

Credit Scores and College Investment*

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Abstract

The private market of student loans has become an important source of college financing in the U.S. Unlike government student loans, eligibility conditions on private student loans are based on the credit history of the student and the parents, who often serve as cosigners. Interest rates vary significantly with credit scores (from 7.4 to 15.4 percent). We quantify the effects of credit scores on college investment in a heterogeneous life-cycle economy that exhibits a government and private market for student loans. We find that students with better credit scores invest in more college education. The effect of credit scores on college investment is largest for students with low parental contributions for college and medium levels of ability. The importance of credit scores varies across alternative credit market arrangements: an increase in eligibility conditions in the private market for student loans induces a 5.2 percent decline in the four-year college investment rate, whereas a relaxation in borrowing limits for government student loans leads to a 5.1 percent increase in the four-year college investment rate, with most of the changes coming from students with low and medium credit scores.

JEL Codes: E24; I22;

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1 Introduction

There is a new phenomena in college financing: undergraduate students and their parents are borrowing from the private student loan market to finance college. The volume of nonfederal, private student loans is now \$17.6 billion (in 2007-08), which represents 20 percent of total student loan volume; this compares to \$2.5 billion just ten years ago (College Board, 2008). Borrowing from the private market is very different than borrowing from the government student loan program: credit scores determine loan eligibility in the private market, whereas no credit history is required for government student loans. Furthermore, interest rates on private loans vary significantly across credit scores (see Table 1). The main contribution of our paper is to measure the extent to which credit scores affect college investment via the private market for student loans.

Table 1: Credit Scores and Interest Rates on Private Student Loans

FICO score	Interest rate
<640	no loans
640-669	15.41%
670-699	13.91%
700-729	11.91%
730-759	9.91%
760-850	7.41%

We develop a heterogeneous life-cycle model in the tradition of Auerbach-Kotlikoff where agents differ with respect to parental contributions for college, credit scores (as measured by FICO scores), and an observable index of college ability (as measured by SAT scores); all of which affects the college investment decision. Our model displays important features of the government student loan program and the private market for student loans.

Our main finding is that students with better credit scores invest in more college. In the model, students make a choice between investing in two or four years of college. They use parental contributions and student loans to finance college as well as their earnings from work during college. Students borrow first from the government program, where eligibility conditions depend on their parental contribution and the cost of college. In addition, there is a fixed limit on the amount that can be borrowed in this market. Consequently, this borrowing limit may bind for students with low and medium levels of parental contributions; once students exhaust the funds available from the government these students turn to private credit markets to finance the rest. However, those with very low credit scores are excluded from private markets. Out of those who are eligible to borrow in private markets, students with high credit scores get low interest rates and high loan amounts. As a result, a high

enough credit score relaxes the borrowing constraint that a student with low or medium levels of parental contribution for college faces in the government market. In addition, higher credit scores result in cheaper loans and thus make college a more attractive financial investment. Our model indicates that 51% of students from the lowest tercile of credit scores complete four years of college, whereas 78.3% of students from the top tercile of credit scores complete four years of college. On average, students who complete four years of college have credit scores that are 26 FICO point higher than students who complete two years of college. This result is confirmed with data from the Survey of Consumer Finances (SCF): people with worse credit status are less likely to have a four-year college degree, compared to those with better credit status. This is robust to controlling for differences in income, household size, total borrowed, etc.

Our analysis of the impact of credit scores on college investment focuses on the intensive margin (the effect of credit scores on how much college to invest in). Our approach is motivated by findings from the SCF data: high-school graduates with better credit scores are as likely to enroll in college as high-school graduates with relatively low credit scores. In an extended version of the model where we account for the college enrollment decision we find that college enrollment rates do not vary across groups of credit scores. The intuition is that two year colleges are relatively less expensive (per year of college). In addition, the government limit is relatively more generous for two years of college education than for four years. Thus, the government constraint associated with investment in two year colleges binds only for a small fraction of high-school graduates. As a result, credit scores do not have a significant effect at the extensive margin (on the decision to enroll in college or not).

The magnitude of the effects of credit scores vary across different types of students: higher credit scores have the largest impact on college investment for low-income students and students with medium levels of abilities. As mentioned, these are precisely the individuals who are most likely to borrow from the government and the private market. In addition, their relatively high levels of ability provide them with relatively high returns to their college investment, giving them the incentive to invest in more college.¹ Consequently, better credit conditions in the private market induced by high credit scores are quite valuable for these groups of students.

We report borrowing behavior for students that differ in income, ability and credit scores. We find that low-income students borrow more from both the government and the private market to finance college than high-income students, facts that are consistent with the College Board (2007b). In addition, students with relatively low levels of ability are more likely to participate in the private market for student loans. However, students with average ability

¹Our model accounts for the observed variation in earnings for college graduates of different ability levels.

levels use the government student loan program the most, which is consistent with findings from the Beyond Post-secondary Survey (produced by the National Center of Education Statistics) and contrasts with the implications of other papers that study the student loan market (Garriga and Keitly, 2007; Lochner and Monge-Naranjo, 2008; Ionescu, 2009). Finally, students with low credit scores participate in the government student loan program at high rates, whereas students with average credit scores participate in the private market the most.

We find that the relationship between credit scores and college investment has important policy implications. Specifically, in a policy experiment where the government increases its borrowing limits (as recently implemented by the U.S. government), we find that students will shift their borrowing away from the private market and towards the government. In fact, the average government loan is 42 percent larger than in the benchmark, while the average loan from the private market falls by approximately the same amount (in percentage terms). This leads to a five percentage point increase in the four-year college investment rate. More interesting is that students with relatively low credit scores, who face high borrowing costs in the private market, experience large increases in four-year college investment rates (11 percentage points). A larger government student loan program reduces default rates in the government market and increases default rates in the private market. This is caused by a change in the riskiness of the pool of borrowers: in this regime, borrowers in the private market are typically low-income and low-ability (compared to the benchmark), who have lower earnings profiles after college and high debt levels.

Alternatively, if private markets make it more difficult for students to borrow for college (by requiring higher credit scores for participation in the market), we find that the four-year college investment rate falls by approximately five percentage points. Tougher eligibility conditions in the private market have significant adverse effects on four-year college investment rates for the poorest students and students with average credit scores. Default rates in the government student loan program decrease as private creditors make it more difficult for some students (and especially those who are more likely to default) to get a private student loan.

We are the first to document a link between credit scores and college investment, which adds to the rich literature on the determinants of college investment. The role of parental contributions in the college investment decision has been extensively studied, with important contributions by Becker (1975), Carneiro and Heckman (2002), Cameron and Taber (2004), Keane and Wolpin (2001), and more recently by Belley and Lochner (2007) and Stinebrickner and Stinebrickner (2007). College preparedness (or ability) has long been considered an important determinant of college investment, as documented in Heckman and Vytlačil

(2001) and Cunha et al. (2005). We account for these two determinants in our model in conjunction with the importance of credit scores. In addition, our model includes two other important components that are consistent with the data: we assume that income and credit scores are positively correlated (SCF, 2004), as are income and ability (College Board, 2009). We argue that accounting for the role of credit scores in the college investment decision is important when analyzing the implications of various student loan policies. In recent years, the focus has been on the effectiveness of financial aid in promoting college investment, and specifically student loans. Papers that study the implications of student loan policies within a quantitative macroeconomic approach include: Garriga and Keightley (2007), Lochner and Monge-Naranjo (2008), Schiopu (2008), Chatterjee and Ionescu (2009), and Ionescu (2009).² They analyze higher education financing in heterogeneous economies where people vary in ability and/or parental income. Our analysis complements this work by showing how credit scores affect college investment in addition to differences in income and ability. In addition, we are the first to quantify how borrowing behavior changes across different groups of students.

The only paper that incorporates both the private and government student loan markets is Lochner and Monge-Naranjo (2008). They consider an environment where credit constraints arise endogenously from a limited commitment problem in borrowers to explain the recent increase in the use of private credit to finance college as a market response to the rising returns to school. In their paper, as in ours, interest rates in the private market for student loans are not derived endogenously from a general equilibrium profit condition. However, our framework is different in that we model various dimensions of uncertainty associated with college investment, including earnings and interest rate uncertainty, that allows us to capture default behavior in the student loan market. Furthermore, we model a menu of interest rates tied to credit scores and a feedback of default behavior into credit scores and interest rates, such that default in the private market for student loans lowers credit scores and raises interest rates. This allows the interest rate in the private market to reflect default risk in equilibrium.³

Pricing default risk is a crucial feature of models that analyze investment and borrowing behavior under various credit market arrangements as advocated by quantitative theories of default. In this direction of research, our paper is mostly related to studies that focus on the role of credit worthiness in unsecured credit markets, in particular Athreya, Tam and Young

²In addition, there is also a large empirical literature that studies the effectiveness of the U.S. government student loan program, with contributions by Dynarski (2003), Hoxby (2004), and Lucas and Moore (2007), for example.

³Several unique features of the student loan market allow us to take this approach. Details are discussed in Section 3.

(2008) and Chatterjee, Corbae and Rios-Rull (2008). The first paper considers the amount of information that can be gleaned from credit scores to explain the rise of unsecured credit, bankruptcy rates and credit discounts, while the second paper develops a theory of terms of unsecured credit and credit scoring consistent with the data and emphasizes the importance of correctly pricing default risk.

The paper is organized as follows. In Section 2, we describe several important facts about credit scores, college education and student loans that motivate our study and provide important details for our model. We then develop our model in Section 3 and calibrate it to match important features of the markets for government and private student loans in Section 4. Our quantitative results are contained in Section 5, and Section 6 presents an extension of the model that studies the effects of credit scores on the college enrollment decision. We conclude in Section 7.

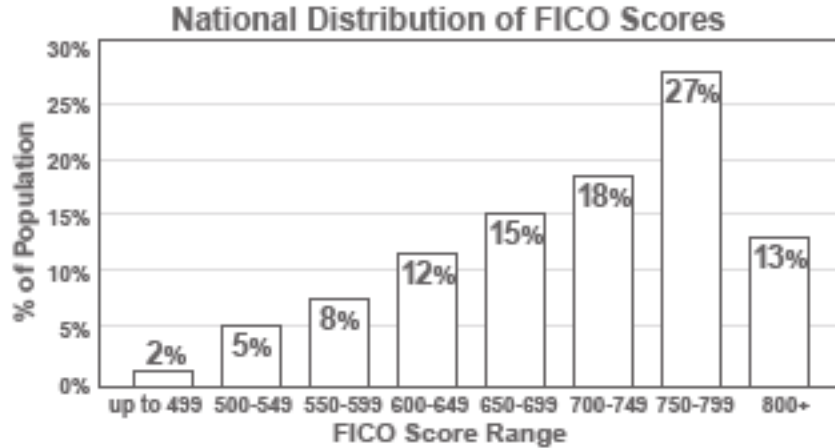
2 Facts about Credit Scores, College Education and Student Loans

2.1 Credit Scores

Similar to other forms of debt such as unsecured debt (i.e., credit cards), personal loans, and mortgages, interest rates in the private market for student loans are tied to the credit score of the applicant and the cosigner. Credit reporting agencies such as FICO calculate credit scores for individuals based on a large set of information about their past credit history. FICO reports that the following components form part of the credit score calculation: payment history (35%), amount of outstanding debt (30%), length of credit history (15%), new credit/recent credit inquiries (10%), and types of credit used (10%).⁴ It is important to note that FICO scores are based on information found in credit reports, and do not explicitly depend on income, employment tenure, education, assets, etc. The national distribution of FICO scores is given in Figure 1. FICO scores are by far the most commonly used credit scores. For student loans in particular, Sallie Mae uses FICO scores to determine the credit conditions for each borrower.

⁴<http://www.myfico.com/CreditEducation/WhatsInYourScore.aspx>

Figure 1: Credit Scores



Source: <http://www.myfico.com/CreditEducation/CreditScores.aspx>

2.2 Credit Status and College Education

Using data from the Survey of Consumer Finances (SCF), we document two facts that are important in our model: (1) people with better credit are more likely to have a bachelor's degree than people with worse credit, and (2) income and credit status are positively correlated.⁵

We use a sample of 7,222 individuals from the SCF between the ages of 18 and 60 with at least some college education. We classify individuals into two groups: those with some college (49% of the sample), which includes an associates degree, and those with a bachelor's degree (51% of the sample). While the SCF does not explicitly report credit scores, it does contain detailed information about the various types of credit that individuals use (including student loans) and information related to the credit status of individuals.

We use four different measures of credit status reported in the SCF. For example, the SCF asks if respondents have been turned down for any type of credit in the last five years, and if so, if it was due to having bad credit.⁶ The SCF also provides some insight into repayment behavior and outstanding debt, which are the two most important components that enter the credit score calculation. Individuals are asked how frequently they repay the total balance owed on their credit cards each month, and the amount of outstanding debt on credit cards, in addition to their respective credit limits. The SCF also contains detailed

⁵For brevity, we provide a snapshot of our data analysis. The full set of empirical results can be obtained from the authors.

⁶We construct a variable for bad credit that represents a composite of the following four reasons for being turned down for credit: 1) Haven't established a credit history; 2) Credit rating service/credit bureau reports; 3) Credit records/history from other institution; other loans or charge account; previous payment records; bankruptcy; or 4) Bad Credit.

information about outstanding student loans, including the amount borrowed, the interest rate on the loan, and the lending institution. Approximately 21% of the 2004 sample has an outstanding student loan at the time of survey.

Using the subsample of individuals with student loans, we examine if credit status affects the likelihood of getting a bachelors degree. Specifically, we run probit regressions with the dependent variable being a binary variable that takes the value 1 if the person has a bachelor's degree and 0 if they have some college. The independent variables include the various credit status measures and the following controls: household wage income, sex, marital status, household size, age, total amount borrowed in student loans, the interest rate on the student loan, and if the student loan was borrowed from the private market.⁷

Table 2: Percent of College Students with a Bachelor's Degree, by Credit Status

Credit Status	% with a Bachelor's Degree
Turned down for credit	47.7%
Not turned down for credit	60.8%
Having bad credit	38.2%
Not having bad credit	58.7%
Hardly ever paying balance	60.1%*
Almost always paying balance	60.5%*
Having high debt/limit ratio	48.2%
Having low debt/limit ratio	62.6%

Estimated means. * denotes that the means are not significantly different at the 10% level.

Table 2 reports the estimated probability of having a bachelor's degree (compared to having some college), after controlling for differences in individual and household characteristics. Overall, our results show that a worse credit status is associated with a lower likelihood of having a bachelor's degree. For example, of those who have been turned down for credit in the last five years, only 48 percent have a bachelors degree, compared to 61 percent of those who have not been turned down for credit. Similarly, having bad credit results in a lower probability of having a bachelor's degree; those with bad credit are 20.5 percent less likely to have a bachelor's degree than those without bad credit. While we do not find a significant difference in college completion rates based on repayment behavior, we find that a higher debt/limit ratio is associated with lower likelihood of a bachelor's degree. Thus, three different measures of credit status reveal that credit status has a significant effect on college investment, even after controlling for differences in income, household size, total borrowed, etc.

⁷Since the four credit status measures are highly correlated, we run different probit regressions for each of the four credit measures as the independent variable. All four probit regressions include the same set of control variables.

In Table 3, we report the correlation between household wage income and credit status. Specifically, we run probit and OLS regressions in which the various credit status measures are the dependent variables, and the natural logarithm of household wage income is the independent variable, in addition to education, gender, marital status, household size, and age. We find a robust, negative correlation between household wage income and bad credit status for three of the four measures of credit status. In all of the cases, the correlation coefficient is quite small. For example, a 1 percentage point increase in wage income makes you 3.6 percent less likely to be turned down for credit and 4.9 percent less likely to hardly ever repay your credit card balance.

Table 3: Correlation between Income and Credit Status

	Turned down for credit	Bad credit	Hardly ever repay	Debt/Limit Ratio
Income	-0.036	-0.005*	-0.049	-0.035

Point estimates on natural logarithm of household wage income. * indicates that the coefficient is not significant at the 10% level.

Our simple empirical analysis confirms two important facts. First, for people who have outstanding student loans, our results indicate that having a better credit status leads to a greater likelihood of having a bachelor’s degree. The positive relationship between credit status and college education is robust to controlling for differences in individual and household characteristics, including household income. Second, we document a small, positive correlation between household income and good credit.

2.3 Student Loans

2.3.1 Government Student Loans

Federal loans are administered through the U.S. Federal Student Loan Program (FSLP), and include Perkins, Stafford and PLUS Loans. Complete details on the FSLP, including recent changes to the system, can be found in Ionescu (2009). However, some general features of the program are important in our set-up.⁸ First, students and their families can borrow from the U.S. government at partially subsidized interest rates, which vary with the 91-day U.S. Treasury bill rate up until 2006.⁹ Second, no credit history is required to obtain a government student loan. Third, Federal student loans are need-based that take into account both the cost of attendance (total charges) and the expected family contribution, which is

⁸In our analysis, we focus on Stafford student loans, which represents 80% of the FSLP in recent years.

⁹Recent legislation changed the structure on interest rates for subsidized student loans to be declining, fixed rates over time. The rates on Stafford loans starting in July 2006 were fixed at 6.8%. The rates for loans dispersed starting in 2011 will be set at 3.4%, and then will be reset at 6.8% in July 2012.

determined by each college and university. However, there is a limit to how much students can borrow from the government. Dependent students could borrow up to \$23,000 over the course of their undergraduate career using Stafford loans, while independent students can borrow nearly twice that amount (US Department of Education).¹⁰ This limit on government loans has remained constant since 1993. Borrowing from the government is quite common, with nearly 50% of full-time college students borrowing from the government in recent years (Steele and Baum, 2009). Of those who borrow from the government, approximately one-half borrow the maximum amount (Berkner, 2000; Titus, 2002).

Typically, repayment of government student loans begins six months after college graduation, and can last up to ten years. Student loan amounts and payment history appear on credit reports. If a student fails to make a payment on their student loan in 270 days, they are considered to be in default. National default rates in the FSLP for the 2005 cohort were 4.6% (U.S. Department of Education).¹¹ Students cannot typically discharge their FSLP debt upon default, and penalties on defaulters include: garnishment of their wage, seizure of federal tax refunds, possible hold on transcripts and ineligibility for future student loans.¹² In addition, the default is listed in the historical section of the borrower's credit report, specifying the length of the default. Once the defaulter starts repaying his government student loans, credit market participation is not restricted but the default remains on the credit report for up to seven years.¹³

2.3.2 Private Student Loans

The system for obtaining private student loans is much different than the FSLP. First, credit history is important. Most private student loans require certain credit criteria, which can be met by enlisting a cosigner that meets the credit criteria. For Sallie Mae, the largest creditor of private student loans, approximately 60 percent of their applicants had a cosigner (in 2008). Second, loan limits in private loans are set by the creditor and do not exceed the cost of college less any financial aid the student receives (from all possible sources). Third, interest rates and fees vary significantly by credit status, and interest accumulates while in college. For example, Sallie Mae's leading private loan for students is the Signature Student Loan, where interest rates begin at Libor + 4.8% and cap at Libor + 8.3%.¹⁴ In pricing these loans, various credit characteristics matter, including credit scores, the number

¹⁰<http://studentaid.ed.gov/PORTALSWebApp/students/english/studentloans.jsp#03>

¹¹<http://www.ed.gov/offices/OSFAP/defaultmanagement/cdr.html>

¹²For details, see Ionescu (2009).

¹³<http://www.studentloanborrowerassistance.org/collections/credit-scores/>

¹⁴The margins represent weighted averages and are from June 2008; they were obtained from: <http://www.salliemae.com/about/investors/>

of delinquencies and bankruptcy filings within a certain period, debt-to-income ratios, and collections history. There are also some private student loan companies that use non-credit characteristics such as school attended, grade-point average, etc. in pricing a loan. In addition, it is possible to find “credit-ready” loans that are offered to applicants with no credit or a thin credit file. Many college students (especially first-time freshman) tend to fall into this category. These credit-ready loans tend to have higher interest rates and/or fees to compensate for the risk inherent in the population. Based on conversations with Sallie Mae, the most common reason for denial is creditworthiness. In particular, Sallie Mae does not grant private student loans when the FICO score of the applicant or the co-signer is less than 640 (in 2008). In light of the credit market tightening that occurred in 2008-09, private creditors have increased the credit requirements for these loans; Sallie Mae now requires a 670 FICO score (in 2009).

Borrowing from the private student loan market is more prevalent, especially in recent years. Based on a Sallie Mae/Gallup survey (2008), approximately 27% of students who borrow from private credit markets to finance college. However, in other reports, Sallie Mae and the College Board (2008) report that only 10% of college students participate in private student loans. More recently, based on the 2007-08 NPSAS data, 19% percent of full-time undergraduates borrow from private markets (Steele and Baum, 2009). Schools are not required to report these numbers, and since the private student loan market is relatively new, estimates vary by source.

Since the existence of private student loans is quite new and not much is known about them (especially for incoming undergraduate students), we argue that private student loans do not influence whether or not potential students enroll in college. That is, private student loans do not significantly affect the decision to go to college or not. However, once the student enrolls in college and researches the various forms of financial aid, having access to private student loans may affect how much college the student decides to complete. Thus, private student loans do not affect the extensive margin (the decision to enroll in college or not), but do affect the intensive margin (how much college to invest in). This is confirmed by studies that suggest the decision to enroll in college is made early on (early in their high school career). Furthermore, a majority (85%) of college-qualified students who did not enroll in college did not apply for college and even more (88%) did not apply for financial aid (Hahn and Price, 2008).

Similar to government student loans, private lenders report the total amount of loans extended, the remaining balance, repayment behavior and the date of default to credit bureaus. In addition, default in the private student loan market is rare. Sallie Mae reports that net charge-offs as a percentage of all of the private loans in repayment are 3.92% (annualized).

Instead, lenders work with students to help them manage their student loan repayment responsibility. For example, lenders may offer a number of repayment plans to assist customers with managing their monthly payments. And those experiencing financial hardship may be offered, at the lender's discretion, a period of forbearance, an approved period of time when customers do not need to make payments on their loans. Private student loans are also not dischargeable in bankruptcy.

3 Model Description

3.1 Environment

We consider a life-cycle economy where agents live for $T - 1$ periods. Time is discrete and indexed by $t = 0, \dots, T$ where t represents the time after high school graduation. Each agent's life is characterized by four phases: college, young adult, parent, and retirement. Table 1 illustrates the life-cycle for a typical agent in the model.

The first phase represents the time spent in college. For simplicity, we assume that all agents in the model are college-bound (i.e, we do not analyze those who do not attend college.)¹⁵ During this phase, young agents consume and invest in education. To finance their consumption and human capital accumulation, young agents receive parental contributions for college and can borrow from the government and the private market. Agents in their second phase of life are young, working adults who use their labor earnings to consume, pay off their school loans (both public and private), and save (or borrow). In the parent phase, agents use their labor income similarly (to consume and save). Each agent in this phase has one child that goes to college and may transfer some of their resources to their child to use for their child's college education. Also, the credit score in this phase matters for their child's student loans. In the last phase of life, retired agents live off of their savings. We assume that old agents die with certainty at the end of this period.

Agents are heterogeneous in parental contributions $b^0 \in B$, credit scores $f^0 \in F$, and ability $a \in A$, which are jointly drawn from the distributions $F(b^0, f^0, a)$ on $B \times F \times A$. Discounted lifetime utility consists of:

$$\sum_{t=1}^T \beta^{t-1} u(c_t) + \rho \beta^{Tch} x(b^1, f^1) \quad (1)$$

¹⁵Since the goal of the paper is to consider the importance of credit scores on education investment via the private student loan market and this market mostly affects investment in college at the intensive margin rather than at the extensive margin, we feel this is a reasonable assumption (for details see Section 2.3.2).

Table 4: Phases of the life-cycle

College ($t = 0$)	Young Adult ($1, \dots, T_2$)	Parent ($T_2 + 1, \dots, T_3$)	Retirement ($T_3 + 1, \dots, T$)
Consumption (c_0)	Consumption (c_t)	Consumption (c_t)	Consumption (c_t)
Investment in education (h)	Earnings ($z_t y_t$)	Earnings ($z_t y_t$)	Interest Earnings
Earnings (y_0)	Borrow/Lend (s_{t+1})	Borrow/Lend (s_{t+1})	
Borrow for school ($d_0^g + d_0^p$)	Repay student loans (p_t)	Transfers (b^1, f^1) at $t = T_{ch}$	
Parental contributions (b^0)	Credit score (f_t)		
Credit score (f^0)			

where c_t represents the consumption of the agent during period t , $\beta \in (0, 1)$. We assume a constant relative risk aversion such that $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ where $\sigma > 0$. During the parent phase (at $t = T_{ch}$), altruistic agents have children who go to college and derive utility from transferring resources to their child, (b^1, f^1) . The agent's problem is to maximize his utility (equation 1) subject to his budget constraints.¹⁶

In the first phase of life, the college student consumes c_t , invests in human capital h , receives contributions from his parents b^0 and borrows from the government d_0^g and the private market d_0^p . Thus, the budget constraint for the college student is:

$$c_t + h \leq b^0 + d_t^g + d_t^p + y_t(h); \quad t = 0. \quad (2)$$

With regards to human capital accumulation, we allow students to choose to complete four years of college, h_4 , or two years of college, that is attend college for half of this period, h_2 . The human capital choice is in terms of length, not quality. However, we allow for college heterogeneity conditional on schooling length $h \in \{h_2, h_4\}$ in the sense that the college cost increases in b^0 given h . People from lower income groups tend to enroll in relatively less expensive colleges regardless of the type of the institution (two-year versus four-year). Furthermore, we assume that the relative cost of 4 year college to two-year college declines in b^0 . Both these two features are consistent with our findings from the Beginning Post secondary Students Longitudinal Study (BPS) data (see section 4 for details). Agents who complete two years of college will earn labor income $y_0(h_2)$. Agents who complete four years of college work during college (and receive $y_0(h_4)$), but since they attend college the entire period, they forgo earnings $y_0(h_2)$. We assume that earnings during college do not depend on the ability of the student. The types of jobs that students have during college do not necessarily value student's skills or college preparedness (see Autor et al., 2003). However,

¹⁶This modeling is one way to close up the model, but it is not essential for the goal of the paper. Alternatively, we could model only phases 1 and 2 in the current model and impose a reasonable terminal node to account for the utility derived from consumption later in the life-cycle as well as from transferring resources to ones child.

in the calibration section we allow earnings during college to vary with b^0 and estimate the levels of earnings $y_{0,i}(h_4)$ to match four-year college completion rates for income group i . Our model delivers that people from low income backgrounds tend to work more during college, which is consistent with empirical findings (see Stinebrickner and Stinebrickner, 2003).¹⁷ Agents who complete two years of college should be interpreted as students who complete two-year colleges and those who drop-out from four-year colleges. Thus, we are explicitly considering drop-outs of four-year colleges since they represent a significant portion of college students (Chatterjee and Ionescu, 2009; Gladieux and Perna, 2005). In addition, we assume all students attend college full-time.¹⁸

The rate at which the college student borrows from the government R_t^g is exogenous and does not vary across individuals, but evolves stochastically over time. The amount the student can borrow from the government d_t^g depends on the cost of college per period in college $\bar{d}(h, b^0)$ and the parental contribution b^0 . The cost of college reflects the actual cost of college (i.e., tuition and fees), and depends on how much college is obtained; it also varies with the initial parental contribution b^0 . In this environment, the college investment decision is purely a financial decision. Based on the cost of college and the return to college (i.e., lifetime earnings), students make a decision whether to complete two or four years of college.

Parental contributions for college depend on parental income and assets. Thus, the borrowing limit for a young agent from the government is: $d_t^g(h, b_0) = \max[\min\{\bar{d}(h, b^0) - b^0, d_{\max}(h)\}, 0]$, where $d_{\max}(h)$ is the exogenous borrowing limit imposed by the government for each period in college, where $h \in \{h_2, h_4\}$. This limit only depends on the length of schooling.

The college student can also borrow from private credit markets d_t^p at the interest rate R_t^p . The rate students pay for private school loans depends on the credit score of their parents, such that $R^p(f^0)$ with $R^{p'}(f^0) < 0$. The interest rate on private loans evolves stochastically over time according to a two-stage Markov process. The transition probability matrix is the same for all agents. The mean of the process, and thus, the actual interest rates are adjusted by credit score. Note that interest rates and the supply of loans are exogenous; this is a partial equilibrium analysis.¹⁹ The amount students can borrow from private credit markets for school cannot exceed the difference between the cost of college $\bar{d}(h, b^0)$ and what they receive in government loans. In addition, students with very low credit scores

¹⁷In addition, for a nice paper that considers how borrowing constraints affect labor supply decisions for college students, see Garriga and Keightley (2007).

¹⁸Since most of the data on participation in student loans programs (both private and public) significantly vary with full-time and part-time enrollment, we need to focus on one group. Also, full eligibility for government student loans is conditioned on full-time enrollment in college.

¹⁹Considering the various mechanisms that could affect the supply of private student loans is beyond the scope of this paper. However, we conduct robustness checks on this assumption in Section 6 of the paper.

cannot borrow at all in the private market and borrowers with low credit scores may not be able to borrow the entire amount. Thus, the borrowing limit in private credit markets is: $d_t^p(h, b_0, f_0) \leq \min\{\bar{d}(h) - d_t^g, d_{\max}(f_0)\}$ with $d'_{\max}(f_0) > 0$. It is important to note that our model assumes private creditors will meet the demand of student loans for borrowers with sufficiently high credit scores.

In the next phase of life as young adults, agents consume c_t , save/borrow s_{t+1} , earn labor income $z_t y_t(h, a)$ and pay back part or all of their school loans p_t . They also face wage garnishment in the case of default on government or private student loans (μ_g, μ_p) . Hence, the budget constraint is:

$$\begin{aligned} c_t + s_{t+1} &\leq z_t y_t(h, a)(1 - \mu_g - \mu_p) - p_t^i; & i \in g, p; t = 1, \dots, T_2; \\ \mu_i &= 0 & \text{if } p_t^i \geq \underline{p}^i \end{aligned} \quad (3)$$

Labor income is given by the product between the deterministic component, $y_t(h, a)$ and the stochastic component z_t . The deterministic component depends on the human capital accumulated during college such that $y_t(h_4, a) > y_t(h_2, a)$ for any t and a . Also, for both education groups, earnings increase in the ability level of the student a . In particular, the premium from getting a 4 year college degree increases in a , which is consistent with the data (details are provided in Section 4). Also earnings increase over time at a declining rate $y'_t(t) > 0$ and $y''_t(t) < 0$.²⁰ The idiosyncratic shocks to earnings each period, z_t evolve according to a Markov process with support $Z = [\underline{z}, \bar{z}]$, where $\underline{z}$ represents a bad productivity shock and $\bar{z}$ represents a good productivity shock. The Markov process is characterized by the transition function Q_z and it is assumed to be the same for all agents.

The agent enters repayment on both the public and the private loans. The loan amounts at the beginning of this repayment period are given by d_t^g for government loans and $d_t^p R_t^p$ for private loans. Note that the interest on government loans does not accumulate during college, but it does accumulate for private loans. This is consistent with what we observe in the data.²¹ We assume α_t^i is the share of total debt the agent pays in period t toward loan i , where $i \in g, p$ and $\alpha_t^i \in [0, 1]$. Thus, the size of payment on student loans (both government and private) at time t is represented by:

$$p_t = \sum_i p_t^i = \sum_i \alpha_t^i d_t^i; \quad i \in g, p. \quad (4)$$

²⁰We abstract from modeling human capital accumulation after college in order to focus on the role of parental funds and credit scores in the college investment decision.

²¹In some cases, students pay interest on their private student loans while in college (to shorten the life of the loan). We abstract from this possibility.

Consequently debt evolves according to:

$$d_{t+1}^g = d_t^g(1 - \alpha_t^g)R_t^g \text{ and } d_{t+1}^p = d_t^p(1 - \alpha_t^p)R_t^p(f_t); \quad (5)$$

Agents default on private student loans when payments in each period are less than the required amount, $p_t^p < \underline{p}^p$. In period t , the agent is required to pay the fraction $\underline{\alpha}_t^p$ which depends on the principal of the loan p_t^p , the interest rate R_t^p , and the time left until the end of the repayment phase, $T_2 - t$. Thus, default occurs if the fraction that he chooses to repay, $\alpha_t^p < \underline{\alpha}_t^p$. In this case, wages are garnished at the rate $\mu_p > 0$. In addition, the default is reported to credit agencies and credit scores are revised downward. Thus, when the agent with score f_t in period t chooses $\alpha_t^p < \underline{\alpha}_t^p$, the score becomes $g^p(\alpha_t^p, f_t) = \underline{f}$. When the borrower pays the exact amount that it is required ($\alpha_t^p = \underline{\alpha}_t^p$), his score does not change, $g(\underline{\alpha}_t^p, f_t) = f_t$. For any payment $\alpha_t^p \in (\underline{\alpha}_t^p, 1)$, the score is gradually updated according to the function $g^p(\alpha_t^p, f_t) = \alpha_t^p a(f_t) + b(f_t)$, where $a(f_t) > 0$ and $b(f_t) > 0$. When he pays his entire loan in period t ($\alpha_t^p = 1$), his score improves to the next bin, $g^p(1, f_t) = f_{t+1}^{i+1}$ for $i \in \{1, \dots, 6\}$.

Since we focus on the effect of credit scores on education investment via the private market for student loans, we want to capture the feedback of the repayment behavior in this market on the credit score. Thus, in our set-up, repayment behavior in the private student loan market affects credit scores and the model produces a variation in credit scores across adults later in the life-cycle.²²

Agents default on government student loans when payments are less than the required amount, $p_t^g < \underline{p}^g$. In period t , the agent is required to pay the fraction $\underline{\alpha}_t^g$ which depends on the principal of the loan p_t^g , the interest rate R_t^g , and the time left until the end of the repayment phase, $T_2 - t$. Thus, default occurs if the fraction that he chooses to repay, $\alpha_t^g < \underline{\alpha}_t^g$. In this case, there are consequences to default captured by the wage garnishment μ_g .²³ When the agent makes the required minimum payment on government student loans ($p_t^g \geq \underline{p}^g$), there is no wage garnishment, thus $\mu_g = 0$. We require that agents must pay off their school loans at the end of this period; thus, for $t = T_2$, $p_{t+1} = \sum_i (d_t^i - p_t^i)R_{t+1}^i$; $i \in g, p$.

As a parent, agents consume c_t , borrow/lend s_{t+1} , earn labor income $z_t y_t(h, a)$, and earn/pay the risk-free rate on their last period savings/borrowings, according to:

$$c_t + s_{t+1} \leq z_t y_t(h, a) + R^f s_t; \quad t = T_2 + 1, \dots, T_{ch} - 1, T_{ch} + 1, \dots, T_3. \quad (6)$$

²²Our model is not a theory of credit scores. Assessing the impact of credit market participation on credit scores and explaining observed variation in credit scores across individuals is beyond the scope of this paper.

²³We assume that default in the government market does not affect future credit scores.

Additionally, in period $t = T_{ch}$, the parent transfers funds to their child b^1 so that the budget constraint is:

$$c_t + s_{t+1} \leq z_t y_t(h, a) - b^1 + R^f s_t - p_{t+1}; \quad t = T_{ch}. \quad (7)$$

Finally, the budget constraint in the last phase of life (retirement) is:

$$c_t + s_{t+1} \leq R^f s_t; \quad t = T_3 + 1, \dots, T \quad (8)$$

where the agent consumes c_t using his return on past period savings s_t .

3.2 Equilibrium

The agent $i \in B \times F \times A$ maximizes utility (equation 1) subject to his budget constraints (equations 2 - 8) by choosing $\{h, c_t, s_{t+1}, \alpha_t^g, \alpha_t^p, d_{t+1}^g, d_{t+1}^p, f_t, b^1\}$ taking prices $\{z_t y_t, R^f, R_t^g, R_t^p(f_t)\}$ and policy parameters $\{d_{\max}, \mu_g, \mu_p\}$ as given.

Our economy is a partial equilibrium analysis in the sense that the average interest rates on student loans in both the government and private markets do not arise endogenously out of an equilibrium profit condition. While this is certainly the case for the government market in the real world, our framework may seem restrictive for the private market for student loans. By design, the interest rate in the private market is how private creditors cover the cost of default. Even though we do not model a general equilibrium framework, we claim that the average interest rate in the private market captures default risk.²⁴ We show that our model is consistent with the fact that in a riskier environment, as measured by a higher default rate, the average interest rate in the market charged by the private creditor is higher. This happens for the following reasons. First, our economy features a menu of interest rates for private loans which depend on the borrowers' credit scores along with a feedback of the repayment behavior on credit scores. Thus, the interest rate that the borrower faces each period depends on the risk of default in that period, which in turn evolves over time given the borrower's past repayment behavior in the private market. Second, student loans are not dischargeable after default. In our model, agents need to repay their loans in the first period after default and they will do so at a higher interest rate since their credit scores are severely damaged. As a result, the interest rate charged by the private creditor increases with the average risk in the market. Nondischargeability is a key difference between the student loan market and unsecured credit markets that allows us to take this approach.²⁵ An important

²⁴A standard GE setup will be intensive computationally given the high dimension of the state space and the number of periods for the repayment phase in which the credit scores evolve.

²⁵Chatterjee et. al. (2008) contains a theory of the terms of credit and credit scoring where the pric-

observation is, that in our economy, altruistic agents repay their student loans eventually. The utility loss from transmitting a bad credit score to ones child prevents our agents from not repaying their loans. Thus, the incentive to default declines over time. This discussion can be conveniently explained using the present-value profit condition for the private creditor in the economy. The functional form is given by:

$$PV_\pi = \int_{d_p > 0} \left[\sum_{t=1}^{T_2} \beta^{t-1} \left[\int \int_{\alpha_t^p \geq \underline{\alpha}_t^p} (\alpha_t^p d_t) d\alpha dR^p + \int_{\alpha_t^p < \underline{\alpha}_t^p} \int (\mu_p z_t y_t) dz d\alpha \right] - d_0^p \right] df$$

Note that the private creditor collects a wage garnishment from defaulters during the period when default occurs and collects repayments every period until the loan is paid in full from all participants in the private market, including defaulters (except for the period when default occurs). These payments, $\alpha_t^p(d_t, R_t^p(f_t), T_2 - t)$, depend on the time left for repayment, the principal and the per period interest rate, which in turn depends on the credit score of the borrower. The credit score is updated each period given the repayment behavior in the previous period, $f_{t+1} = g(\alpha_t^p, f_t)$. We assume that the private creditor borrows in the risk-free capital market and so the difference between the present value of repayment and the loan amount is positive and increases in the case where default is more likely to occur. In the results section, we calculate total profit for the private creditor in the policy experiments and compare them to the benchmark economy, and show that the average profit is increasing in the default risk. This monotonicity is mostly due to the difference between repayment and the loan amount, rather than the wage garnishment. Thus, the average interest rate captures most of the default risk whereas the wage garnishment captures only a small part of it.

We recast the problem in a dynamic programming framework and solve backwardly for all the choices in the model. The value functions for the four phases in the life-cycle are given below. For the retirement phase, the value function is:

$$V_4(s, t) = \max_{s'} u(s(1+r) - s') + \beta V_4(s', t+1).$$

ing of default risk is generated out of the zero-profit condition in a general equilibrium framework with dischargeability rules.

For the parent phase, there are three value functions:²⁶

$$\begin{aligned}
V_3^{post}(a, h, s, z, t) &= \max_{s'} u(zy(h, a) + s(1 + r) - s') + \beta E_{z'} V_3^{post}(a, h, s', z', t + 1); \\
V_3^{par}(a, h, s, f^1, z, Tch) &= \max_{s', b'} u(zy(h, a) + s(1 + r) - s' - b^1) + \beta E_{z'} V_3^{post}(a, h, s', z', Tch + 1) + \beta \rho V_3^{ch}(b^1, f^1) \\
V_3^{pre}(a, h, s, f^1, z, t) &= \max_{s'} u(zy(h, a) + s(1 + r) - s') + \beta E_{z'} V_3^{pre}(a, h, s', f^1, z', t + 1).
\end{aligned}$$

with $V_3^{ch}(b^1, f^1) = (1 - \phi)b^{1(1-\sigma)}/(1 - \sigma) + \phi d(f)^{1(1-\sigma)}/(1 - \sigma)$. We assume separability in b^1 and f^1 such that $x(b^1, f^1) = (1 - \phi)\omega(b^1) + \phi\nu(f^1)$ and $\nu', \omega' > 0$, $\nu'', \omega'' < 0$. The parameter ϕ measures the relative weighting that parents put on transferring funds to their child versus transferring their credit score.

For the young adult, the value function is given by:

$$\begin{aligned}
V_2(a, h, s, f, d_p, d_g, r_p, r_g, z, t) &= \max_{\alpha_p, \alpha_g, s'} u(zy(h, a) + s(1 + r) - s' - \alpha_i d_i) + \\
&\quad \beta E_{r'_i, z'} V_2(a, h, s', f'(\alpha_p), d'_p(\alpha_p), d'_g(\alpha_g), r'_p, r'_g, z', t + 1),
\end{aligned}$$

with $i \in \{g, p\}$. Finally, for the college phase, the value function is given by:

$$V_1(a, b, f, r_p, r_g, 1) = \max_h u(b - h + d_p(b, f, h) + d_g(b, h) + y(h) + \beta^j E_{r'_i, z'} V_2(a, h, f'(\alpha_p), d'_p, d'_g, r'_p, r'_g, z', 2)$$

where $j \in \{1, 2\}$ in case $h \in \{h_2, h_4\}$.

4 Parameterization

The model period and phases are detailed in Table 5. Each model period represents one year, and agents live for 55 years ($T = 55$). The first phase (college) lasts 4 years, the young adult phase lasts 10 years, the parent phase lasts 24 years, and the retirement phase lasts 20 years. Thus, $T_1 = 1$, $T_2 = 11$, $T_3 = 35$, $T = 55$. The period when parental transfers are made to their child is $T_{ch} = 22$ and is set to match the average parental age of college students (which is 43 years old).

There are four sets of parameters that we calibrate: 1) standard parameters such as the discount factor, the coefficient of risk aversion, the coefficient of altruism, the risk free interest rate; 2) parameters for the initial distribution of characteristics: parental income, credit scores and student's ability; 3) parameters specific to student loan markets such as college costs, tuition, borrowing limits, default consequences, interest rates on student loans, etc.;

²⁶In the computations, we divide the problem for the parent phase into three sub-phases: post-child, child, and pre-child. Also, we introduce an extra feature for the young adult phase: a finer grid for the credit scores (other than the 6 bins mentioned above), which are needed for the evolution of credit scores over time.

Table 5: Model periods and phases

Phase	Age	Years	Periods (t)
College	18-22	4	1
Young Adult	23-32	10	2-11
Parent	33-56	24	12-35
Retirement	57-76	20	36-55

and 4) parameters for the earnings dynamics of individuals by education and ability groups. Our approach includes a combination of setting some parameters to values that are standard in the literature, calibrating some parameters directly to data, and jointly estimating the parameters that we do not observe in the data by matching moments for several observable implications of the model. More specifically, we jointly estimate seven parameters: the wage garnishment for government and private loans, the mean and standard deviation from the initial distribution of parental contributions, and earnings during college by income terciles. These seven parameters are set to match seven targets: the national two-year cohort default rates in both the government and private student loan market (5.5% and 4.0%), the four-year college completion rate by income terciles from BPS data (57%, 64.6% and 82.7%), and the participation rates in the government and private student loan market from the College Board (50%, 30%). Table 6 reports how well the model does in replicating the seven data points. We provide details on the procedure in the following subsections.

Table 6: Model Predictions vs. Data

Parameter	Name	Value	Variables Targeted	Data	Model
	Earnings during college for:		4-year college completion rate:		
$y_{T1,1}(h_4)$	1st tercile of income	\$18,009	1st tercile of income	57%	50.1%
$y_{T1,2}(h_4)$	2nd tercile of income	\$6,552	2nd tercile of income	64.6%	65.4%
$y_{T1,3}(h_4)$	3rd tercile of income	\$4,968	3rd tercile of income	82.7%	81%
μ_b	Mean of parental contribution	\$41,245	Participation rate in govt mk	50%	51%
σ_b	St. dev. of parental contribution	\$38,839	Participation rate in private mk	30%	29%
μ_g	Wage garnishment govt mk	0.035	Default rate in govt mk	5.4%	5.4%
μ_p	Wage garnishment private mk	0.05	Default rate in private mk	3.9%	3.9%

Figures are in 2007 dollars.

Table 7 reports the values for the remaining parameters of the model. The discount factor is set to match the risk free rate (R^f) of 4%, thus $\beta = 0.96$. We assume a CRRA utility function with the coefficient of risk aversion as standard in the literature, $\sigma = 2$. In setting the parameter for altruism, ρ , we use estimates from Nishiyama (2002). His calibrated altruism parameter is 0.626 for a coefficient of relative risk aversion of 2. We set the parameter ϕ , which measures the relative weighting that parents put on transferring

Table 7: Parameter Values

Parameter	Name	Value	Target/Source
β	Discount factor	0.96	Real avg rate=4%
σ	Risk aversion coeff	2	Literature
ρ	Coef of altruism	0.626	Nishiyama (2002)
ϕ	Weighting of credit scores	0.5	—
T_{child}	Period of parental contribution	22	Avg age of college students' parents
R^f	Risk-free rate	1.04	Average rate in 2000-2008

funds to their child versus transferring their credit score to $\phi = 0.5$. We run robustness checks on this parameter and know that it does not alter our main findings. We assume CRRA functions with $\sigma = 2$. We evaluate the utility one derives from consuming b^1 and from consuming the level of debt that one can obtain in the private market for a given f^1 evaluated at the interest rate R_i^p . We assume a uniform grid for debt, that ranges from 0 to the maximum amount of debt that can be obtained in the private market for the average level of parental contributions. We run robustness checks and find that our results are not sensitive to these debt levels as long as credit scores induce heterogeneity in the amounts that one can borrow.

In what follows, we discuss in detail the parameterization of the initial distribution of individual characteristics, the parameters specific to the student loan market, and earnings dynamics.

4.1 Initial Distribution of Parental Contributions, Credit Scores and Ability

For the parental contribution for college, we consider a uniform grid, $B = [0, 100,000]$ in 2007 dollars with 20 levels of b^0 . For initial credit scores, we set six bins corresponding to the bins used by Sallie Mae to determine the conditions on student loans, $F = \{< 640, 640 - 669, 670 - 699, 700 - 729, 730 - 759, 760 - 850\}$. We measure the ability level, a , by the SAT scores of students and consider 3 groups of SAT scores: $A = \{< 900, 900 - 1100, 1100 - 1600\}$ corresponding to terciles of SAT scores.

We estimate a joint distribution of parental contribution, credit scores, and ability accounting for correlations between all these three characteristics. We assume a normal distribution for parental contributions for college, $B(b^0) \sim (\mu_b, \sigma_b)$. While the expected family contribution is a good predictor for the actual parental contribution for college, differences may arise between the two. Rather than using an exogenous distribution for the expected family contribution for college, we estimate the moments of the distribution of parental

contributions to match participation rates in the government student loan and the private student loan market (50% and 30%). Recall that the parental contribution determines the mass of people who are eligible to borrow under the government market and also those for whom the borrowing limit binds. We assume that all borrowers who face this borrowing limit in the government market will turn to the private market. We obtain $\mu_b = \$41,245$ and $\sigma_b = \$38,839$ in 2007 constant dollars, which are consistent with the Baccalaureate and Beyond (B&B) data from the U.S. Department of Education that yields a mean expected parental contribution of \$52,250 (over four years of college) and a standard deviation of \$37,943.²⁷

For the distribution of credit scores, $F(f^0)$, we use the national distribution of FICO scores provided in Section 2.3 and assume a normal distribution where $F \sim (716, 54)$. For the distribution of ability, $A(a)$, we use the national distribution of SAT scores and assume a normal distribution with a mean of 1016 and a standard deviation of 226 (College Board, 2007).

Our model assumes a positive correlation between all three initial characteristics.²⁸ Based on the results in section 2.2, there is a small, positive correlation between credit scores and parental contribution for college, such that $\rho(b_0, f_0) = 0.15$, where ρ is the correlation coefficient. For the correlation between ability and initial parental contributions, we use $\rho(b_0, a_0) = 0.4$, which is in the middle of the estimates from Ionescu (2009).

4.2 Student Loan Parameters

4.2.1 College Costs and Loan Limits

Recall that the amount agents can borrow from the government is represented by: $d_0^g = \max[\min\{\bar{d}(h, b^0) - b^0, d_{\max}(h)\}, 0]$, where $\bar{d}(h, b^0)$ is the net price of college, b^0 represents parental contributions to college, and $d_{\max}(h)$ is the exogenous borrowing limit imposed by the government.

To set the appropriate borrowing limits for government school loans, we need the net price of college, which is total student charges (tuition, fees, room and board) net of grants and education credits, as reported by the College Board (2007a). We calibrate the model to academic years 2003-2004 through 2007-2008. The net price of college for these four years was \$88,380 for private universities and \$38,080 for public universities (in 2007 dollars). The net price for a two-year college was \$13,920 (for two years). Since agents in the model pay

²⁷<http://nces.ed.gov/surveys/hsb/index.asp>

²⁸Our findings from the SCF data presented in Section 2 show a positive correlation between credit scores and income. In addition, data suggest a strong positive correlation between SAT scores and parental income (see College Board, 2009).

for college as a consumption good (h), we must also calculate the total direct cost of college in terms of tuition and fees. Total tuition and fees for four-year private and public colleges and two-year public colleges were \$90,657, \$23,541, and \$4,671 (for two years), respectively, using the same College Board data.

To match the actual costs of attending four years and two years of college, we use the BPS data on dropout and completion rates for the cohort of students starting college in 1995-96. Our sample consists in high-school graduates who enroll in four-year and two-year colleges, are enrolled exclusively full-time and without a delay after graduating from high-school. Also, we consider students with SAT scores above 700. According to the national distribution of SAT scores, less than 8 percent of students have scores below 700. Also according to the BPS data, 56% of these students enrolled in less than two-year colleges or enrolled into two-year colleges and dropped out, 45% delayed their enrollment in college and 55% did not enroll full-time in the first semester when they enrolled in college and thus were not eligible for student loans. The four-year college group consists of college graduates, i.e. students who obtained their bachelor degree by 2001. Those who drop-out of four-year colleges are put into the two-year college group. The 2-year college group also includes those who complete a two-year degree (those who drop-out of two-year colleges are not considered). We find that 67% of students completed a four-year degree (59.1% of these students attended a public institution and 40.9% a private institution) and 33% completed a two-year degree (71.2% of these students were drop-outs from four-year colleges and 28.8% completed a two-year degree).²⁹ Using these weights and assuming they have been constant over time, the average net price for getting a four-year degree is \$58,654. For two years of college, the net price is \$20,535.³⁰ The average direct costs (tuition and fees) using the same weights are: \$50,993 for a four-year degree and \$18,762 for two years of college.

Our setup focuses on the duration of college investment while ignoring college heterogeneity in other dimensions such as quality of the school. However, we recognize the fact that students from different family background may sort into different types of schools and we allow the cost of college to vary with student income. In particular, our findings from the 1996 BPS sample show that the cost of college increases in the income level of students. An interesting finding is that the relative cost of four years of college relative to two years of college declines in the parental income of students. This is an essential feature to be captured in our model so that we can correctly account for the borrowing behavior in the two markets for student loans and the relevance of credit scores for borrowing and college

²⁹<http://nces.ed.gov/programs/coe/2004/section3/table.asp?tableID=61>

³⁰Note that for drop-outs of 4-year colleges, we assume they pay the net price of attending a 4-year college (public and private) for 2 years. Thus, our 2-year net cost is higher than the cost of 2-year colleges since it includes drop-outs from 4-year colleges that paid a much higher net price.

investment behavior. We measure students' income by the expected family contribution and look at college costs by income terciles. Since the BPS data provide information only for the cost of college in the first academic year, we use these measures and obtain relative differences in the cost of college for two and four years of college across income terciles. We apply these differences to the average cost of college for four and two years of college and obtain college costs by institutions and income groups of students as follows: for the four-year group the costs are \$57,716, \$56,777, and \$60,942 and for the two-year group, costs are: \$19,180, \$20,535, and \$24,231.³¹

With respect to government student loans, the Stafford loan limit for dependent undergraduates is \$23,000 for up to five years of post-secondary education. Dependent students who enroll in college for two years are eligible for \$6,125 in Stafford loans during this period (\$2,625 for the first year and \$3,500 for the second year of college). As a percent of average net college price, students attending four-year institutions could therefore borrow approximately 40% of the net average college price from the federal government. Students attending college for two years could borrow 30% of the net average college price from the government. Note that unlike the cost of college, these limits do not vary with the income of students. As a result, the limits represent a higher percentage of net college cost for low-income students than for high-income students.

Loan limits in the private market for school loans are set by the creditor and do not exceed the cost of college less any financial aid the student receives, including government student loans in the case of borrowers with a good credit score. In addition to this, borrowers with credit scores lower than 640 cannot borrow in the private market and borrowers with credit scores lower than 700 cannot borrow more than the average amount that it is borrowed in the private market. Thus, the borrowing limit in private credit markets is: $d_t^p(h, b_0, f_0) \leq \min\{\bar{d}(h, b^0) - d_t^g, d_{\max}(f_0)\}$ with $d_{\max}(f_0) = 0$ if $f_0 < 640$, $d_{\max}(f_0) = \text{mean}(d^p)$ if $640 \leq f_0 < 700$ and $d_{\max}(f_0) = \bar{d}(h, b^0)$ if $700 \leq f_0$.

4.2.2 Student Loan Interest Rates and Default Penalties

The interest rates on government and private student loans follow a stochastic process, given by a 2 by 2 transition matrix $\Pi(R^{g'}, R^g)$ on $\{\underline{R}^g, \overline{R}^g\}$ and $\Pi(R^{p'}, R^p)$ on $\{\underline{R}^p, \overline{R}^p\}$. The interest rates on private loans depend on credit scores, whereas the interest rate on government loans do not.

The government sets the interest rates based on the 91-day Treasury-bill rates plus a margin of 3.1%. We use the time series for 91-day Treasury-bill rates for 2000-2007, adjusted

³¹Certainly our calculations are simplified in assuming that the weight for private and public schools are the same across income groups of students.

for inflation. We fit the time series with an AR(1) process: $R_t = \mu(1 - \rho) + \rho R_{t-1} + \varepsilon$, $\varepsilon \sim N(0, \sigma^2)$, which yield estimates of $\rho = 0.9902$ and $\sigma = 0.2097$ and mean 3.11%. We aggregate this to annual data; the autocorrelation is given by 0.89 and the unconditional standard deviation by 1.511. We approximate this process as a two-state Markov chain. The support is $R^g \in \{1.047, 1.0772\}$, and the transition matrix is $\begin{bmatrix} 0.7037 & 0.2963 \\ 0.2963 & 0.7037 \end{bmatrix}$.

Sallie Mae sets the interest rates based on the 3-month LIBOR rates plus a margin that differs across credit scores, which are described in Table 4.³² We consider 6 bins of credit scores on the set $F = [\underline{f}, \overline{f}]$ corresponding to the 5 groups of FICO scores in Table 4, including the group with FICO scores less than 640.³³ The minimum FICO score that Sallie Mae would accept for private student loans was 640 in 2008; thus, for any credit scores below 640, $d^p = 0$. We use the time series for 3-month LIBOR rates between 2002-2007 and fit it with an AR(1) process. The estimates of the two moments are given by $\rho = 0.9888$ and $\sigma = 0.2117$ and the mean is 3.41%. We aggregate this to annual data; the autocorrelation is given by 0.872 and the unconditional standard deviation by 1.408. We have approximated this process as a two-state Markov chain. The support for each of the bins of credit scores is $R_1^p \in \{1.06, 1.0882\}$, $R_2^p \in \{1.085, 1.1132\}$, $R_3^p \in \{1.105, 1.1332\}$, $R_4^p \in \{1.125, 1.1532\}$, and $R_5^p \in \{1.14, 1.1682\}$. The transition matrix is $\begin{bmatrix} 0.7003 & 0.2997 \\ 0.2997 & 0.7003 \end{bmatrix}$.

We calibrate the default punishments to match the repayment behavior in the data. We set the wage garnishment for default in the government student loan market as $\mu_g = 0.035$ to match the default rate for government student loans of 5.4% in 2007. In practice this punishment varies across agents, depending on collection and attorney's fees, and can be as high as 15%. The wage garnishment for private student loans $\mu_p = 0.05$ is set to match the default rate for private student loans, which is 3.92%. Also, recall that the repayment behavior in the private market affects the credit score of the individual. The fraction of the student loan that is paid in period t is α_t^p for private loans. When the agent chooses α_t^p such that $p_t^p = \alpha_t^p d_t^p < \underline{p} = \underline{\alpha}_t^p d_t^p$, the score is severely damaged and becomes $\underline{f}$. For any payment greater or equal than the minimum require in each market, the score is gradually updated according to the function $g^p(\alpha_t^p, f_t) = \alpha_t^p a(f_t) + b(f_t)$. When the borrower pays the exact amount that it is required in each of these markets, his score does not change, f^i and when he pays his entire loan in period t , his score improves to the next bin, f^{i+1} for $i \in \{1, \dots, 6\}$. We use these upper and lower bounds for each bin of credit scores in each market and compute the linear function for the credit score evolution on a finer grid of credit

³²The margins are from June 2008 and were obtained from: <http://www.salliemae.com/about/investors/>

³³We compute the interest rate on private college loans based on the mean of 3-month LIBOR rate for the period December 2000-December 2007.

Table 8: Credit Scores and Interest Rates

FICO	Margin	R^p
640-669	12	15.41%
670-699	10.5	13.91%
700-729	8.5	11.91%
730-759	6.5	9.91%
760-850	4	7.41%

scores: $g^p(\alpha_t^p, f_t^i) = \frac{\alpha_t^p(f_t^{i+1} - f_t^i) + (f_t^i - \alpha_t^p f_t^{i+1})}{1 - \alpha_t^p}$. Note that this function depends on the minimum required payment, which depends on the loan amount due each period to the private creditor, which in turn depends on the parental contribution and credit score. In fact, this evolution delivers that the cut-off of payment that induces an improvement in the credit score is decreasing in parental contribution and increasing in credit scores. This implies that a lower payment is required from individuals with low credit scores in order to increase their credit score relative to the payment required from individuals with high credit scores. This feature of the model delivers that people with low credit scores can improve their credit scores more than people with high credit scores with the same repayment behavior.

4.3 Parameterization of Earnings

The deterministic component of lifetime earnings, $y_t(h, a)$ is based on earnings data from the 1969-2002 CPS. We generate synthetic cohorts for each year in the CPS, by using earnings for the heads of households age 25 in 1969, age 26 in 1970, and so on until age 58 in 2002. We consider a five-year bin to allow for more observations, i.e., by age 25 at 1969, we include high school graduates in the sample that are 23 to 27 years old. We include all adults who have completed at least 12 years of schooling. There are an average of 5,000 observations in each year's sample. People with 16 and 17 years of education are classified as people with 4 years of college (BA) in the model. For individuals with some college in the model, we use earnings for people with more than 12 years and less than 16 years of education in the data. The life-cycle profiles for the two education groups are given in Figure 2. For individuals with two years of college, earnings during college $y_t(h_2)$ is \$68,788 (in 2007 dollars). This matches two years of earnings for people with some college education (i.e., less than four years of college) from the CPS data for heads of households age 23 in 1967 and age 24 in 1968. We obtain a lifetime earnings premium of 1.35 for those with a 4 year college degree compared to those with some college, but no four-year college degree, which is consistent with empirical estimates (Cheeseman Day and Newburger, 2002). Note that we do not distinguish (in terms of earnings) between people with some college and no degree and people with an

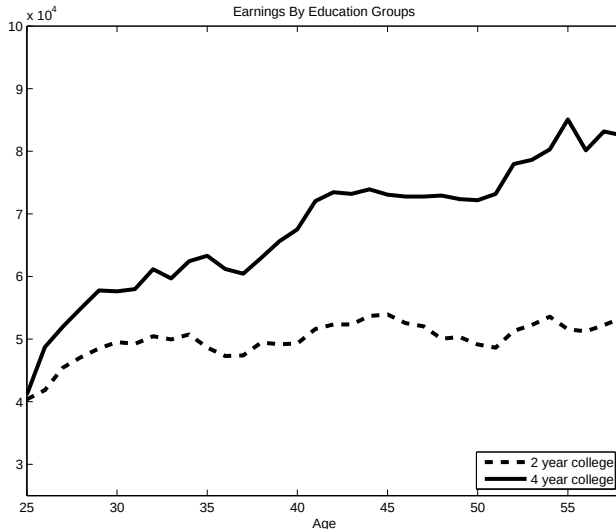
associate degree. More generally, in our model what matters for earnings differences by education groups is the duration of college education rather than the acquired degree. Kane and Rouse (1993) find that degree recipients do not earn more than non-degree recipients with the same number of credits. Bound, Lovenheim and Turner (2009) document that the average number of years of college for people a bachelor's degree is 5.3 years. Thus, the college degree premium that we use delivers an average return per additional year of college education of roughly 10%, which is consistent with estimates in the literature (Willis, 1986; Restuccia and Urrutia, 2004).

Earnings also vary with the ability level of the individual, as measured by SAT scores. We use annual earnings by education groups in the fifth year after acquiring the highest degree for college-going high school graduates in the National Education Longitudinal Study of 1988 (NELS:88) data set. Similar to our analysis based on the BPS data, we construct a sample of high-school graduates that enrolled in college full-time without a delay (the cohort of 1992). We group individuals by terciles of SAT scores, i.e. ≤ 900 , $900 - 1100$, and > 1100 . We find that earnings increase in the SAT score regardless of the education level of the individual (2 years versus 4 years). Furthermore, the premium from completing 4 year college relative to 2 year increases in the ability level, but at a declining rate. We apply these earnings differences between students with four years and two years of college by SAT scores to the annual earnings from the CPS data for the two education groups. We obtain the following differences in premia from acquiring a college degree over the lifecycle: 1.272, 1.338 and 1.341 across the three ability groups. Our calibration is consistent with empirical evidence that individuals of higher ability levels experience higher returns to their education investment (see Rosen and Willis (1979), Cuhna et al. (2005), Heckman and Vytlacil, 2001). Also, most of the increase in returns is captured by the difference between the first and the second tercile of ability, which is consistent with the findings in Ashenfelter and Rouse (1998) and Hendricks and Schoellman (2009). An important observation is whether these returns are due to the innate ability of the individual or the quality of the school these individuals attend before college or the quality of college itself or it is primarily due to family characteristics. In our case, we directly consider a measure of ability that embodies both innate ability and acquired ability since we think of the ability as college preparedness. In addition, our model captures a correlation between ability and parental income. Finally, empirical findings show that returns to schooling are mostly driven by the ability of the student and length of schooling rather than the quality of the school.³⁴

Finally, students can work during college in the model. We pick the value of earnings dur-

³⁴Dale and Krueger (1999) find that students who attend more selective colleges do not earn more than other students who were accepted and rejected by comparable schools but attended less selective colleges.

Figure 2: Lifetime Earnings - CPS data



ing college across income terciles in the model to match the fraction of college students that complete 4 years of education across individuals from terciles of expected family contribution in the BPS sample: 57% , 64.6% and 82.7%. We obtain \$18,009, \$6,552, AND \$4,968 for earnings during college. Our calibration produces declining earnings by parental income of students. Even though we do not model time allocation between market and school work during college, our model captures the fact that some students may use earnings during college to supplement funds needed to invest in college (which is consistent with findings in Garriga and Keitly(2007)). Also, according to the NCES data, 46% of full-time enrolled college students choose to work during college years (Berkner, He, and Cataldi,2002). Furthermore the model captures the fact that people from low income backgrounds work more during college and thus may decrease their chances of acquiring a college degree. Diverting time from school work to job work may affect school performance. Research finds that working during college has a significant impact on dropping out (see Manski (1983) and Stinebrickner and Stinebrickner (2003) for details).

In the parameterization of the stochastic idiosyncratic labor productivity process, we follow Storesletten, Yaron and Telmer (2001) who build a panel from the Panel Study of Income Dynamics (PSID) to estimate the idiosyncratic component of labor earnings. They use annual data from PSID from 1968 to 1991 for wage earnings. With $u_{ij} = \ln(z_{ij})$, the stochastic part of the labor income process for household i at time j , the estimated model

is:

$$\begin{aligned} u_{ij} &= y_{ij} + \epsilon_{ij} \\ y_{ij} &= \rho y_{i,j-1} + \nu_{ij} \end{aligned}$$

where $\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$ and $\nu_{ij} \sim N(0, \sigma_\nu^2)$ are innovation processes. The variables y_{ij} and ϵ_{ij} are realized at each period over the life cycle and are referred to as persistent and transitory “life-cycle shocks”, respectively. Fernández-Villaverde and Krueger (2002) report $\rho = 0.935$, $\sigma_\epsilon^2 = 0.017$, and $\sigma_\nu^2 = 0.061$. We have approximated this process as a two-state Markov Chain, normalizing the average value for the idiosyncratic shock to be 1. The resulting support is the set $Z = \{0.8266, 1.1734\}$ with the transition probability matrix given by

$$\begin{bmatrix} 0.89 & 0.11 \\ 0.11 & 0.89 \end{bmatrix}.$$

5 Quantitative Results

5.1 Benchmark

In the benchmark economy, the four-year college completion rate is 65.6 percent. This represents the percentage of students who complete four years of college, out of the pool of all college students (i.e., those who complete two and four years of college). Students in the model borrow on average \$31,050 (in 2007 dollars) to finance college: \$15,028 from the government and \$16,022 from the private market. Not surprisingly, since the cost of financing four years of college is significantly higher than financing two years of college, students with four years of college borrow \$39,682 (from both sources) compared to \$12,458 for students with two years of college, as evident in Table 9. However, in both cases, more than half of borrowed funds is from the private student loan market. Thus, the private student loan market is an important source of funds for college students in the model.

Default rates in the government and private student loan markets are 5.4 and 3.9 percent, respectively. For the benchmark economy, all of the default comes from students with four years of college.³⁵ Students with four years of college take on three times as much debt as students with two years of college. Higher debt levels necessary to finance the additional years of college may be accompanied with large adverse earnings shocks, which pushes agents with four years of college into default. Conversely, the relatively low cost of acquiring two

³⁵This is due to the fact that students with two years of college in the model do not include those with more than two years of college who do not complete the bachelor’s degree. These students have large amount of student debt, relatively low income (since they did not complete the degree), and high default rates, but are not captured in our model, such that default rates for the two-year college group are understated.

years of college leads to lower debt levels such that no student with two years of college defaults in either the government and private student loan market.

Table 9 also reports mean parental contributions, credit scores, and ability levels for students who complete two and four years of college. Agents who complete four years of college receive nearly 60 percent more in parental contributions compared to those who invest in two years of college. Ability is also an important factor in the college investment decision: the average ability level of students completing four years of college is 279 SAT points higher than the average ability of those completing two years of college. These results are consistent with our findings from the BPS data where high-ability and high-income students invest in more college and are more likely to acquire their bachelor’s degree than low-ability or low-income students.

What is novel in our quantitative results is that parental credit scores, in addition to parental contributions and student ability, have a significant effect on college investment. Students with four years of college have parental credit scores that are 26 FICO points higher than students with two years of college (723 versus 697). Recall that higher parental credit scores allow students to borrow from the private market at lower interest rates and higher levels. The lower cost of borrowing influences more borrowing from the private market (\$20,245 versus \$7,266), which leads to more college investment. Thus, higher credit scores leads to more college investment.

Table 9: Model Predictions by College Education

Variables	2 years	4 years
Participation rate in govt market	46.2%	53.7%
Participation rate in private market	27.6%	30%
Avg govt debt (for those who borrow)	\$5,192	\$19,437
Avg private debt (for those who borrow)	\$7,266	\$20,245
Mean parental contributions (b_0)	\$26,206	\$41,545
Mean ability (a)	821	1100
Mean parental credit score (f_0)	697	723

Next, we consider how the college investment decision varies for students with different parental contributions, ability and credit scores. Table 10 reports the results. First, four-year college completion rates are higher for students who receive more parental contributions, while participation rates in both private and government student loan programs are lower. This result is consistent with the data that shows wealthier households have more college education and participate less in student loan programs (College Board, 2007b). In fact, the wealthiest households (those in the highest b_0 group) do not borrow from the private market and borrow very little from the government since most of them are not eligible. However,

Table 10: Variation in Initial Characteristics: Benchmark

	4-year college completion rate	Participation rates (govt/private)	Average debt (govt/private)	Default rates (govt/private)
Parental Contributions (b_0)			for those who borrow	
Low	50.1%	97.8%/77.4%	\$14,780/\$17,326	7.8/4.4
Medium	65.4%	55.5%/9.6%	\$15,400/\$5,216	1.3/0
High	81%	5.4%/0%	\$2,664/0	0/-
Ability of the student (a)				
Low	27.6%	47%/38%	\$15,462/\$18,816	13.2/4.5
Medium	79.8%	66%/33%	\$14,780/\$13,538	2.3/2.4
High	89.1%	40%/16%	\$14,966/\$14,345	1.5/5.7
Parental credit score (f_0)				
Low	51%	56.7%/23.7%	\$10,557/\$7,204	3.8/0
Medium	67.2%	51.3%/33.6%	\$15,525/\$14,221	5.1/5.4
High	78.3%	45.3%/29.7%	\$19,996/\$24,026	8/5.5

Note: For parental contributions, the low group ranges from \$0-\$25,337, the medium group from \$25,338-\$58,622, and the high group over \$58,622. For ability, the low group ranges consists of ability index less than an SAT score of 900, the medium group from 900-1,100 SAT scores, and the high group greater than an SAT of 1,100. For credit scores, the low group ranges from 640-689, the medium group from 690-735, and the high group from 736-850.

middle-income students heavily rely on the government student loan market, as evidenced by their 56 percent participation rate and \$15,400 average government loan.

Approximately one-half of the poorest students in the model (those in the lowest b_0 group) complete four years of college. There are several factors at play here. First, since ability and parental contributions are positively correlated in our framework, the poorest students in the model experience relatively low returns to college investment. In addition, the relative cost of four years of college (compared to two years of college) is highest for poor students, as documented in the calibration. The combination of relatively low returns to college investment and the high cost of college explains the relatively low four-year college completion rate for this group of students. However, poor students are assumed to earn the most in the form of supplemental income during college (which is consistent with the data). The extra earnings allow some of them to invest in college, despite their low parental contributions.

Notice (in Table 10) that students with the lowest parental contributions take on the most student loan debt (more than \$32,000 for the average borrower), even though only half complete four years of college. They are eligible for more student loans (both government and private) since their parental contributions are low. Thus, poor households are borrowing at relatively high levels just to complete two years of college. Large amounts of student loan debt and low lifetime earnings lead to high default rates for this group. In fact, the poorest

students have the highest default rates, making them the most risky borrowers in the model.

Not surprisingly, high-ability students (those in the top third of ability levels) have the highest four-year college completion rates, at 89 percent. This compares to low ability students, with a four-year college completion rate of only 28 percent. In addition, Table 10 illustrates a large increase in four-year college completion rates between low- and medium-ability agents, from 28 percent to 80 percent. This is due to a large increase in relative earnings between these two types of agents, as documented in the calibration.

Participation in the private student loan market falls in ability, such that students with the lowest abilities borrow from the private market the most. This is not true for the government student loan market: agents with medium level of ability borrow from the government at higher rates than those with low and high ability, which is consistent with the data.³⁶ High participation in the government student loan market by agents with medium level of ability and their consequent high four-year college completion rates suggest that the government student loan program is effective in promoting college investment for this group of students. To our knowledge, we are the first to report differences in borrowing behavior across ability types that are consistent with the data. Most other models of student borrowing (Lochner and Monge-Naranjo, 2008; Ionescu, 2009) infer that participation in the government student loan program would rise in ability, which contrasts to our findings in the model and in the data.

Table 10 confirms the positive relationship between credit scores and college investment. Agents with the lowest parental credit scores borrow from private markets less often and invest less in college than agents with higher parental credit scores. This is attributed to the fact that students with the lowest parental credit scores receive the worst loan conditions and hence are less likely to borrow from private creditors. What is surprising is that participation in the private student loan market is slightly lower for agents with the highest parental credit score (above 735), compared to agents with parental credit scores in the middle range (between 690 and 735). For those who borrow from private markets, the amount they borrow is higher, which is consistent with having access to cheaper loans. But fewer of them borrow (from both the private and government market). Agents with the highest parental credit scores have the most to lose from defaulting in the private market: if they default, their credit scores will be severely revised downward. Thus, students with high parental credit scores prefer to default in the government student program. However, there is some incentive for students with high credit scores to default in the private market given their relatively high debt burden. This counteracts the repayment incentives created by the penalty on credit

³⁶The 2003 cohort of the BPS shows that borrowing rates and levels were highest for students in the middle third of the ability distribution, as measured by SAT scores.

scores as a result of default. Therefore, students with high credit scores default at high rates.

In this environment where interest rates in the private market for student loans depend on credit scores, there is an important role for earnings uncertainty. For students who borrow from the private market, interest rates can be twice as high for someone in the lowest range of credit scores compared to someone in the highest range of scores. Thus, the cost of a student loan, especially when financed over ten or more years, can be significantly higher for students with low credit scores. If this student experiences a bad shock in lifetime earnings, this may significantly reduce college investment. Thus, earnings uncertainty in this model amplifies the effects that credit scores have on college investment, compared to an environment without earnings uncertainty.

Notice that, in general, students are using the private market for student loans in conjunction with the government student loan program. Students with better parental scores borrow more (in levels) from both the private and government market compared to students with low parental scores. Similarly, poor students use both student loan markets more than rich students. Thus, it seems as if the two program are complementary: students are using a mix of parental contributions and private and public loans to finance college, which is consistent with the results of Lochner and Monge-Naranjo (2008).

Since parental contributions and ability are important determinants of college investment, our results imply that poor students can achieve relatively high four-year college completion rates, as long as their parent's credit score is high enough. In addition, we document that good parental credit scores have significant effects on the college investment decision for students with medium levels of abilities. Thus, the private market for student loans provides students with another mechanism to fund college through the use of credit scores, and that this market may be especially important for low-income and medium-ability students. However, credit scores are not as important in the college investment decision for wealthy students since their high levels of parental contributions and ability lead to high four-year college completion rates independent of participation in the private market.

To recap, the benchmark economy delivers several interesting findings. We find that parental credit scores have quantitatively significant effects on the college investment decision. Students with the highest credit scores, who get attractive interest rates on private loans, borrow at very high levels from both the private market and the government to finance college. This leads to high college completion rates for this group. However, for those with low credit scores, it is very costly to borrow from the private market. As a result, they invest less in college, and have four-year college completion rates that are 27 percentage points lower than students with high credit scores.

Poor students in the model borrow at high levels from both the government and private

market; however, they complete four years of college at much lower rates, leading to low lifetime income, and high default rates. In fact, default rates in both the government program and private markets are highest for students from the poorest families, making them the most risky creditors. However, poor students with relatively good credit scores benefit from having access to the private market for student loans to the extent that their four-year college completion rates increase with their credit score. Thus, the existence of a private market for student loans is important for low-income students.

We also find that ability matters for college investment, and in a way that is intuitive (the highest ability agents invest the most in college). However, the method of financing college varies across ability levels. Participation rates in the government program are highest for medium-ability students, while participation in the private market is highest among low-ability students.

5.2 Policy Experiments

We next conduct two policy experiments. First, we consider the case in which the government increases the maximum borrowing limit on government student loans. Second, we tighten the conditions for obtaining student loans from the private market. Table 11 summarizes the results for the experiments.

Table 11: Benchmark vs. Experiments

Variables	Benchmark	Tighter Private Mkt	Higher Govt Limits
4-year college completion	65.6%	60.4%	70.7%
Participation in govt mkt	51%	50%	53%
Participation in private mkt	29%	21.9%	25%
Default rate in govt mkt	5.4%	3.5%	3.7%
Default rate in private mkt	3.9%	1.5%	10.3%
Average govt debt	\$15,028	\$13,308	\$21,270
Average private debt	\$16,022	\$13,955	\$12,690

5.2.1 Higher Limits on Government Student Loans

For the first time since the early 1990's, the U.S. government in 2008 increased the amount undergraduates can borrow. Undergraduate students can now borrow up to \$31,000 total for college (up from \$23,000) and \$12,000 (up from \$6,125) for the first two years of college.³⁷

³⁷This increase consisted of unsubsidized student loans, in that the government does not pay for the interest accumulated during college. For simplicity and ease of comparability, we assume that these loans were

It is important to note that the increase in the government loan limits is more generous in the early stages of a college education: loan limits for the first and second year of college are now \$6,000 per year (up from \$2,625 the first year and \$3,500 the second year); the increase in the loan limits for additional years of college are now \$7,000 per year (up from \$5,500).³⁸ Thus, the percentage increase in the loan limit is larger in the first two years of college. We analyze the effects of this policy in our model economy.

As evident in Table 11, a more generous government student loan program increases participation rates in the government student loan program by two percentage points and decreases participation in the private student loan market by four percentage points. In addition, students are borrowing much more (in levels) from the government (42 percent more than in the benchmark), and borrowing less from private markets (21 percent less). Since government student loans are cheaper than private student loans (i.e., the interest rates are lower), students are taking on more total debt to finance college. Hence, a more generous government student loan program leads to a five percentage point increase in four-year college completion rates.

Who is taking advantage of the more generous student loan program? Table 12 illustrates how students with different parental contributions, abilities and credit scores respond to this policy. Almost all types of agents borrow more from the government and less from the private market, both in participation rates and in levels. Thus, it seems as if students would substitute private student loans for government student loans if the government were to increase its borrowing limits. This contrasts to the complementary relationship between the two markets in the benchmark economy.

The largest shift away from private loans and into government loans occurs for students with the lowest parental credit scores. Recall that students with low credit scores get the worst loan conditions in the private market, such that the wedge between interest rates in the private and government market is quite large. As a result, they borrow from the government at very high rates and levels, leading to high default rates. Nonetheless, students with the lowest credit scores experience some of the largest increases in four-year college completion rates (from 51% to 61%).

Poor students (those in the lowest tercile of parental contributions) experience the largest increases in four-year college completion rates as a result of a more generous government student loan program. Almost all of them (99%) borrow from the government, resulting in four-year college completion rates that are 11 percentage points higher than in the benchmark.

subsidized. Lucas and Moore (2007) find that there is little difference between subsidized and unsubsidized Stafford loans.

³⁸<http://www.finaid.org/loans/historicallimits.phtml>

Once again, this is accompanied by relatively high debt levels and default rates.

Aggregate default rates on government student loans decrease from 5.4% to 4.1%, while default rates in the private market increase from 3.9% to 10.2%. With more generous student loans, the pool of students participating in the private student loan market is smaller but consists of students that are more risky (relative to the benchmark), whereas the pool of students participating in the government student program is less risky. Notice in Table 12 that students with medium parental contributions and medium ability, who have relatively low default rates, fall out of the pool of borrowers in the private student loan market.

Next, we attempt to identify the primary cause of the dramatic increase in the private market default rate in this experiment, compared to the benchmark. Specifically, we quantify how much of the default is due to a shift in the distribution of borrowers and how much is due to a change in the agents' choices. We conduct the following exercise: we take the distribution of agents derived from the policy experiment, and insert it into the benchmark economy. We then compare the default rates with the benchmark results. We find that all of the increase in the default rate is due to a shift in the distribution of agents, and not from a change in the agents' choices.

Recall that the present value of the private creditor's profit accounts for wage garnishments collected in the period of default and average interest rates charged by the private creditor such that the average default risk in the private market changes:

$$PV_\pi = \int_{d_p > 0} \left[\sum_{t=1}^{T_2} \beta^{t-1} \left[\int \int_{\alpha_t^p \geq \underline{\alpha}_t^p} (\alpha_t^p d_t) d\alpha dR^p + \int_{\alpha_t^p < \underline{\alpha}_t^p} \int (\mu_p z_t y_t) dz d\alpha \right] - d_0^p \right] df.$$

We compute the private creditor's profit in this experiment and find that total profits are 30% higher in the policy experiment than in the benchmark economy. As expected, revenues from wage garnishment increase (the second term in the equation), which increases in the default risk. In addition, revenues from repayments (the first term in the equation) goes down, but by less than the value of loans (the third term in the equation). The difference between the present value of repayments and the present value of loans is higher in the policy experiment both in aggregate levels and in per borrower terms. This implies that the average interest rate charged on loans increases in the default risk (since the cost of loans is constant for the creditor). We find that the increase in repayment minus loan value accounts for 88% of the change in profits, while the increase in the wage garnishment accounts for the rest. The average net collection, which reflects the adjustment in the interest rate to the default risk, captures most of the risk. Again, this result relies on the nondischargeability of loans and the fact that agents find it optimal to repay their loans in full by the end of the

repayment period. Also, the cost associated with loans does not vary with the default risk.

Table 12 shows that students with high credit scores have the highest default rates in the private market. This is somewhat surprising given that these students receive the best conditions on loans in the private market, and potentially have the most to lose in the form of credit score reductions as a result of default. However, closer examination of our results indicate that it is precisely the good loan conditions (i.e., low interest rates) that influences them to take on large amounts of debt and that the debt is relatively cheap to push off into the future. In addition, there is a long horizon in which the penalties on credit scores take place. That is, lower credit scores are not realized for several model years after default, which makes the relative cost of default lower for these agents. Lastly, recall that the model does not include other credit markets that depend on credit scores (such as a mortgage market or an unsecured credit market). If we had other markets in the model that relied on credit scores, then agents who defaulted would be penalized in other ways, however, that is beyond the scope of the current paper.

Table 12: Variation in initial characteristics: Higher government limits

	4-year college completion rate	Participation rates in govt market	Participation rates in private market	Average debt (govt/private)	Default rates (govt/private)
Parental Contributions (b_0)				for those who borrow	
Low	61.5 (+11.4)	99 (+1.2)	75.9 (-1.5)	\$23,722/\$12,668	5.8/10.5
Medium	69.3 (+3.9)	59.4 (+3.9)	0 (-9.6)	\$17,140/-	4.8/0
High	81	5.4(+0)	0	\$2,664/-	0/-
Ability (a)					
Low	31.5 (+3.9)	48.6 (+1.6)	36.3 (-1.7)	\$23,660/\$14,097	7.5/14.3
Medium	85.2 (+5.4)	67.5 (+1.5)	25.5 (-7.5)	\$38,813/\$11,302	1.7/7.6
High	95.1 (+6)	42.9 (+2.9)	14.1 (-1.9)	\$20,431/\$11,551	0.6/4.1
Parental credit score (f_0)					
Low	60.6 (+9.6)	61.2 (+4.4)	21.3 (-2.4)	\$17,761/\$5,775	2/0
Medium	72.6 (+5.2)	52.5 (+1.2)	29.7 (-3.9)	\$22,108/\$11,122	3.7/9.7
High	78.6 (+0.3)	45.6 (+0.3)	24.9 (-4.8)	\$25,107/\$20,431	6.7/19.3

Note: Numbers in parenthesis represent percentage changes from the benchmark.

The main finding from this experiment is that an increase in government borrowing limits leads to more college investment for almost every type of student. The largest increases occur for the poorest students, who have the most financial need, and for students with low parental credit scores, who face high interest rates in the private credit market. A more generous student loan program results in significantly higher four-year college completion rates, but at the cost of relatively high debt levels. As a result, less risky borrowers are pushed out of the private market and into the government student loan program. The shift

in the distribution of participants delivers higher default rates in the private market and lower default rates in the government market.

5.2.2 Tighter Private Market for Student Loans

As credit markets have tightened in recent years, creditors have increased the minimum credit score required to borrow in the private market for student loans. For example, Sallie Mae increased the minimum credit score required to obtain a student loan from 640 to 670 in 2008. In this experiment, we assume that private creditors impose a minimum credit score of 670. This implies that students with parental credit scores between 670 and 730 face borrowing limits (recall $d_{\max}(f_0) = \text{mean}(d^p)$), whereas students with parental credit scores above 730 do not face borrowing limits.

From Table 11, we see that with a higher minimum credit score required to borrow from private markets, fewer students borrow from private markets compared to the benchmark (22% versus 29%), and at lower levels (average private debt is 13% lower for those who borrow). We also see a small decline in the percentage of students borrowing from the government (1 percentage point less than the benchmark) and a reduction in the amount borrowed from the government (11 percentage points). As a result of lower borrowing levels, four-year college completion rates fall by more than five percentage points (from 65.6% to 60.4%) when private credit markets tighten.

If you recall in the benchmark, the government and private market for students loans were complements to one another. In this case, there exists even more complementarity between the two markets: for most types of agents, reductions in the participation rates in the private market is accompanied by significant reductions in the participation rates in the government market. Since students are borrowing less from both sources, default rates fall in both markets, compared to the benchmark. This contrasts to the previous experiment, where a more generous government student loan program influenced students to substitute government student loans for private loans.

Certainly, some of the reduction in four-year college completion rates comes from students with the lowest credit scores who no longer qualify for private loans. However, other groups of students are affected as well. As illustrated in Table 13, the poorest students experience the largest drop in college completion rates (14 percentage points) as a result of tighter private credit markets. In addition, students with average parental credit scores (in the 690-735 FICO range) also complete four-years of college at much lower rates than in the benchmark, and much of this is due to lower borrowing levels from the private market. They are eligible to borrow from private markets (since their credit score is greater than 670), but more of them face restrictions on borrow limits in this environment. In fact, they borrow less than

half as much from the private market as in the benchmark.

Table 13: Variation in initial characteristics: Tighter Private Market

	4-year college completion rate	Participation rates in govt market	Participation rates in private market	Average debt (govt/private)	Default rates (govt/private)
Parental Contributions (b_0)				for those who borrow	
Low	35.7 (-14.4)	95.7 (-2)	57.9 (-19.5)	\$10,327/\$15,177	4.6/1.7
Medium	64.2 (-1.2)	54.3 (-1.2)	7.8 (-1.8)	\$15,202/\$5,074	1.1/0
High	81 (-0)	5.4(+0)	0	\$2,664/-	0/-
Ability a					
Low	18.2 (-7.4)	45.6 (-1.4)	29.3 (-8.7)	\$11,929/\$15,438	13.2/4.5
Medium	74.6 (-5.2)	64.8 (-1.2)	24.3 (-8.7)	\$13,407/\$11,520	2.3/2.4
High	88.2 (-0.9)	39.3 (1.3)	12 (-4)	\$14,631/\$15,432	1.5/5.7
Parental credit score (f_0)					
Low	47.4 (-2.6)	53.4 (-3.3)	3.9 (-20.4)	\$9,632/\$7,632	1.1/0
Medium	58.2 (-9)	51.3 (-0.2)	32.4 (-1.4)	\$12,209/\$7,017	2.3/0
High	75.3 (-3)	45.3 (-0)	29.4 (-0.3)	\$18,791/\$22,493	6.2/3.4

Note: Numbers in parenthesis represent percentage changes from the benchmark.

As suspected, having less access to private credit reduces college investment, especially for low-income students. Students with average parental credit scores face tighter credit limits as well, which leads to significantly lower four-year college completion rates for this group. Overall, total student borrowing falls with tighter private markets, which reduces four-year college completion rates by five percentage points. Default rates in the government student loan program decrease as private creditors make it more difficult for some students (and especially those who are more likely to default) to get a private student loan.

The profit of the private creditor in this policy experiment decreases relative to the benchmark economy. Most of this decline is due to a reduction in the repayment of loans. There are fewer people defaulting in this economy and borrowers have higher credit scores on average, which implies lower average interest rates. This result confirms the monotonic relationship between default risk and the average interest rate in the private market, which is consistent with theories of default risk. However, the positive relationship between the private creditor's profit and risk of default may seem counterintuitive. Under these circumstances, why would a private creditor take such an action (as Sallie Mae did in response to the financial market crisis of 2008-09)? Recall that we assume that the private creditor faces a constant cost of funds (in particular, the cost of funds does not vary with default risk in the market) and there are no restrictions in the supply of funds, neither of which was true during the financial crisis. If these assumptions are relaxed, a rationale for tightening credit conditions can certainly arise. Our model does not try to explain this behavior. Rather, we

are interested in studying the impact of such a policy on college investment and borrowing, knowing that this policy may occur for reasons that are beyond the scope of our model.

6 The Effects of Credit Scores at the Extensive Margin

6.1 College Enrollment

In this section, we study the effects of credit scores on the decision to enroll in college. In order to do so, we extend the benchmark economy in the following way: in addition to choosing between two years and four years of college education, a student of ability a , with parental contribution for college b_0 and credit score f_0 may choose not to go to college. Thus, given the prices in the economy and policy parameters, the optimization problem becomes

$$\max\{V^{Col}(a, b_0, f_0, r_p, r_f), V^{NoCol}(a, b_0, f_0, z)\}$$

where $V^{Col}(a, b_0, f_0, r_p, r_f)$ is the value function associated with the college path, which equals $V_1(a, b, f, r_p, r_g, 1)$ given in Section 3 and $V^{NoCol}(a, b_0, f_0)$ is the value function associated with the no college path.

On the no college path, there are no student loans and thus no repayment/default behavior. There is no uncertainty in interest rates. There is uncertainty in earnings, which is modeled similarly to the college path. Earnings are given by $z_t y_t(h_0)$ where h_0 represents no investment in college. We assume that $y_t(h_0) < y_t(h_2, a)$ for all ability levels a . Students who have some college education earn more than high-school graduates. Agents who do not go to college solve a consumption-savings problem subject to earnings uncertainty for the first three phases in the life-cycle, similar to the problem solved by agents who go to college during the third phase of their life-cycle. On the no college path, as well as on the college path, agents are altruistic and derive utility from transmitting the credit score and some parental funds to their child at period T_{child} . In the no college case, the score transmitted to one's child is simply the initial score f_0 . After period T_3 agents retire and consume their savings. Finally, we assume that agents may allocate the initial parental funds to consumption or savings in the first period. Their budget constraints are given by

$$\begin{aligned} c_t + s_{t+1} &\leq z_t y_t(h_0) + b_0; & t = 1 \\ c_t + s_{t+1} &\leq z_t y_t(h_0) + R^f s_t; & t = 2, \dots, T_{ch} - 1, T_{ch} + 1, \dots, T_3 \end{aligned} \tag{9}$$

$$c_t + s_{t+1} \leq z_t y_t(h_0) - b^1 + R^f s_t - p_{t+1}; \quad t = T_{ch} \tag{10}$$

$$c_t + s_{t+1} \leq R^f s_t; \quad t = T_3 + 1, \dots, T$$

On the no college path the agent $i \in B \times F \times A$ maximizes utility (equation 1) subject to his budget constraints (the set of equations 9) by choosing $\{c_t, s_{t+1}, b^1\}$ taking prices $\{z_t y_t, R^f\}$ as given.

6.2 Quantitative Implications

We assume the same stochastic process of earnings for people who do not go to college as for the college going people. The deterministic component of earnings is calibrated to the earnings profiles in the CPS data. The life-cycle earnings profile for the no college group is constructed similarly to the ones for the other two education groups in an extended sample that includes people with 12 years of education. We estimate the forgone earnings from going to college to match the college enrollment rate in the NELS data and obtain a value of \$141,612 in 2007 dollars. The NELS data delivers an enrollment rate of 89.9% for high-school seniors in 1992 that enrolled in college without a delay after graduation and who have SAT scores higher than 700. The rest of the parameters on the no college path that are common to those on the college path are set as described in Section 4.

Table 14 presents college enrollment rates by groups of initial characteristics obtained in the calibrated extended economy. College enrollment rates vary across people with different ability levels, which is consistent with findings in the literature. People of high ability levels take advantage of the returns to higher education the most. However, college enrollment rates do not vary significantly across people of different levels of credit scores. High-school graduates have the option to invest in two years of college, which represents a relatively cheaper investment. In addition, government limits on student loans are more generous for two years of college. Thus the government constraint associated with investment in two year colleges binds only for a small fraction of high-school graduates. These are students with very low levels of parental contribution. But these students also have relatively low levels of ability and thus do not find college a worthwhile financial investment in the first place. As a result, while good credit scores relax the government constraint associated with two year college investment for the marginal student (low parental contribution and medium level of ability), this effect is not quantitatively important.³⁹

³⁹It is important to note that in our model two year students include students who go to two year colleges and dropouts from four year colleges; our calibration of college costs and government loan limits adjust for this fact. A more detailed college investment decision that distinguishes between no enrollment, enrollment in two year colleges, enrollment in four year colleges with separate paths for dropouts and graduates would deliver an even smaller effect of credit scores on the college going decision.

Table 14: College enrollment by initial characteristics

	College enrollment rate
Parental Contributions (b_0)	
Low	82
Medium	91.3
High	95.6
Ability a	
Low	74
Medium	99.2
High	100
Parental credit score (f_0)	
Low	91.3
Medium	89.2
High	90.4

7 Summary

It is now quite common for undergraduate students to borrow for college from private credit markets. Different from the government student loan program, private creditors set the conditions for student loans based on the credit history of the student and the parent. As a result, credit scores may affect the college investment decision. In this paper, we develop a life-cycle model where students finance college through parental contributions, government student loans, and private credit markets. Our main finding is that students with better credit scores invest in more college. Specifically, students who complete four years of college have credit scores that are 26 FICO points higher than students who complete two years of college. We are able to confirm the link between credit scores and college investment using data from the Survey of Consumer Finances, which provides support to our analysis.

Our findings indicate that credit scores are especially important in the college investment decision for certain types of students. For example, low-income students with relatively good credit scores benefit from having access to the private market for student loans. This is the group of students for whom the limit on government loans bind. Similarly, students with average abilities who have relatively high lifetime earnings use the private market to supplement the government student loan program, leading to more college investment. Overall, good credit scores provide another mechanism to help students fund college via the private market for student loans. Finally, credit scores play an important role for college investment at the intensive margin, whereas their role at the extensive margin is minimal.

The relationship between credit scores and college investment has important policy im-

plications. With a more generous student loan program, we find that college investment increases, with the largest increases coming from students with low parental contributions and credit scores. In this case, students substitute private student loans for government student loans. However, a riskier pool of people access the private market in this case, leading to higher default rates in the private market. Alternatively, as private markets tighten, as they have in recent years, college investment falls, especially for poor students for whom the credit score matters the most for college investment. In this case, the reduction in borrowing from the private market is accompanied by reductions in borrowing from the government, leading to less college investment.

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