected by negative grant shocks. The results show that students from the lower half of the wealth distribution are particularly sensitive to the uncertain grant system. Negative shocks to grants force them to leave college, as they have limited alternative sources of income to self-insure. In contrast, wealthy students are less affected by these shocks and are less likely to drop out of college. Next, I decompose the relative contribution of each dropout factor in explaining the observed college dropout rates, which is an essential step in defining the policy space for the grant system. I find that keeping financial aid constant across academic years can reduce dropout rates by up to 43%, while ability beliefs explain 10% of total dropout rates, with the remaining dropouts attributed to labor market opportunities.

After analyzing the impact of the grant system on college dropouts, I proceed to policy analysis. I find that eliminating uncertainty in grants increases the welfare of newborns by up to 2.4% of their lifetime consumption. This significant gain is due to increased productivity of skilled labor, a decrease in the gap between skill prices, and a redistribution of wealth from high-income to low-income individuals. Eliminating grant volatility also increases the proportion of skilled workers in the economy, which then results in an increase in overall output and consumption. Additionally, reducing uncertainty leads to further welfare gains for risk-averse individuals who are ex-ante identical. Finally, I demonstrate that removing uncertainty in the current grant system is cost-effective for the government, as overall government revenue increases due to increased tax bases in consumption, capital gains, and earnings resulting from a more productive (skilled) workforce.

The findings emphasize the importance of implementing policies aimed at reducing uncertainty in grants, as they can enhance access to financial aid, improve educational opportunities for financially disadvantaged talented individuals, and therefore, improve sorting in college. Therefore, it is crucial to elevate these policy measures in the policy debate surrounding dropout rates, recognizing the positive impact they can have on overall welfare.

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Appendix

A NLSY Surveys

The NLSY79 sample consists of individuals born between 1957 and 1964. At the time of the first interview, respondents' ages ranged from 14 to 22. The respondents were 49 to 58 at the time of their last interview, in 2018. Originally, there were 12686 respondents in the sample, out of whom 6111 belong to a representative, cross-sectional sample designed to represent the civilian segment of people living in the US in 1979 and born between 1957 and 1964.[48]

The NLSY97 surveys 8984 individuals who were born between 1981 and 1984. It began in 1997 and is still ongoing. From 1997 to 2011, the survey rounds were taking place annually, and biannually afterwards. Each round thoroughly surveys the respondents about information on their family characteristics, education process, and labor market outcomes.

A.1 Data cleaning

Below I carefully describe the methodology I used to construct the dataset.

Financing College. Respondents are supposed to report the amounts they receive from each source for each academic semester. There are 6 main sources: grants, family aid, loans, out of pocket, family loans, and other finances. The finances reported in the NLSY97 are biannual. I convert them into an annual level by considering the overall money students got and the years

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[48] In my analysis, I focus on a cross-sectional sample consisting of 5295 oversampled minorities, including Hispanic or Latino, Black, and economically disadvantaged non-Black/non-Hispanic individuals. An additional 1280 respondents were specifically selected to represent the population serving in one of the four branches of the US military.

they attended undergraduate studies.[49]

Ability. Throughout the empirical analysis, I measure ability using two scores: the ASVAB math verbal percentile score and the PIAT (for the Mathematics Assesment subtest[50]) percentile score. While using the first measure, I drop 918 individuals who did not take the ASWAB test. On the other hand, while working with the second measure, I drop 2940 individuals whose PIAT test scores are missing.

Weekly hours. As the measure of hours worked, I take the number of hours students work in the second week of October (week 41) and in the second week of April (week 14) conditional on being enrolled in college. The reason for selecting the middle week of an academic semester as the reference week is to capture the workload during the study period.

A.2 Sample selection in the NLSY79 and NLSY97

The questionnaires within the two surveys are not identical.Therefore, the variables I use in the regressions slightly differ across samples. For the NLSY79, parental education is measured as the number of years they spend in schooling;[51] while the NLSY97 parental education is measured as a binary variable, high school graduate or higher.[52] As for the place of residence, in the NLSY79, I include two variables, urban/rural and south/nonsouth, in the NLSY97 only one variable, urban/rural, as there is no information about south/nonsouth. Furthermore, in the NLSY97, an intact family is measured by whether a youth is living with both parents at age 14. For the NLSY79, the actual number of siblings are reported, while I use the number of youth under 18 for the younger cohort. Finally, as a measure of financial situation in the NLSY97, I use family wealth rather than family income, because it captures the financial state of the household more comprehensively.[53] However, the qualitative findings are robust to the choice between those two measures.

B Graduation & Enrollment Rates in the NLSY97

Enrollment & dropout rates. To capture college enrollment and dropout rates in the NLSY datasets I proceed as follows. If a respondent is coded as enrolled in a college in the months of October and April,[54] then she is considered as a college enrollee. I define a dropout as someone who has attended college for at least one semester but has not earned any degree, whether it be a 2-year or 4-year degree. Finally, I summarize all college participation margins in Table 24 for the cohort of NLSY97, and 25 for the cohort NLSY79.

Inconsistency in Table 23. 22 individuals are not coded as enrolled in a 4-year degree institution, however, their degree is reported to be higher than a 2-year college degree. Therefore,

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[49] I construct an average measure of college finances from each source by collecting the total amount they report during their time spent in college, and dividing it by the number of years during which they are enrolled for a degree (excluding years enrolled in a masters or higher degrees).

[50] One of the PIAT subtests, the Mathematics Assessment, was given in Round 1 to all respondents 9th grade or lower, regardless of age.

[51] There is no information what degrees parents actually earned.

[52] I only control for mothers' education, since there are lots of missing information about fathers' education, particularly in NLSY97.

[53] There is no information about family wealth in NLSY79.

[54] The middle of autumn and spring semesters.

when I sum up the dropouts in the lowest row, I find that 22 people are missing. I drop these 22 individuals while restricting my analysis to bachelor degree recipients only.

Table 23: Education attainment in the NLSY97 data

	2-year[55]	4-year	Any degree
Enrollments	20.10 (1806)	42.87% (3852)	62.97% (5658)
Dropouts	78.02% (1409)	39.72% (1530)	46.06% (2606)
Graduates	21.98% (397)	60.28% (1530)	53.94% (3052)

Table 24: Enrollment, graduation, and dropout rates by ability and wealth (NLSY97)

College participation rates by ability quintiles						
	Quint 1	Quint 2	Quint 3	Quint 4	Quint 5	All
Bachelor degree						
Enrollment rates	0.12	0.30	0.52	0.66	0.86	0.49
Graduation rates	0.05	0.15	0.29	0.44	0.65	0.31
Dropout rates	0.57	0.52	0.45	0.33	0.25	0.36
Any degree						
Enrollment rates	0.33	0.60	0.73	0.84	0.94	0.69
Graduation rates	0.10	0.24	0.39	0.55	0.72	0.40
Dropout rates	0.69	0.60	0.47	0.35	0.23	0.42
College participation rates by wealth quintiles						
Bachelor degree						
Enrollment rates	0.29	0.36	0.46	0.57	0.72	
Graduation rates	0.13	0.18	0.27	0.39	0.55	
Dropout rates	0.56	0.51	0.42	0.31	0.24	
Any degree						
Enrollment rates	0.51	0.57	0.67	0.75	0.87	
Graduation rates	0.21	0.26	0.36	0.49	0.63	
Dropout rates	0.60	0.55	0.46	0.34	0.27	

Table 25: Enrollment, graduation, and dropout rates by ability and wealth (NLSY79)

College participation rates by ability quintiles						
	Quint 1	Quint 2	Quint 3	Quint 4	Quint 5	All
Bachelor degree						
Enrollment rates	0.22	0.41	0.57	0.73	0.91	0.57
Graduation rates	0.05	0.12	0.20	0.34	0.58	0.26
Dropout rates	0.78	0.70	0.64	0.53	0.37	0.54
Any degree						
Enrollment rates	0.22	0.41	0.57	0.73	0.91	0.57
Graduation rates	0.10	0.20	0.32	0.47	0.65	0.35
Dropout rates	0.57	0.50	0.43	0.36	0.29	0.39
College participation rates by family income quintiles						
Bachelor degree						
Enrollment rates	0.46	0.49	0.53	0.62	0.75	
Graduation rates	0.17	0.19	0.22	0.29	0.43	
Dropout rates	0.63	0.62	0.59	0.53	0.43	
Any degree						
Enrollment rates	0.46	0.49	0.53	0.62	0.75	
Graduation rates	0.25	0.27	0.30	0.40	0.52	
Dropout rates	0.46	0.45	0.43	0.35	0.31	

C Federal Financial Aid

C.1 Receiving aid

After refiling the Free Application for Federal Student Aid (FAFSA), a student's financial need is estimated. More specifically, financial need is calculated as the difference between the cost of college attendance (henceforth, COA) and expected family contribution (henceforth, EFC). If the gap is positive, then a student receives a package of financial aid, which is inclusive of three components: Pell grants, federal loans, and work-study.

1. *Pell Grants*: The rule of assigning Pell grants follows: $\min(COA - EFC, 6905\$) = PELL$, when EFC$>$ 700, Pell$=$ 0 when $COA - EFC < 700$.[56] The average COA reported by the NCES is 24300. That means as long as EFC is less than \$17395, students theoretically have a chance to get Pell grants.

2. *Federal Loans:*[57] Loan limits by year of undergraduate studies and by type of loans are given in Table 26.

3. *Work-study*: Finally, work-study is a program in place in many colleges that let students hold part-time jobs while in school in order to subsidize the cost of education. It is supposed to help students close the remaining financial need that EFC, grants, and loans do not cover. However, in practice, a student is not guaranteed to use this portion of financial aid if campus jobs are not available.

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[56] `https://ifap.ed.gov/dpcletters/attachments/GEN1804AttachRevised1819PellPaymntDisbSched.pdf`

[57] `https://studentaid.ed.gov/sa/types/loans/subsidized-unsubsidized`

Table 26: Federal loan limits

	Dependent student	
	Subsidized loan limit	Total
First year	3500	5500
Second year	4500	6500
Third year & beyond	5500	7500

Note: interest rate for the both types of loans are 5.05%.

C.2 Staying eligible:

For maintaining eligibility, a student is supposed to follow the following steps:

1. Fill Out the *FAFSA* Form Each Year (17% of students who stay enrolled, and exhibit GPA higher than 3 does not reapply for the Grants. Such students have a higher likelihood of dropping out later on.

2. Recalculating Expected Family Contribution.

3. Meeting Satisfactory Academic Progress (SAP) requirements

   - Cumulative GPA to be higher than 2.0
   - Accomplish 12 credit hours i.e. approximately 12 hours per week classes, plus 24-36 hours work outside the class.

C.3 Measuring SAP in the model

The Satisfactory Academic Progress (SAP) requirements involve qualitative and quantitative measures. The qualitative measure examines the quality of the student's academic performance as measured by grade point average. The quantitative measure assesses the student's advancement towards completing the required credit hours for earning a degree. This requirement is aligned with being a full-time student, which will be further explained.

In the model, I consider full-time students, i.e., students who attempt full-time credits. The minimum pace requirements, measured earned credits divided by attempted credits, for them to maintain Pell-grants (and most other types of grants) is 67%. Note that failing in 33% of chosen credits yields GPA lower than $\overline{GPA}$ threshold, which, on its own, disqualifies students from grants. Therefore, for full-time students, both the qualitative and quantitative measures of SAP coincide. This enables me to use just GPA requirements in the model to capture whether students are qualified for the grants.

D Working hours and GPAs

There are approximately 19 papers that study how the working hours affect postsecondary educational attainment outcomes measured by GPA, credit accumulation, and persistence in college (summarized in a review paper Neyt et al. (2019)). Understanding the relationship is hard due to high endogeneity between working and studying decisions. Giving a causal interpretation, one must adequately control for all possible confounds.

There has been a series of empirical studies in the literature that attempt to determine the causal effect of working hours on educational attainment using methods such as propensity score matching Scott-Clayton and Minaya (2016), IV (Stinebrickner and Stinebrickner (2003)), FE Wenz and Yu (2010), Darolia (2014), and dynamic discrete choice modeling (Bozick (2007)). All of those papers found negative effects either on GPA or on persistence in college or on both of them together. Besides, working while studying has been associated with psychological and psychosomatic stress (Steinberg and Dornbusch (1991)). The theory of the allocation of time by Becker (1965) suggests that time spent working crowds out time spent on activities that enhance academic performance (i.e., studying, doing homework, and attending classes). There is an obvious trade-off in time allocation between working in the labor market or using this time for studying.

E Showing that the loss of grants is consistent across different GPA bins.

In this section, I examine grants uncertainty within different levels of GPA performance. Through a series of tables, I demonstrate that grants uncertainty remains consistent regardless of students' GPA performance. These findings indicate that grants uncertainty is not dependent on academic ability as an explanatory factor for the fluctuations observed in grant disbursements between academic years.

In this analysis, the sample is restricted to Bachelor's degree traditional students who are younger than 22. The analysis focuses on students who meet the academic eligibility requirements to maintain the grants: (1) a grade point higher than 2.00 and (2) a total credit hours higher than 24 in year 2. Financial requirements are also taken into account.

Table 27: Grants Transition - Year 1 to Year 3. GPA$\geq$ 2 Controlling for academic eligibility criteria, earnings, and college enrollment; Source: US Department of Education, National Center for Education Statistics, 2011-12 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:11/12).

Pell in Year 3 / Pell in Year 1	\$5000+	[4000, 4999)	[3000, 3999)	[2000, 2999)	[1000, 1999)	[0, 999)	Sample size
GPA$\geq$ 2							801992
[5000, 5550]	66.32	8.96	3.33	5.81	1.48	14.10	581734
[4000, 5000)	31.17	27.28	10.02	6.29	6.86	18.38	22604
[3000, 4000)	25.88	13.91	16.78	11.37	6.96	25.10	22111
[2000, 3000)	12.93	4.25	5.62	11.88	15.39	49.93	21338
[1000, 2000)	5.54	8.46	13.47	9.19	12.97	50.37	22082
[0, 1000)	2.52	0.76	0.71	0.90	1.42	93.69	132124

Table 28: Grants Transition - Year 1 to Year 3. GPA≥ 3 Controlling for academic eligibility criteria, earnings, and college enrollment; Source: US Department of Education, National Center for Education Statistics, 2011-12 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:11/12).

Pell in Year 3 Pell in Year 1	\$5000+	$[4000, 4999)$	$[3000, 3999)$	$[2000, 2999)$	$[1000, 1999)$	$[0, 999)$	Sample size
GPA$\geq$ 3							585205
$[5000, 5550]$	68.17	9.61	2.83	4.27	1.87	13.25	79906
$[4000, 5000)$	29.62	25.07	10.37	8.47	9.62	16.86	15743
$[3000, 4000)$	25.85	10.38	18.65	11.76	5.46	27.91	15885
$[2000, 3000)$	9.45	3.72	7.46	12.12	16.11	51.14	16532
$[1000, 2000)$	0.00	8.49	14.59	8.75	15.72	52.45	15997
$[0, 1000)$	2.28	0.72	0.74	0.77	1.47	94.02	441141

Table 29: Grants Transition - Year 1 to Year 3. GPA≥ 3.5 Controlling for academic eligibility criteria, earnings, and college enrollment; Source: US Department of Education, National Center for Education Statistics, 2011-12 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:11/12).

Pell in Year 3 Pell in Year 1	\$5000+	$[4000, 4999)$	$[3000, 3999)$	$[2000, 2999)$	$[1000, 1999)$	$[0, 999)$	Sample size
GPA$\geq$ 3.5							322341
$[5000, 5550]$	69.47	11.02	2.53	2.77	0.61	13.59	35004
$[4000, 5000)$	34.69	21.99	13.48	7.34	3.03	19.47	7878
$[3000, 4000)$	25.02	11.61	9.51	15.35	2.03	36.48	7088
$[2000, 3000)$	12.12	3.73	10.86	15.47	18.49	39.33	8035
$[1000, 2000)$	0	12.67	9.64	10.42	18.05	49.22	7696
$[0, 1000)$	1.95	0.75	0.57	0.78	1.29	94.66	256640

Table 30: Grants Transition - Year 1 to Year 3. GPA$\in [2, 3]$ Controlling for academic eligibility criteria, earnings, and college enrollment; Source: US Department of Education, National Center for Education Statistics, 2011-12 Beginning Postsecondary Students Longitudinal Study, Second Follow-up (BPS:11/12).

Pell in Year 3 Pell in Year 1	\$5000+	$[4000, 4999)$	$[3000, 3999)$	$[2000, 2999)$	$[1000, 1999)$	$[0, 999)$	Sample size
GPA$\in [2, 3]$							265588
$[5000, 5550]$	63.14	7.10	4.98	8.99	1.50	14.29	58593
$[4000, 5000)$	32.00	29.93	8.37	0.82	3.31	25.57	6939
$[3000, 4000)$	36.75	18.11	10.21	6.12	11.07	17.74	9121
$[2000, 3000)$	20.21	8.96	0.16	9.72	13.22	47.73	6419
$[1000, 2000)$	11.08	11.67	12.91	11.75	6.72	45.87	7942
$[0, 1000)$	3.54	0.92	0.84	1.16	1.89	91.64	176574

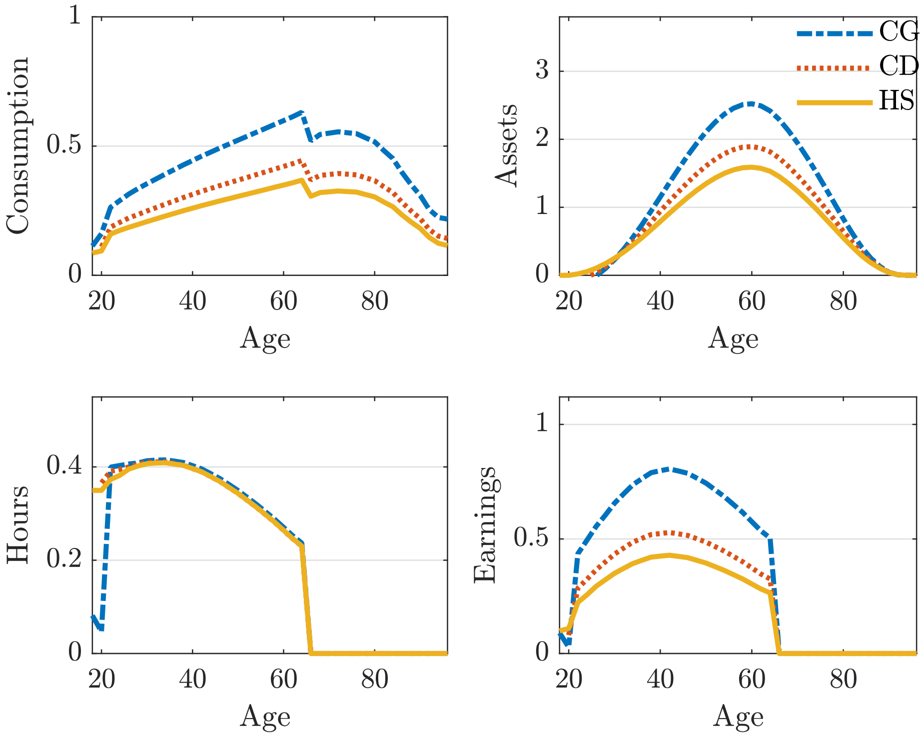
F Life-Cycle Profiles

Figure 8 plots the life-cycle profiles of average consumption, asset holdings, hours worked, and earnings for each education level: high school graduates, college dropouts, and college graduates. They exhibit shapes that are typical of any life-cycle model. Consumption rises steadily over the working life for both skilled and unskilled workers. Slightly it dips when workers retire because pension benefits are only a fraction of average earnings. Gradually consumption decreases as they age and face rising death hazards.

Wealth exhibits the typical hump-shaped profile. For young individuals who are not attending college, the initial wealth is slightly positive. College students, on the other hand, take out loans and, therefore, have negative wealth. On average, it takes about eight years to pay off student loans.

Labor supply does not differ much across skill types. At the age of one, when the young generation enters the workforce, both college-bound and non-college-bound individuals have low labor supply. This is evident in the case of college students as they spend time attending college. For those who are not attending college, the relatively low level of labor supply reflects their low productivity, which is in line with the data. In the second period, college students work less in comparison to the first period. This can be explained by considering that the selection into college already shows up in the second period: richer and more able students remain in college. Consequently, they need to work less to self-finance college.

Figure 8: Life-cycle profiles of average consumption, asset holdings, hours worked, and earnings for college graduates (blue), college dropouts (red) and high school graduates (green), respectively.



Finally, the life-cycle earnings profile also matches the data pretty well. Earnings are relatively low for young individuals as they enter the economy. Notably, college students have limited time for work, while those who are not in college have low productivity. As a result, college-educated workers experience a more rapid increase in earnings compared to those without a college education (both high school graduates and dropouts). Average earnings decline gradually before retirement and drop to zero at the time of retirement. Though the wage rate for dropouts is the same as high school graduates, they still earn more than their non-college counterparts. This is because dropouts have higher probabilities of drawing a high fixed effect of θ (see Section 4).

G Decomposition of the Welfare Gains

For the decomposition, it is useful to define certainty-equivalent bundles. The bundle characterizes the constant amount of consumption and work hours an individual can consume and work for throughout her lifetime to achieve the same lifetime utility, $V(\cdot)$, as she has in the uncertain world. Formally, the derivation of certainty equivalent bundles proceeds as follows.

$$\sum_{t=1}^{J} \beta^{t-1} \varphi_t U(\tilde{c}, 1 - \tilde{l}) = V(\{c_t, l_t\}_{t=1}^{J}), \tag{33}$$

where for notational simplicity, I suppressed the state space. For each point of a state space of newborns, $(1, a, \eta, \theta, \mu_{e_0})$, there is an associated bundle $(\tilde{c}, \tilde{l})$ that solves equation (33). Since there are two unknowns and one equation, there is a continuous set of $(\tilde{c}, \tilde{l})$ that solves the equation. To tackle this issue, in practice, I set the certainty equivalent working hours, $\tilde{l}$, to average hours in the economy. Then, it becomes possible to easily solve the remaining unknown, $\tilde{c}$, as follows:

$$\tilde{c} = \left(\frac{V(\{c_t, l_t\}_{t=1}^{J})(1 - \frac{1}{\gamma})}{\sum_{t=1}^{J} \beta^{t-1} \varphi_t} \right)^{\frac{1}{\nu(1-\frac{1}{\gamma})}} \frac{1}{(1 - \tilde{l})^{\frac{1-\nu}{\nu}}}. \tag{34}$$

Finally, it is useful to define average certainty equivalent hours, $\tilde{H}$ and consumption, $\tilde{C}$:

$$\tilde{H} = \int \tilde{l}(1, a, \theta, \eta, \mu_{e_0}) \, d\phi(1, a, \theta, \eta, \mu_{e_0}), \tag{35}$$

$$\tilde{C} = \int \tilde{c}(1, a, \theta, \eta, \mu_{e_0}) \, d\phi(1, a, \theta, \eta, \mu_{e_0}). \tag{36}$$

Given the following variable set in each economy $\Big(\tilde{c}, \tilde{l}, \tilde{C}, \tilde{H}, V(\cdot), C, H\Big)$, I am equipped to decompose the welfare gains in level, ω_{level}, uncertainty, $\omega_{\text{uncertainty}}$, and, inequality, $\omega_{\text{inequality}}$, effects.

Level effect. To isolate the level effects, I compare the average consumptions between economies A and B, while controlling for the possible differences in leisure across these two economies. To compensate leisure differences, I calculate a 'leisure-compensated' consumption bundle, $\hat{C}^B$, for economy B:

$$V\Big(\{\hat{C}^B, L^A\}_{t=1}^{J}\Big) = V\Big(\{C^B, L^B\}_{t=1}^{J}\Big). \tag{37}$$

Given the utility form in equation (30), it can be shown that:

$$\hat{C}^B = C^B \left(\frac{1 - L^B}{1 - L^A} \right)^{\dfrac{1-\nu}{\nu}}. \tag{38}$$

Then, the gains in welfare due to the level effect is calculated as:

$$\omega_{\text{level}} = \frac{\hat{C}^B}{C^A} - 1. \tag{39}$$

Uncertainty effect. The cost of uncertainty, $p_{uncertainty}$, in economy i is defined as a fraction of consumption an individual would be willing to give up to avoid all uncertainty facing in her consumption path. It solves the following equation:

$$V\big(\{(1-p^i_{uncertainty})C^i, H^i\}^J_{t=1}\big) = V\big(\{\tilde{C}^i, \tilde{H}^i\}^J_{t=1}\big). \tag{40}$$

After calculating $p^i_{uncertainty}$ for $i \in \{A, B\}$, the welfare gain in reduced uncertainty in economy B relative to economy A is defined as follows:

$$\omega_{\text{uncertainty}} = \frac{1-p^B_{\text{uncertainty}}}{1-p^A_{\text{uncertainty}}} - 1. \tag{41}$$

Inequality effect. The cost of inequality, $p_{inequality}$, answers what fraction of consumption an individual should give up to be indifferent between being born into economy i and into economy where everyone consumes and works the same amount. For that purpose, the value of average certainty equivalent bundles and average values of certainty equivalent are compared. Formally, this is summarized as follows:

$$V\big(\{(1-p_{\text{ineq}})\tilde{C}, \tilde{L}\}\big) = \int V\big(\tilde{c}(1,a,\theta,\eta,\mu_{e_0}), \tilde{l}(1,a,\theta,\eta,\mu_{e_0})\big) d\phi(1,a,\theta,\eta,\mu_{e_0}) \tag{42}$$

It follows that the welfare gains in reducing inequality in economy B relative to economy A for an individual with a state space $(\cdot)$ is given by:

$$\omega_{\text{inequality}} = \frac{1-p^B_{\text{inequality}}}{1-p^A_{\text{inequality}}} - 1. \tag{43}$$

Finally, following Floden (2001), it can be shown that $\omega_{CEV} \approx (1+\omega_{level})(1+\omega_{inequality})(1+\omega_{uncertainty}) - 1$.

H Robustness of Welfare Gains to the Elimination of Grants Uncertainty

In this section, I discuss the robustness of the results on the welfare gains of policy 1. I am mainly interested in how robust the welfare gains are when only the fraction of the stochastic shock, ζ, is eliminated. This clarifies whether a policy that is successful in decreasing at least a partial amount of the uncertainty would still yield welfare gains. Figure 9 summarizes the results. It exhibits the welfare gains as a function of the standard deviation of ζ. Specifically, the X-axis refers to the fraction of the uncertainty eliminated, and Y-axes presents the welfare gains in terms of consumption equivalence. The figure plots the total gains in terms of consumption equivalence. It can be observed that the total and level gains increase as the variance of the stochastic shock decreases.

Figure 9: The effects of eliminating fraction of the stochastic shock in the grant system