Sources of Rising Student Debt in the U.S.: College Costs, Wage Inequality, and Delinquency*

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Abstract

This paper examines the quantitative effects of rising college costs, wage inequality, and delinquencies on growing student debt balances in the U.S. We build an incomplete-markets overlapping-generation (OLG) model with choices for a college education, student loans, and delinquency. We solve transitional dynamics with the estimated time-varying changes in college costs and wage inequality, in addition to a stronger preference for college education. We find that these sources increase aggregate student debt balances by $480 billion between 1979 and 2015. Rising college costs increase borrowing by recent college students. The declining average ability of college students and increasing volatility of wage shocks lead to a higher delinquency rate among borrowers over time. Importantly, we find that when borrowers are not delinquent on their payments, the aggregate student debt only increases by 50% of the increase in the benchmark economy, despite all the time-varying sources. This suggests that although the rising college costs largely affect the borrowing behavior of college students, the increasing delinquency rate over time significantly contributes to the rapid growth of U.S. student debt.

Keywords: Student Debt, College Cost, College Choice, Wage Inequality, Delinquency.

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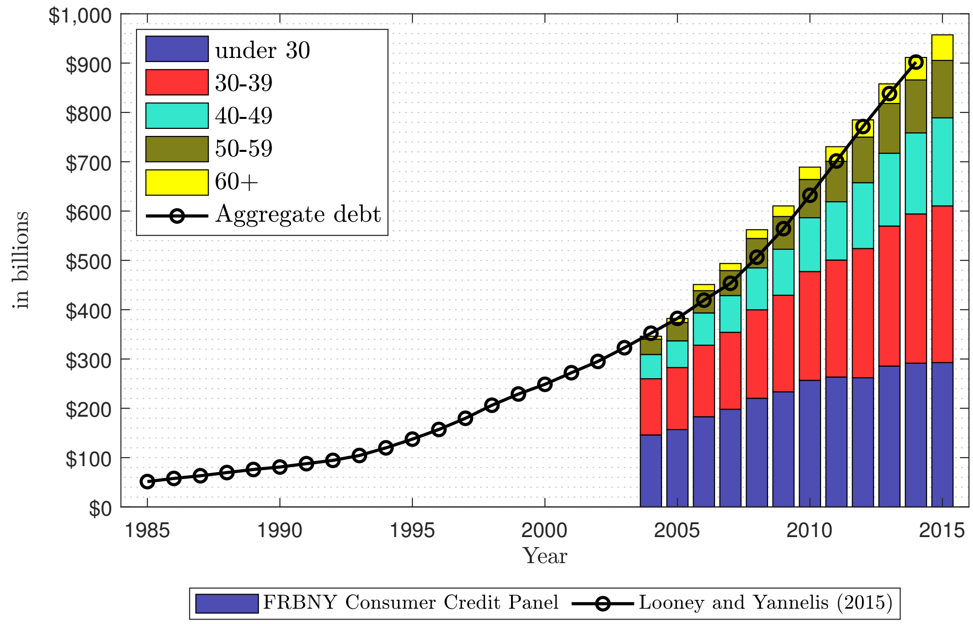
1 Introduction

Figure 1: Total outstanding student debt balance



Note: Dynamics of the outstanding student debt in the U.S. between 1985 and 2015. The bar graphs show the aggregate amounts as well as the age composition of the debt (FRBNY Consumer Credit Panel). The black circled line indicates the aggregate total outstanding debt from the data (Looney and Yannelis (2015)). This amount is expressed in 2004 U.S. billion dollars.

The total outstanding student debt has risen sharply in the U.S. from $50 billion in 1985 to almost $1 trillion in 2015. This 20-fold increase in just 30 years increased the outstanding student debt to approximately 7% of the GDP in 2015.[1] Now, in the U.S., the total outstanding student debt balance exceeds credit card debt and auto loans, making it the second-largest form of household debt after mortgages (Brown et al. (2014)).[2]

Despite growing concern about the rising student debt in the U.S., there is little understanding of the causes of the rapid increase. To fill this gap in the literature, this paper quantitatively studies the contribution of rising college costs, wage inequality,

[1] As shown in Figure D1 in Appendix D, the rise in student debt is accompanied by increases in the total number of borrowers and the average amount of student debt per borrower. For example, the total number of borrowers has doubled from 22 million in 2004 to 44 million in 2015, and the average student debt per borrower has increased from $15,106 to $21,677 over the same period.

[2] Student debt increased even during the Great Recession, while other consumer debt, such as mortgages, credit cards, auto loans, and home equity lines of credit, decreased.

and delinquencies to the rapid growth of U.S. student debt.[3] We focus on these sources as the total student debt balance reflects both changes in the borrowing behavior of college students and the repayment behavior of borrowers.[4] Importantly, to the best of our knowledge, this is the first paper in the literature that investigates the dynamics of student debt and simultaneously examines the implications of rising college costs, wage inequality, and the delinquent behavior of borrowers for the growing student debt in the U.S.

We build an incomplete-markets overlapping-generations (OLG) model in which individuals choose whether to pursue a college degree, how much they want to borrow from government student loans, and whether to be delinquent on the payments for student debt after graduation. Individuals born with different abilities and parental transfers decide to attend college or not. College education is costly: individuals pay the education cost, face the psychic cost of education, and lose out on four years of earnings. College students can finance their education through three different sources: parental transfers, labor income, and government student loans. Individuals enter the labor market with one of the two skill levels and receive skill-specific hourly wages and labor market experience premia. Once in the labor market, individuals with student debt have to pay it off following a fixed payment schedule. However, for each period, they can choose to be delinquent on their scheduled payment, with the utility cost of delinquency.

We solve the model's transitional dynamics with the following estimated time-varying sources: college wage premia, variances of persistent and transitory wage shocks, and college costs. The first two (wage inequality) are estimated using the 1968–2015 Panel Study of Income Dynamics (PSID) data, while the last is estimated using the National

[3]Notably, rising wage inequality also affects rising net tuition. Cai and Heathcote (2022) show that rising income inequality is the key driver of the increase in U.S. college net tuition between 1990 and 2016. This is because rich households become more willing to pay higher tuition for better education, experience, and networks, providing top-quality universities the incentive to raise their tuition and fees.

[4]Given that the federal government has increased its investment in higher education since the 1960s, rising student debt can be a natural consequence of the growing number of college-educated alongside rising wage inequality and education costs. On the other hand, it can reflect the financial distress borrowers face when paying off their existing student debt; therefore they choose to roll over their debt and increase the total balance in the economy.

Longitudinal Survey of Youth (NSLY) 97 alongside data on tuition, fees, and costs of room and board (TFRB). We find that the college wage premia have almost doubled between 1968 and 2015, and the variance of wage shocks increased sharply during the same period. The average annual college education cost has increased from $\$4,723$ in 1979 to $\$12,000$ in 2015.[5] In addition, we lower the psychic cost of education over time, so the model can match the observed increase in college completion rates in the presence of changes in college costs and wage inequality.[6]

The calibrated economy is consistent with the observed distribution of college completion rates, education costs, and student debt amounts over ability terciles and parental transfer quartiles in the data. Matching the micro-level data to this level of rigor is unprecedented in the literature, but it is essential to study the secular increase in student debt balances over time. College completion rates increase in both ability and parental transfers. The net education cost is greater for individuals with high ability and large parental transfers, reflecting that they are more likely to attend a top-quality college with higher tuition. Furthermore, the amount borrowed by a college student is increasing with ability. This is because as ability is persistent through labor income, high-ability individuals wish to borrow more from future income to smooth out their consumption. Given that there are no other financial assets students can use to borrow from the future, they use student loans as a means.

We find that rising college costs, wage inequality, and delinquencies, in addition to a stronger preference for college education, increase student debt balances from $45 billion in 1979 to $525 billion in 2015. This explains 50% of the observed increase in the U.S. These sources explain most of the dynamics of student debt until 2007, suggesting the importance of other factors, such as the Great Recession or the 2006 student loan reform for the increasing student debt since 2007. Rising college costs largely determine the borrowing behavior of college students, leading a higher fraction of college students to borrow from government student loans and a substantial amount when they do. At

[5]These amounts are in 2004 U.S. dollars.

[6]The decreasing psychic cost of education is consistent with empirical findings in Moschini, Raveendranathan and Xu (2023) that college students become overly optimistic about their graduation probability.

the same time, a more volatile wage shock process over time increases the delinquency rate of recent college graduates. This is because a more volatile wage shock process implies a higher probability of a persistent negative wage shock, preventing individuals from paying off their student debt as planned. In addition, a stronger preference for college education lowers the average ability of college graduates, which further raises the delinquency rate for student debt in the economy.

Crucially, and most importantly, we find that in a counter-factual economy without a delinquency choice, but with all the time-varying sources, aggregate student debt only increases by 50% of the increase in the benchmark economy. This is first because the no delinquency option discourages college students from borrowing as they do not have the option to defer their payments when they experience financial hardship. Second, without delinquencies, no student debt is rolled over. In sum, although rising college costs largely affect the borrowing behavior of college students, we find that delinquency significantly contributes to the rising student debt in the U.S.

The remainder of the paper is organized as follows. Section 2 discusses the related literature. Section 3 presents the model economy. Section 4 discusses the estimation and calibration. Section 5 presents the quantitative results, and Section 6 concludes.

2 Related Literature

This paper contributes to the literature that explores the implications of different student loan policies for educational attainment, borrowing, and repayment behavior in a quantitative macroeconomic framework. Ionescu (2008) studies the 2006 reform that eliminated a lock-in interest rate option for federal student loans in a model in which individuals face earnings and interest rate risks. Ionescu (2009) further quantifies the effects of flexible repayment options and relaxed eligibility for student loans on college enrollment, borrowing, and default rates. Our model is built on the recent paper by Abbott et al. (2019), which examines the effects of government grants and loans on college degree attainment, welfare, and the aggregate economy. However, we extend their model with a delinquency choice for student debt and focus on the dynamics of student debt rather than on educational policies.

Central to our analysis is the interaction among college attainment, parental transfers, and borrowing. A large body of literature discusses the role of credit constraints and family income in education decisions, including Belley and Lochner (2007), Hai and Heckman (2017), Keane and Wolpin (2001), Chetty et al. (2017), and Carneiro and Heckman (2002). For example, using the NLSY79, Keane and Wolpin (2001) and Carneiro and Heckman (2002) find that family income has a small effect on college attendance during the early 1980s. Consistent with this, our calibrated economy implies that few individuals are credit constrained for their college education, especially in 1979.

Another important component of student loans, especially in recent periods, is the private lending market. Ionescu and Simpson (2016) and Lochner and Monge-Naranjo (2011) explore the interaction between the private lending market and government student loans. Despite the recent importance, our work is agnostic about the role of private loans in the dynamics of student debt. This is because private loans account for only a relatively small fraction ($6-7\%$) of the total outstanding student debt.[7] In addition, the private lending market operates in a starkly different way from government loans, which is hard to introduce into the model. For example, in the private market, the terms, eligibility, and interest rates of loans depend on borrowers' default risk.

The interaction between student loans and labor market outcomes is essential for determining college graduates' repayment behavior with regard to student debt. Papers that examine the implications of student debt for job search and labor market outcomes include Ji (2021), Luo and Mongey (2019), Weidner (2016), and Rothstein and Rouse (2011). Interestingly, Ji (2021) finds that indebted agents spend less time on job search and end up with lower-paid jobs, while Luo and Mongey (2019) and Rothstein and Rouse (2011) find that college graduates with high student debt are likely to accept jobs with higher wages but lower job satisfaction. Although our model allows for an endogenous labor supply that depends on age, education, and student debt balances,

[7] See Figures D2 and D3 in Appendix D.

given the complexity of the current model, we do not explicitly account for how student debt affects heterogeneous labor market outcomes among college-educated individuals.

3 Model

3.1 Overview

The life-cycle of individuals consists of three stages: college education, work, and retirement. At age $j = 1$, an individual with different ability $\theta \sim \Theta(\theta)$ and parental transfers $a_0 \sim A(\theta, \xi_a)$ makes a college education decision. For parental transfers, we assume the following log-linear relationship to capture its positive correlation with ability in the data:

$$\log a_0 = \psi_0 + \psi_1 \log \theta + \psi_2 \xi_a, \quad \xi_a \sim N(0,1), \tag{1}$$

where ξ_a is a stochastic component that follows a standard normal distribution.[8] Parental transfers are paid only once at the initial age for individuals who do not attend college, while those who enroll in college receive a fixed amount a_0 every period until graduation.[9]

College education takes four years and lasts until age $J_c = 4$.[10] In each period, an enrolled college student has to pay net tuition and fees and devotes a fixed fraction of time $\bar{t}$ to studying. A college education can be financed through three different sources: parental transfers a_0, labor supply n, and government student loans b. There is no idiosyncratic risk during college, and thus no endogenous dropout. However, college graduates randomly lose their skills with a probability of ϕ_d before they enter the labor

[8]Without a random component, there is a perfect correlation between ability and parental transfers. As a result, in contrast to the data, we do not include individuals with low (high) ability and high (low) parental transfers in the model. A random component is introduced to overcome this issue and allow more heterogeneity across individuals.

[9]Thus, college students receive a larger amount of parental transfers in total than those who do not attend college.

[10]For simplicity, we only study undergraduate students in the model. Student debt issued for graduate school accounts for a small fraction of the total debt in the U.S. For example, as shown in Figure D4, the fraction of the total federal student loans attributable to graduate study has been decreasing since 1980, and graduate students only represent 10% of the total federal loan borrowers.

market. This is to capture the relatively high college drop-out rate in the U.S.

After college, an individual enters the labor market with one of the two distinct skill levels $e \in \{l, h\}$. A fraction $1 - \phi_d$ of college graduates become skilled workers $(e = h)$, while those who lose their skills after graduation or do not attend college enter the labor market as unskilled workers $(e = l)$. Skilled workers earn a higher hourly wage w_t^h than that earned by unskilled workers w^l.[11] Thus, the time-varying college wage premium is $w_t^c = \frac{w_t^h}{w^l}$. Skilled workers also receive higher labor market experience premia $l^h(j)$ over their working lives than unskilled workers $l^l(j)$. Finally, workers face idiosyncratic wage shocks $\varepsilon \sim Q_t(\varepsilon)$ every period.

Student debt is a non-dischargeable long-term debt in the U.S. Individuals need to make a total number of n_T repayments, following a fixed repayment schedule, to pay off their student debt. Each period, workers with existing student debt can be delinquent in their payments. However, those who delay their payments face a utility cost of delinquency χ_d. The remaining student debt after the delinquency choice accumulates interest r_b.

After retirement, individuals receive Social Security benefits $s_t^e(\theta, \varepsilon)$.[12] Retirees do not have the option to be delinquent and must pay off any remaining student debt following a fixed repayment schedule. All individuals retire at age $j = J_r$ and survive until age $j = J$.

3.2 College education

College education involves three types of costs. First, an individual has to pay yearly net tuition and fees:

$$\phi_t(\theta, a_0) = g_t^\phi(\phi_0 + \phi_1 log\theta + \phi_2 a_0), \text{ where } g_0^\phi = 1, \tag{2}$$

[11]We normalize the hourly wage for unskilled workers to 1 in the model.

[12]This is time-varying as it is paid proportional to the wages that vary over time.

which is assumed to be a function of ability and parental transfers to be consistent with the heterogeneous education costs seen in the data.[13,14] Here, g_t^{ϕ} represents the growth rate of the education costs over time, with $g_0^{\phi} = 1$ at a steady state. Second, for every period, a college student needs to devote a fixed fraction of time $\bar{t}$ to studying, decreasing the total time endowment available for the labor supply during college education. Lastly, an individual who pursues a college degree faces a psychic education cost $\chi_{c,t}(\theta, a_0, \xi_\chi)$ that depends on its ability, parental transfer, and idiosyncratic preference shock ξ_χ, which is drawn from a standard normal distribution:

$$log\chi_{c,t} = (\chi_0 + \chi_1 log\theta + \chi_2 log a_0 + \chi_3 \xi_\chi) - \Delta_t, \text{ where } \xi_\chi \sim N(0,1) \text{ and } \Delta_0 = 0. \quad (3)$$

This psychic cost of college education is essential to replicate the observed distribution of college completion rates (see Abbott et al. (2019), Cunha, Heckman and Navarro (2004), and Heckman, Lochner and Todd (2006)). In addition, to reproduce the empirically consistent increase in college completion rates in the U.S., we assume that the preference for college education becomes stronger over time, $\Delta_t = \varrho t > 0$.

A college student can finance its education through three different sources: parental transfers a_0, earnings from labor supply n, and government-subsidized student loans b.[15] Here, $b > 0$ is the cumulative student debt for the entire education period, and a college student chooses this debt amount in its first year of college. Under the Federal Student Loans Program (FLSP) in the U.S., students can borrow up to the cost of attendance (COA) minus the expected family contribution (EFC). To be consistent with this, the annualized borrowing amount $\frac{b}{J_c}$ cannot exceed a $\nu < 1$ fraction of the yearly tuition

[13]In the NLSY97, the net education cost, measured as the total educational expenses paid minus grants and scholarships, is higher for wealthy or high-ability individuals than for wealth-poor or low-ability individuals. This reflects the fact that high-ability individuals and those from rich families are more likely to attend a top-quality college that charges higher tuition.

[14]For simplicity, we do not explicitly model differences in the quality of schooling. As a result, tuition is independent of the quality of education. However, by assuming tuition and earnings as a function of ability, we implicitly allow high-ability individuals who pay higher tuition for better education to earn more.

[15]In the data, we measure student loans using both subsidized and unsubsidized federal loans. In contrast, in the model, for simplicity, we assume that all loans are subsidized, as in Ionescu (2009). Except for the fact that the interest for subsidized loans is waived during college, there is little difference between the two types of loans.

$\phi_t(\theta, a_0)$. Furthermore, the total amount borrowed cannot exceed the exogenous student loan limit $\underline{b}$ set by the government.[16] Finally, there is a marginal cost of borrowing student loans that follows a uniform distribution, $\xi_b \sim U(\underline{\xi_b}, \overline{\xi_b})$.

Without the stochastic components of the psychic cost of education and the marginal cost of borrowing, we do not have enough heterogeneity across individuals at the initial age. This makes the adjustment over the transition less smooth. If we instead assume a utility cost of borrowing, given the decreasing marginal utility in wealth, it disproportionately discourages high-ability individuals from borrowing relative to low-ability individuals. This makes the model inconsistent with the increasing amount of borrowing with ability in the data (see Figure 8). For ease of notation, we omit the time subscripts below.

Given the initial heterogeneities, the optimal college education decision at the beginning of life is

$$e(\theta, a_0, \xi_\chi, \xi_b) = \begin{cases} h & \text{if } V_1^h(\theta, a_0, \xi_b) - \chi_c(\theta, a_0, \xi_\chi) \geq EV_1^l(\theta, a_0, \varepsilon') \\ l & \text{otherwise,} \end{cases}$$

where $V_1^h - \chi_c$ is the value of an individual going to college, while $EV_1^l(\theta, a_0, \varepsilon')$ is the expected value of an individual entering the labor force as a high school graduate. Below, we explain the optimization problem of a college student in each school year in detail.

[16] Note that students cannot borrow to consume.

3.2.1 Freshmen

The optimization problem of the first-year college student is

$$V_1^h(\theta, a_0, \xi_b) = \max_{c,n,b} u(c,n) + \beta V_2^h(\theta, a_0, b, \xi_b) \tag{4}$$

$$\text{s.t. } c = a_0 + \pi w^l \kappa_{j=1}^h(\theta, \varepsilon = 0)n - \phi(\theta, a_0) + \frac{b}{J_c} - \xi_b b$$

$$0 \leq \frac{b}{J_c} \leq \min\{\nu\phi(\theta, a_0), \underline{b}\}$$

$$c \geq 0, \quad n \in (0, 1 - \bar{t}].$$

Here, $\pi < 1$ is a discounting factor for labor income during college, which is calibrated to match the average earnings during college. College students earn an unskilled hourly wage w^l times efficiency units of labor,

$$log\kappa_j^e(\theta, \varepsilon) = p^e log\theta + l^e(j) + \varepsilon, \tag{5}$$

that is determined by the skill-specific labor market experience premium, ability, and idiosyncratic income shock.[17] Note that the optimization problems of sophomores and juniors are the same as that for freshmen, except that b is not a choice variable.

3.2.2 Seniors

The optimization problem of a senior is

$$\begin{aligned} V_{J_c}^h(\theta, a_0, b, \xi_b) &= \max_{c,n,a'} u(c,n) \\ &+ \beta\Big[\phi_d EV_{J_c+1}^l(i=0, \theta, a', b, \varepsilon') + (1-\phi_d)EV_{J_c+1}^h(i=0, \theta, a', b, \varepsilon')\Big] \end{aligned} \tag{6}$$

[17] We assume that work experience in college does not increase the labor market experience premium, $l^h(1)$. However, the number of years in college is counted as labor market experience once students graduate. In this way, we can use age as a proxy for a worker's labor market experience regardless of education level.

$$\text{s.t. } c + a' = a_0 + \pi w^l \kappa^h_{j=1}(\theta, \varepsilon = 0)n - \phi(\theta, a_0) + \frac{b}{J_c} - \xi_b b$$

$$a' \geq 0, \quad c \geq 0, \quad n \in (0, 1 - \bar{t}],$$

where ϕ_d is the exogenous probability of losing skills after graduation. When college graduates lose their skills, they enter the labor market as unskilled workers, but still carry the accumulated student debt for college education. Here, i represents the number of repayments made for student debt. For example, if $i = 0$, an individual has not begun repaying their outstanding student debt. Finally, college seniors can save in financial assets a.[18]

3.3 Long-term student debt, delinquency choice, and workers

In the United States, a student loan is a non-dischargeable long-term debt.[19] Thus, individuals must make a total number of n_T repayments, following a fixed repayment schedule, to pay off their debt. Following this, in the model, individuals have to pay

$$\lambda_i = \frac{1}{n_T - i}, \quad i = 1, \ldots, n_T$$

fraction of existing debt in every repayment period.[20] Note that the values of λ_i increase with the number of repayments to guarantee a similar amount of repayment for every repayment period.[21]

[18]Individuals who do not attend college can save parental transfers in financial assets at the initial age. Unless the same thing is allowed, individuals with greater parental transfers may counterfactually prefer not to attend college. To avoid this, we allow senior students to save in financial assets.

[19]Under Chapters 7 and 13 bankruptcies in the U.S., a student loan is non-dischargeable. A student debt holder is considered to be in default once the payment is overdue for more than 270 days. In default, the line of credit is shut down, and the default status is reported to credit bureaus. Government agencies that guarantee student loans make a repayment plan, including penalties for the defaulter, such as wage garnishment and seized federal tax refunds. Including all these penalties, the level of debt under the new repayment plan can be as high as 125% of the original principal (see Ionescu (2009)). If a debtor cannot pay off all their student debt after 25 years of repayments, the remaining debt can be forgiven only if the debtor has a very low income.

[20]In the U.S., borrowers are required to start repaying their student debt 6 months after graduating or dropping out of college.

[21]Without interest accumulation, these λ_i values ensure the same repayment amount every repayment period.

As previously stated, for every period, workers with student debt choose whether to be delinquent on the payments that are due. Thus, the discrete choice problem of a worker is

$$V_j^e(i,\theta,a,b,\varepsilon) = \max\left\{V_j^{e,p}(i,\theta,a,b,\varepsilon),\ V_j^{e,np}(i,\theta,a,b,\varepsilon)\right\},$$

where $V_j^{e,p}$ is the value of repaying the balance that is due during this period, while $V_j^{e,np}$ is the value of delaying the payment.

To be specific, the optimization problem of an individual who decides to repay is

$$V_j^{e,p}(i,\theta,a,b,\varepsilon) = \max_{c,n,a'} u(c,n) + \beta E V_{j+1}^e(i+1,\theta,a',b',\varepsilon') \tag{7}$$

$$\begin{aligned} \text{s.t.} \quad c + a' &= (1+r)a + w^e \kappa_j^e(\theta,\varepsilon)n - \lambda_i b \\ b' &= (1+r_b)(1-\lambda_i)b \\ a' \geq 0, \quad c &\geq 0, \quad n \in (0,1]. \end{aligned}$$

As this individual makes a repayment in this period, the total number of repayments made increases to $i+1$ for the next period. In addition, the interest accrues on the remaining balance of the student debt after repayment.[22]

The optimization problem of an individual who decides to be delinquent is

$$V_j^{e,np}(i,\theta,a,b,\varepsilon) = \max_{c,n,a'} u(c,n) - \chi_d + \beta E V_{j+1}^e(i,\theta,a',b',\varepsilon') \tag{8}$$

$$\begin{aligned} \text{s.t.} \quad c + a' &= (1+r)a + w^e \kappa_j^e(\theta,\varepsilon)n \\ b' &= (1+r_b)b \\ a' \geq 0, \quad c &\geq 0, \quad n \in (0,1]. \end{aligned}$$

[22]In Appendix C, we introduced wage garnishment when borrowers are delinquent on their payments.

Note that a worker who does not attend college ($e = l$) solves the same problem as equation (7), with $b = 0$ and $i = 0$.[23]

3.4 Retirees

After retirement, individuals receive Social Security benefits $s^e(\theta, \varepsilon)$, proportional to their labor income at their last working age and education level. Retirees do not have the option to be delinquent and must pay their remaining debt according to the repayment schedule. To summarize, the optimization problem of a retiree is

$$V_j^e(i, \theta, a, b, \varepsilon) = \max_{c, a'} u(c, 0) + \beta V_{j+1}^e(i+1, \theta, a', b', \varepsilon) \tag{9}$$

$$\text{s.t.} \quad c + a' = (1+r)a + s^e(\theta, \varepsilon) - \lambda_i b$$

$$b' = (1 + r_b)(1 - \lambda_i)b$$

$$a' \geq 0, \quad c \geq 0.$$

4 Taking the model to the data

In this section, we show how we discipline our model using the data. First, we explain how we estimate the time-varying wage processes and education costs that are used as inputs for transitional dynamics. We also show how we estimate the distribution of ability and the gradient of ability on earnings. Finally, we discuss the calibration strategy.

[23]We assume that high school graduates and college dropouts face the same hourly wage w^l and labor market experience premia $l^l(j)$ during the working period.

4.1 Estimation

4.1.1 Time-varying wage processes

We estimate the wage process using the 1968–2017 PSID data.[24] The estimation procedure closely follows Kim (2022) and Heathcote, Storesletten and Violante (2010). We first run the following OLS regression to estimate time-varying college wage premia w_t^c and skill-varying labor market experience premia $l^e(j)$ over the sample period.[25]

$$\log w_{i,j,t,e} = \sum_{t=1}^{T} \beta_{t,0} D_t + \sum_{t=1}^{T} \beta_{t,1} D_t D_{h,t} + \sum_{e=l,h} \left(\beta_{e,2} D_{e,t} \iota_{i,j,t,e} + \beta_{e,3} D_{e,t} \iota_{i,j,t,e}^2 \right) + \widehat{r}_{i,j,t,e}$$

Here, $w_{i,j,t,e}$ represents the hourly wage of an individual i at age j with education level e in year t. $D_{e,t}$ are the education dummies that take the value of 1 if the education level is $e \in \{l, h\}$, with l representing the non-college educated and h representing the college-educated. We regress the log hourly wage on time dummies D_t, an interaction term with time dummies and college education dummy $D_{h,t}$, an interaction term with education and labor market experience ι, and an interaction term with education and experience-squared ι^2.[26]

The estimated college wage premia and skill-specific labor market experience premia are shown on the left and right, respectively, in Figure 2. First, the college wage premia have almost doubled, increasing from 1.25 in 1979 to 1.42 in 2015. This is the first time-varying input in the model. Second, the wage growth is much steeper for the college-educated than for the non-college educated. For example, 25 years of labor market experience more than doubles the hourly wage for college-educated workers (red dashed

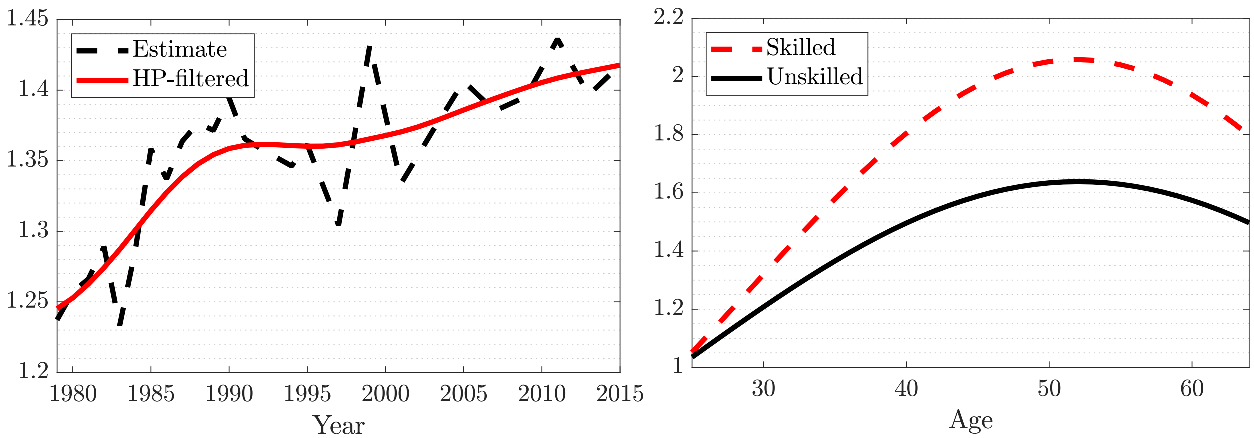
[24] We use survey data from 1968 to 2017, but estimate the variances of wage shocks only through 2015 because of the finite sample bias at the end of the sample period.

[25] As emphasized by Guvenen (2009), introducing heterogeneous income profiles (HIP) is important to capture realistic income inequality.

[26] The labor market experience ι is measured as the age minus years of schooling minus 6. In years missing the variable for years of schooling, we proxy years of schooling using the median of education brackets for individuals with less than a college degree. For example, if individuals responded that they finished grades 6–8, we approximate years of schooling for this individual as 7. For individuals with a college degree or more, we proxy their years of schooling as 16.

line), while it only increases by 50% for non-college educated workers relative to their initial levels (black solid line).

Figure 2: Estimated between-group wage dispersion



(a) College wage premia

(b) Labor market experience premia

Note: The left panel shows the estimated time-varying college wage premia, $w_t^c = exp(\beta_{t,1})$. The black dashed line is a raw estimate and the red solid line is an Hodrick-Prescott (HP) filtered series with a smoothing parameter of 100. The right panel shows the labor market experience premia, $l^e(j) = exp(\beta_{e,3}\iota + \beta_{e,4}\iota^2)$, for college graduates (red dashed line) and non-college graduates (black solid line).

Next, we estimate the time-varying wage shock process using the minimum distance method.[27] The regression residuals $\widehat{r}_{i,j,t,e}$ are assumed to be the sum of idiosyncratic wage shocks $\varepsilon_{i,j,t,e}$ and measurement error.[28] The idiosyncratic shocks consist of a persistent component η and a transitory component ε^v. Specifically,

$$\varepsilon_{i,j,t,e} = \eta_{i,j,t,e} + \varepsilon^v_{i,j,t,e}$$

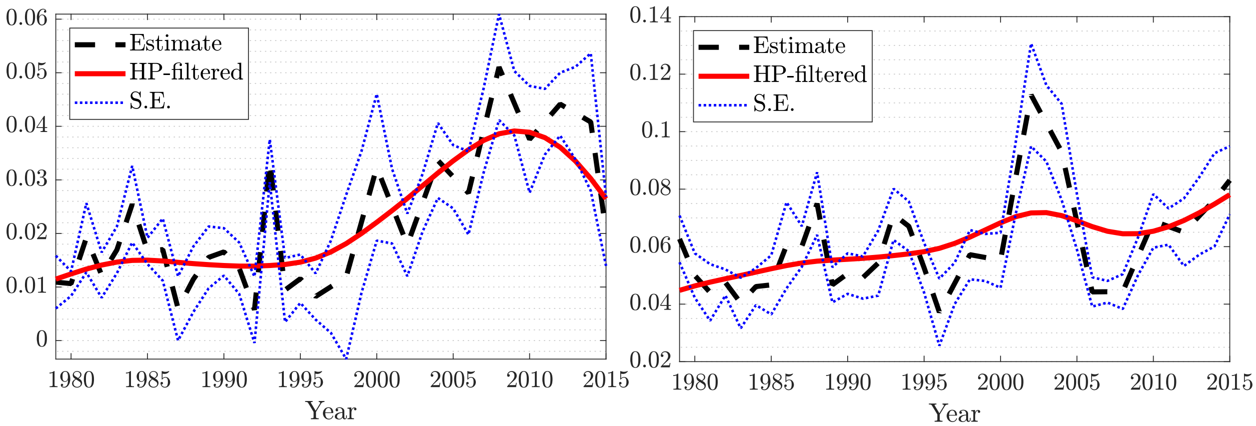
$$\eta_{i,j,t,e} = \rho\eta_{i,j-1,t-1,e} + \varepsilon^p_{i,j,t,e},$$

where $\varepsilon^p_{i,j,t,e} \sim N(0, \sigma^2_{pt})$ and $\varepsilon^v_{i,j,t,e} \sim N(0, \sigma^2_{vt})$. We estimate these year-varying variances of shock $\{\sigma^2_{pt}, \sigma^2_{vt}\}$ and the persistence of the shock $\{\rho\}$.

[27] See Appendix B for the details of the estimation.

[28] We use the estimate from French (2004) for the variance of a measurement error in log hourly wages of 0.02.

Figure 3: Variances of persistent and transitory shocks



(a) Persistent shock

(b) Transitory shock

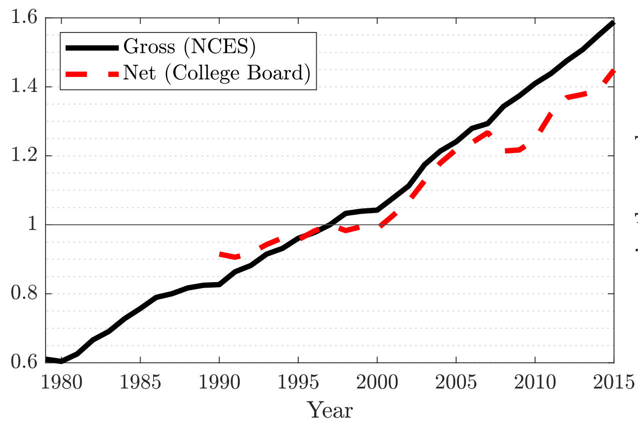
Note: Minimum distance estimates of the wage shocks. The black dashed lines are the estimates, and the red solid lines are the HP-filtered trends with a smoothing parameter of 100. The blue dotted lines are standard errors estimated using a block bootstrapping with 300 replications.

Figure 3 shows the estimated skill-varying variances of shocks, which is the second time-varying input in the model. It shows that there has been an increase in residual wage dispersion, reflecting the rising wage inequality in the U.S. For example, the variance of the persistent shock increases from 0.01 in 1979 to 0.03 in 2015, while that of the transitory shock rises from 0.045 to 0.08 over the same period. The estimated persistence of the shock is $\rho = 0.9792$.

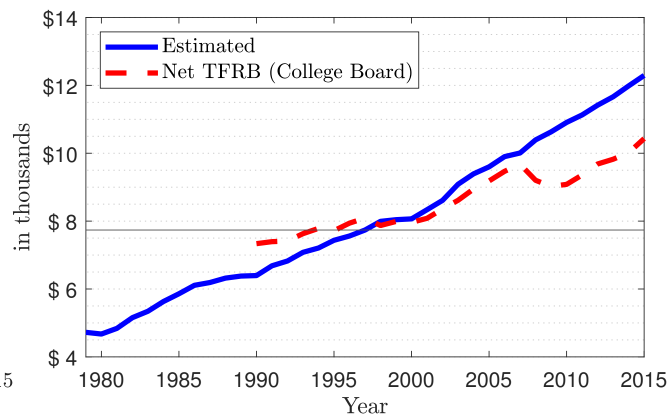
4.1.2 Education costs

Following Gordon and Hedlund (2020), we calculate the average yearly net college cost in the NLSY97. The NLSY97 provides education expenses financed by financial aid and loans from family and friends, federal and other student loans, work-study financial aid, employer assistance financial aid, other financial aid, and out-of-pocket spending. We do not include college costs financed by grants and scholarships to measure the net education cost. The NLSY97 cohort, on average, paid \$7,737 for each year of a college education.

Figure 4: Tuition and fees in the U.S.



(a) TFRB indices (base year = 1997)



(b) In 2004 U.S. dollars

Note: The gross TFRB data are from Table 330.10 in the 2017 NCES Digest of Education Statistics, while the net TFRB data are from the 2018 Trends in College Pricing published by the College Board. The data moment is the enrollment weighted average of 2-year public, 4-year public, and 4-year private non-profit institutions.

Figure 4 (a) shows gross and net TFRB indices, relative to the 1997 levels, between 1979 and 2015. To estimate changes in net college costs over this period, we multiply the average net college cost in the NLSY97 by the gross TFRB index in Figure 4 (a).[29] The estimated time-varying cost successfully reproduces the observed net TFRB in College Board for the available years, as shown in Figure 4 (b). Importantly, college costs have risen rapidly in the U.S., increasing from $\$4,723$ in 1979 to $\$12,000$ in 2015.

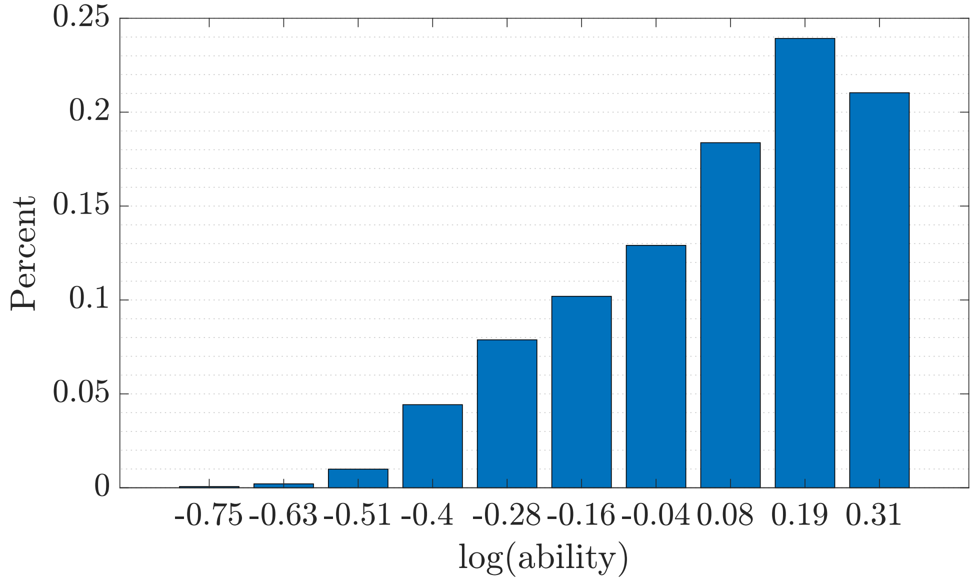
4.1.3 Ability distribution and ability gradient on earnings

We estimate the distribution of ability from the Armed Forces Qualification Test (AFQT) score in the NLSY79 (see Figure 5). Next, to estimate the gradient of ability on earnings p^e in equation (5), we regress the log hourly wages in the NLSY79 on the time dummies and logAFQT80 scores, controlling for the age effect using the labor experience premia $l^e(j)$ estimated from the PSID data.[30] Table 1 summarizes the estimated

[29]Because the net TFRB data are available only since 1990, we use the gross TFRB index instead of the net TFRB index. However, as shown in Figure 4 (a), the gross and net TFRB indices are similar.

[30]We use the PSID estimates to filter out age effects, as we do not have many individuals older than 57 in the NLSY79 sample.

Figure 5: Ability distribution



Note: This figure shows the probability distribution of $log(AFQT80) - E[log(AFQT80)]$ over 10 discretized points, where $E[log(AFQT80)]$ is the average of $log(AFQT80)$. The AFQT80 scores are from the NLSY79

results, which show that the effect of ability on earnings is almost two times higher for skilled workers than for unskilled workers.

Table 1: Estimated ability gradient on earnings

Education level	Gradient
College graduates	0.9724 (0.0929)
Less than college	0.5658 (0.0221)

Note: Standard errors are in parentheses.

4.2 Calibration

4.2.1 Parameters set externally

Demographics Assuming a model period of 1 year, we calibrate the model economy to the 1979 U.S. economy.[31] In the model, individuals begin their life at age 18 ($j = 1$), retire at age 65 ($J_r = 47$), and live until the age 85 ($J = 67$) with certainty.

Education and student loans During college education, individuals spend a fraction $\bar{t} = 0.25$ of their time studying (Abbott et al. (2019)). Individuals lose their skills acquired in college with the probability $\phi_d = 0.3$ at graduation.[32] Similar to the FSLP, we assume that the fixed loan payment period is $n_T = 13$ years. The interest rate for federal student loans is determined by the risk-free interest rate plus 3.1%. We choose a risk-free interest rate r as 3.0%, such that r_b becomes 6.1%, similar to the historical average of federal student loan rates.[33] The borrowing limit $\underline{b}$ is chosen to match the cumulative student loan limit of \$23,000 for the four years of college education in 2004 U.S. dollars.[34] Lastly, using the ratio of the average family contribution to the college expense in the NLSY97, we set $\nu = 0.7$.

Preferences Individuals face a standard separable utility

$$u(c,n) = \frac{c^{1-\sigma}}{1-\sigma} - (\psi + \psi_c \mathbf{1}_{j \leq J_c,\, e=h}) \frac{n^{1+\eta}}{1+\eta} \tag{10}$$

with the coefficient of relative risk aversion σ set to 2. η is chosen to match the Frisch elasticity of labor supply for male, and there is an additional disutility of work during college ψ_c.

[31] We choose 1979 as a benchmark year such that individuals who are 18 years old in 1979 reach their 50s by the end of the transition period. If we choose 1997 instead as a benchmark year, another available cohort for the NLSY data, an individual who enters college in 1997 only turns 30 in 2015.

[32] We measure the college drop-out rate as one minus the graduation rate among college-enrolled students.

[33] The loan rate is the same for both subsidized and unsubsidized loans. In 1992, the FSLP introduced a variable interest rate. In 2006, a fixed rate of 6.8% was introduced but reverted to a variable rate in 2013. During the variable-rate period, the loan rate ranged between 4% and 8%. Note that in the model with a fixed risk-free rate, there is no distinction between fixed and variable interest rates.

[34] This limit applies to the sum of subsidized and unsubsidized loans.

Social security payments Following Kim (2022), social security is paid proportional to the productivity shock in the last working age ε.[35] Specifically, the social security payment function is

$$s_t^e(\theta, \varepsilon) = \delta_s w_t^e \frac{\sum_{j=1}^{J_r-1} \kappa_j^e(\theta, \varepsilon)}{Jr - 1} \overline{n} \tag{11}$$

with a replacement rate $\delta_s = 0.4$ and the average hours worked in the economy $\overline{n} = 0.3$. Table 2 below summarizes the parameters set externally.

Table 2: Parameters set externally

Parameters	Description	Value
$\bar{t}$	A fixed fraction of time for studying (Abbott et al. (2018))	0.25
ϕ_d	College drop-out rate (OECD)	0.3
n_T	Student loan payment periods (FSLP)	13
σ	CRRA parameter	2.0
r	Risk-free interest rate	0.03
r_b	Student loan rate (FSLP)	0.061
$\underline{b}$	Student loan limit in 2004 dollars (FSLP)	\$23,000
$1 - \nu$	Average Expected Family Contribution (NLSY97)	0.3
δ_s	Replacement rate for social security benefits	0.4
η	Frisch elasticity of male labor supply	0.50

4.2.2 Parameters set internally

Table 3 summarizes the parameters and moments calibrated inside the model. First, the time discount factor β is calibrated to match the capital-to-output ratio. ψ and ψ_c are calibrated to match the average hours worked for males between the ages of 25 and 65 and the average hours worked during college, respectively. We also reproduce the average yearly earnings of \$8,936 during college which is close to \$8,377 in the NLSY79. Second, we match the observed college attainment rates over ability terciles and parental transfer quartiles.[36] In the aggregate, 16% of the population has a college degree. Next,

[35] In the U.S., social security benefits are paid based on the average of the highest 35 years of earning. In the model, calculating average earnings requires one more state variable, making computation more challenging. Given that the wage shock is highly persistent, we assume that social security is paid proportional to the wage shock in the last working age.

[36] Unlike the NLSY97, the NLSY79 does not have parental transfer information. Thus, in the NLSY79, we proxy parental transfers using family income.

we target the average parental transfers of $4,720 and the average annual college cost of $4,723 in 2004 U.S. dollars, which is estimated in Section 4.1.2. Given these, 29% of undergraduate students graduate with student debt in the model, compared to $20-30\%$ in the data.

The calibrated economy generates an annual delinquency rate of 11%, which is measured as the fraction of borrowers who are delinquent on their payments. Similarly, using American Bankers Association data, Volkwein et al. (1998) estimate the annual delinquency rates of student loan borrowers to be around 17–21% in the 1980s and early 1990s. Finally, we target the total outstanding student debt to the GDP, which amounts to $45 billion in 2004 U.S. dollars.[37]

Table 3: Parameters set internally

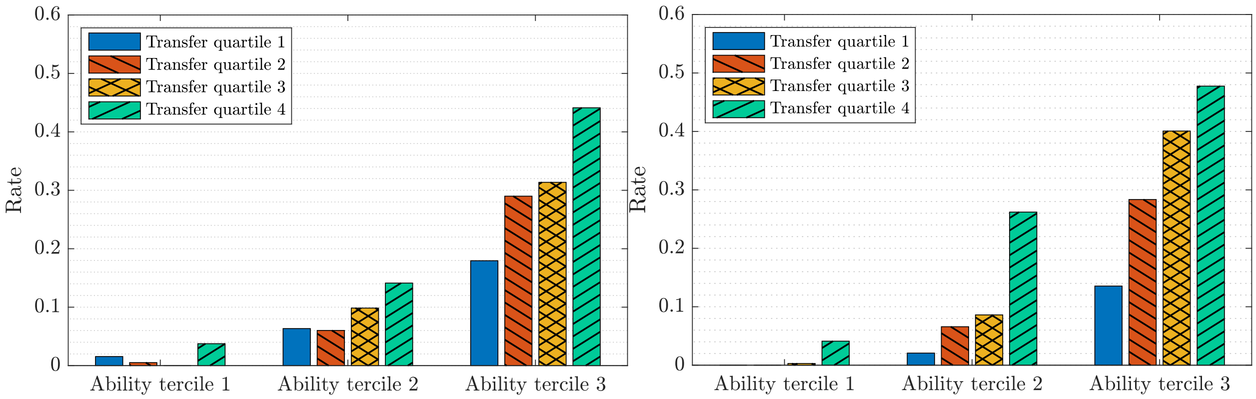
	Values	Moment	Data	Model
β	0.95	Capital to output ratio	3.20	3.17
ψ	70	Average hours worked of male	0.30	0.31
ψ_c	480	Average hours worked during college	0.19	0.23
ψ_0	-2.64	College completion rate 1T	0.01	0.01
ψ_1	0.22	College completion rate 2T	0.09	0.12
ψ_2	0.23	College completion rate 3T	0.34	0.34
ϕ_0	-1.57	College completion rate 1Q	0.05	0.04
ϕ_1	0.50	College completion rate 2Q	0.11	0.11
ϕ_2	1.10	College completion rate 3Q	0.16	0.18
χ_0	3.00	College completion rate 4Q	0.27	0.29
χ_1	-29.8	Aggregate college completion rate (%)	15	16
χ_2	-12.1	Average annual parental transfers ($)	4,720	4,776
χ_3	8.70	Average annual education cost (Figure 4) ($)	4,723	4,827
χ_d	0.07	Delinquency rate (%)	17 - 21	11
$\overline{\xi}_b$	0.25	Total outstanding student debt to GDP (Figure 1)	0.0092	0.0081
$\underline{\xi}_b$	0.22	Fraction of undergraduates borrowing '93 (%)	20 - 30	29
π	0.47	Average earnings during college ($)	8,377	8,936

Note: The college completion rates are across ability terciles (T) and parental transfer quartiles (Q). The average annual parental transfers are from the NLSY97. The delinquency rate is from Volkwein et al. (1998). The fraction of undergraduates borrowing is from Cuccaro-Alamin and Choy (1998). The college completion rates, average hours worked, and average earnings during college are from the NLSY79.

[37] For student debt, data availability is limited. As in Looney and Yannelis (2015), the earliest data for the total outstanding student debt go back to 1985, and thus, we use their 1985 value for the calibration.

Figure 6 further compares the college completion rates by ability terciles and parental transfer quartiles in the NLSY79 (left) to those in the model (right). Similar to Lochner and Monge-Naranjo (2011), the figure shows that the college completion rate is increasing in ability (parental transfers), conditional on parental transfers (ability).

Figure 6: College completion rates in 1979



(a) Data (b) Model

Note: The college completion rates over ability terciles and parental transfer quartiles, calculated from the NLSY79 (left) and the benchmark economy (right). In the NLSY79, we define a college completion rate as the percentage of individuals between the ages of 14 and 22 in 1979 who completed at least 16 years of education by 1988. We use family income as a proxy for parental transfers.

5 Quantitative results

This section presents quantitative results from transition dynamics with time-varying sources: college wage premia (Figure 2 (a)), variances of wage shock (Figures 3), and college costs (Figure 4).[38] In addition, as mentioned in Section 3.2, we calibrate ϱ in

$$\Delta_t = \varrho t \tag{12}$$

[38] We used HP-filtered series for college wage premia and wage shock variances.

to match the observed rising college completion rate in the U.S. between 1979 and 2015 (see Figure 12 (a)).[39,40]

5.1 Comparison of the model to the data

Thus far, we have been agnostic about the model's performance on the distribution of college costs and students' borrowing amounts, which is essential for the model to be a valid framework for studying the dynamics of student debt. This is because, unlike the NLSY97 data, the NLSY79 data do not simultaneously provide information on student debt amounts, parental transfers, and college costs that are key to disciplining our model. To overcome this problem, in this section, we compare the model's simulated moments in 1997 in the transition to data moments. Note that the model is calibrated for the steady state and that all the moments in the transition are not directly targeted.

The results in Table 4 show that the borrowing behavior of new college graduates in 1997 in the model is similar to that in the data, reproducing 58% of graduating seniors holding student debt and an average cumulative student debt of $10,507 upon graduation, compared to 60% and $11,348, respectively, in the data.

Table 4: Untargeted moments

Moment	Data	Transition (1997)
Graduating seniors with student debt (%)	60	58
Average cumulative student debt upon graduation	$11,348	$10,507

Note: The percentage of graduating seniors with student debt is obtained from the NPSAS and the average student debt upon graduation is obtained from the NLSY97.

In Figure 7, we also compare the distribution of the net college cost in the NLSY97 to that in the model across ability terciles (left) and parental transfer quartiles (right).[41] Importantly, in the data, the observed college expenses are higher for students in higher

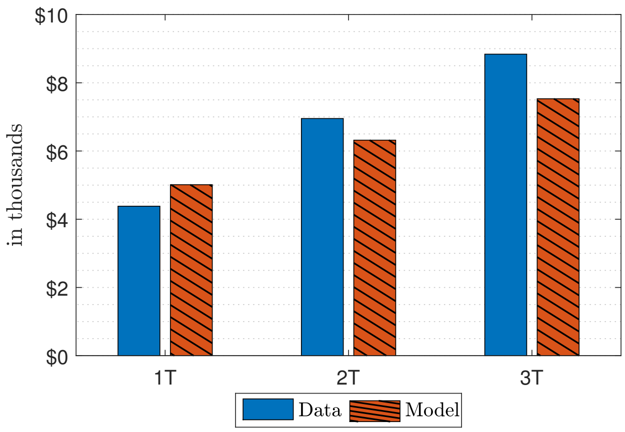
[39]Reproducing the observed changes in college choice is crucial for explaining the dynamics of student debt.

[40]Numerically, to ensure that the model converges to a new steady state, we solve transitional dynamics for 150 periods. We fix time-varying parameters to 2015 levels for periods after 2015.

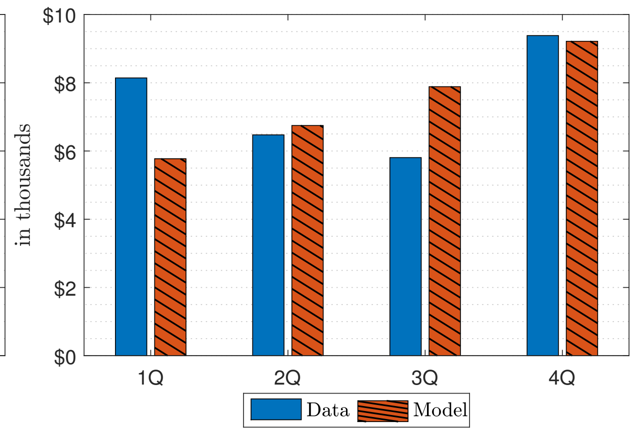
[41]Note that, in contrast to the NLSY79, parental transfer information is available in the NLSY97. See Appendix A for more details of how we calculate parental transfers in the NLSY97.

ability tercile group and the fourth parental transfer quartile group, reflecting heterogeneous costs of college education across individuals. Similarly, the model reproduces the distribution of college costs that increase with ability and parental transfers. This is driven by the fact that students with high ability or from rich families are more likely to attend a top-quality college that charges high tuition.

Figure 7: Distribution of net college costs in 1997



(a) over ability terciles



(b) over parental transfer quartiles

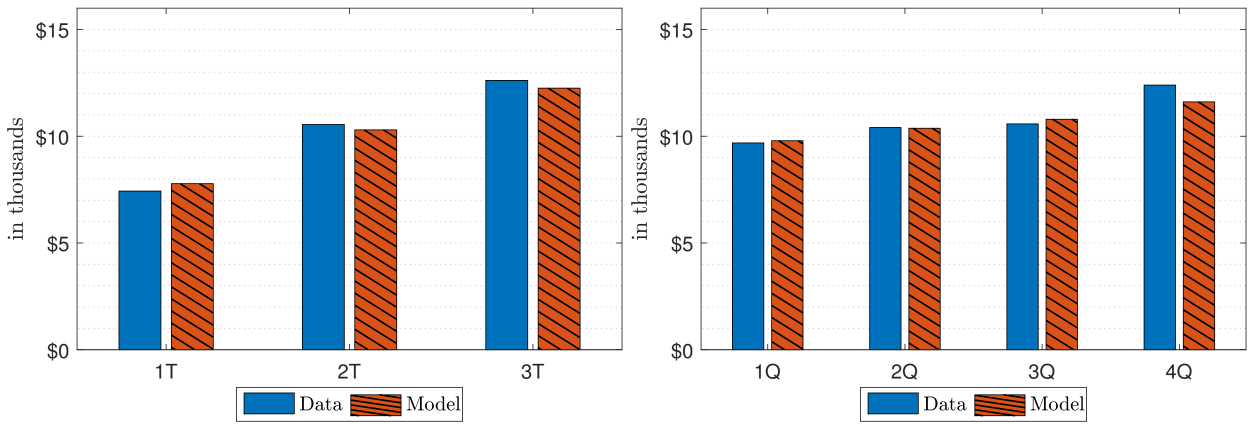
Figure 8 further exhibits the average cumulative student debt at graduation over ability terciles (left) and parental transfer quartiles (right).[42] In the NLSY97, a significant amount of student debt is held by individuals across all ability terciles and parental transfer quartiles. More importantly, the borrowing amount increases in student's ability and its parental transfer. Without targeting, the model successfully reproduces these facts.

5.2 Simulation

To show the implications of the model, we simulate the steady state and present the average net tuition, effective borrowing limit, and borrowing amount of college students

[42]The NLSY97 reports the amount of student loans that an individual takes for each institution and academic term. For each individual, we calculate the yearly average by summing all the student loans across terms, years, and institutions until graduation and divide it by the number of years the individual is enrolled full-time in college. To calculate the cumulative student debt at graduation, we multiply the yearly average of student loans by 4. See Appendix A for more details.

Figure 8: Distribution of student debt in 1997



(a) over ability terciles

(b) over parental transfer quartiles

over their initial abilities in Figure 9 (a). Bars show the fraction of college graduates at each ability level, circles indicate where each ability tercile group is divided, and purple dashed lines show each ability group's average earnings during college education.

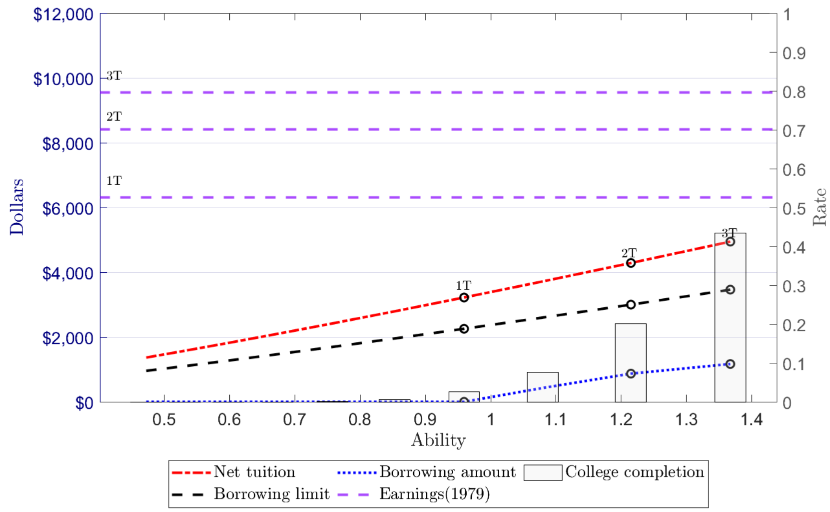
Given our baseline parametrization, Figure 9 (a) shows that for each ability group, the average earnings are much larger than their tuition. This suggests that in 1979, most college students, if they want to, could finance their college education through labor income and were not constrained for their college education (see Carneiro and Heckman (2002), Keane and Wolpin (2001), and Lochner and Monge-Naranjo (2011) etc). This also implies that low-ability students' decisions not to attend college were optimal, not because they were credit constrained for college investment.

Figure 9 (a) also shows that the borrowing amount increases with students' abilities. As ability is persistent through labor income, high-ability individuals wish to borrow more from future income. This is because they expect a higher lifetime income and wish to smooth out their consumption. As there is no other financial asset college students can use to borrow from the future, high-ability students use student loans as a means.

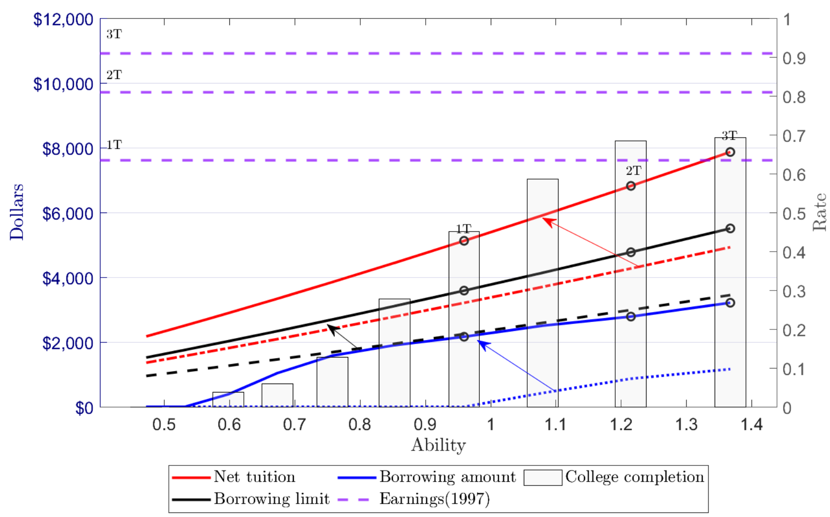
Figure 9 (b) shows how these implications change in 1997.[43] As tuition increases, so does the borrowing limit. As a result, a higher fraction of college students borrow from

[43] Note that this is not a steady-state comparison. We simulate the model over the transition and calculate the moments for the year in transition, which is equivalent to 1997.

Figure 9: Simulation over ability



(a) 1979 economy



(b) 1979 vs. 1997 economies

Note: This figure shows the simulated annualized moments over the initial ability for the year 1979 (top) and compares these moments with those for the year 1997 (bottom). The red dash-dot line in the top figure represents the average net tuition and fees for the year 1979; the black dashed line represents the effective borrowing limit for the year 1979, and the blue dotted line represents the borrowing amount for the year 1979. The solid lines in the bottom figure represent the corresponding moments for the year 1997. The white bars represent the college completion rates, and the black circles indicate where the ability tercile is divided. The left y-axis indicates the dollar values of moments, while the right y-axis indicates the college complication rates.

government student loans, and on average, they borrow a larger amount, compared to 1979. A stronger preference for college education encourages low-ability individuals to attend college, decreasing the average ability of college students.

Finally, although not shown in Figure 9, there is a 15 percentage points increase in the fraction of student borrowers who max out their government student loans between 1979 and 1997.[44] Note that students who max out government loans are not necessarily credit constrained for their schooling. As seen in the data, these are high-ability individuals who attend colleges with higher education costs and borrow from the high future income.[45]

The borrowing behavior of college students is less affected by parental wealth, as shown in Figure 10.[46] This is because the borrowing behavior is largely driven by the consumption smoothing motive rather than credit constraint for college investment.[47] Thus, with larger parental transfers, individuals reduce their labor supply instead of changing the borrowing amount to finance their college education.

5.3 Dynamics of student debt, college choice, and borrowing

In this section, we present the aggregate results from transitional dynamics. Figure 11 first shows the dynamics of the aggregate student debt in the benchmark economy (bars) and in data (line). Quantitatively, rising college costs, wage inequality, and delinquencies, in addition to a stronger preference for college education, increase the aggregate

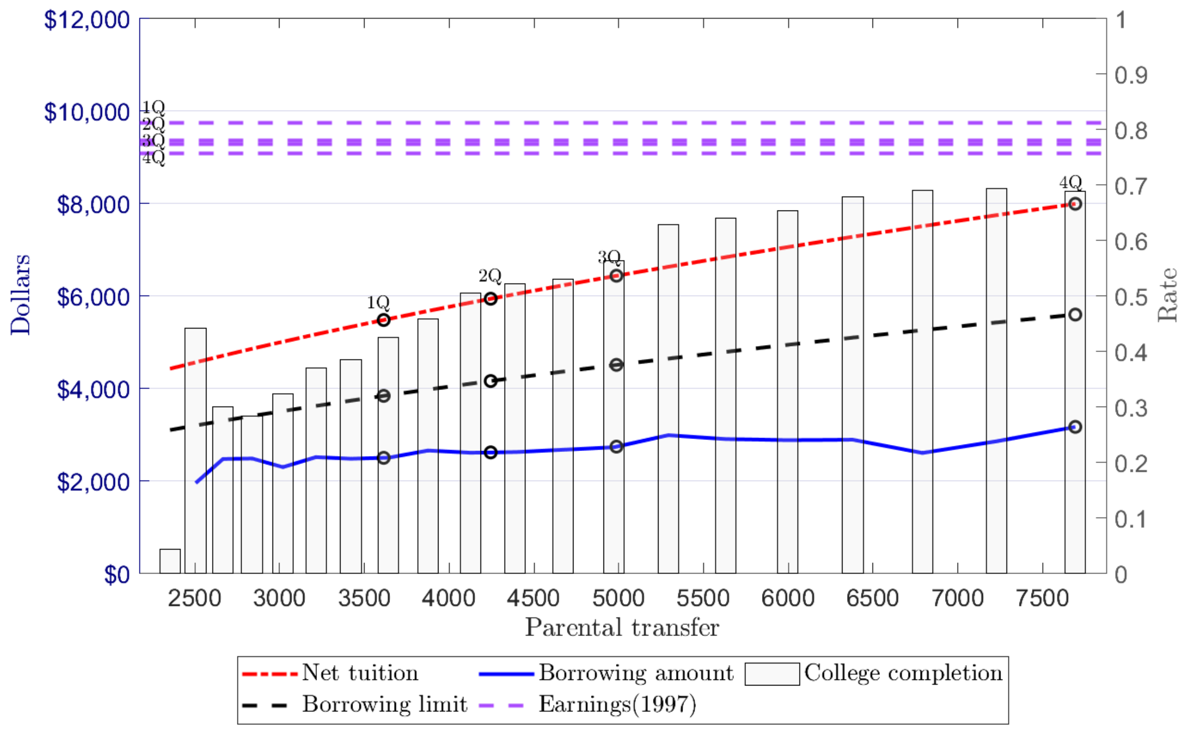
[44]Similarly, in the National Center for Education Statistics (NCES) data, the fraction of dependent student borrowers who max out their loans increased from 30% in 1989 to 50% in 1993 (Refer to Figure 6 in Trends in Undergraduate Borrowing: Federal Student Loans in 198990, 199293, and 19959). This may be why increasingly recent college students borrow from private lenders.

[45]Identifying whether individuals are credit-constrained for schooling in the data is not trivial. We can identify the effects of credit constraints on schooling when marginal students who did not go to college change their schooling decisions with better access to credit or larger parental transfers. In the model, when we relax the borrowing constraint allowing students to borrow up to the entire education cost ($\nu = 1.0$), the college completion rates rarely change from the benchmark economy ($\nu = 0.7$).

[46]See Figure D5 for the corresponding figure for the 1979 economy.

[47]The college enrollment rate is increasing in parental transfers because of a positive correlation between ability and parental wealth, not because individuals are credit constrained for their college investment.

Figure 10: Simulation over parental transfers

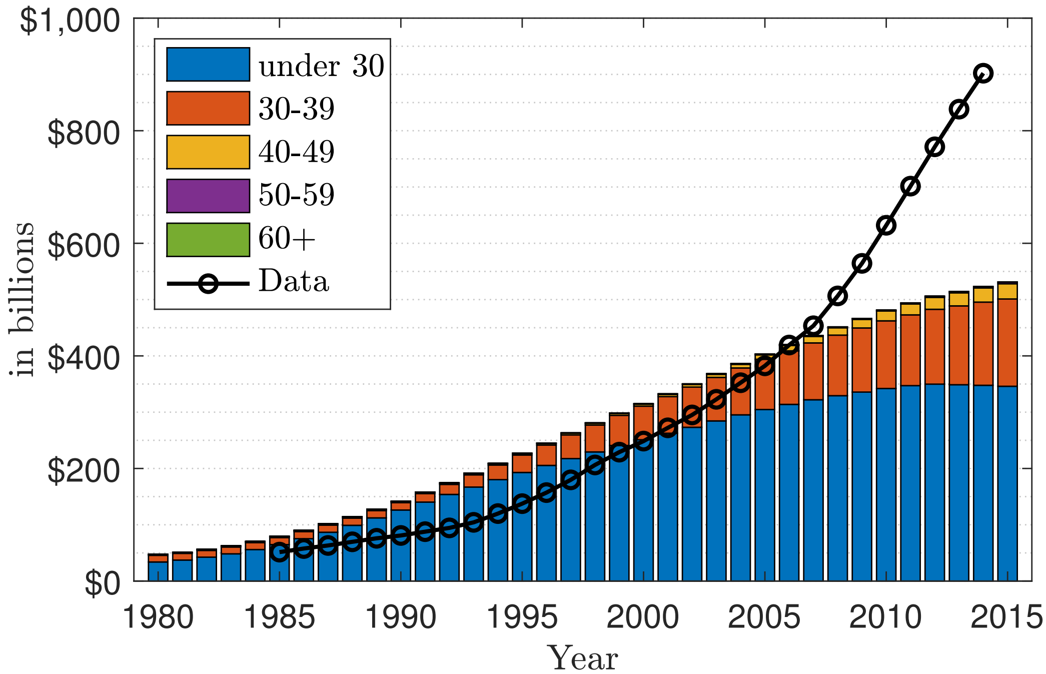


(a) 1997 economy

Note: This figure shows the 1997 simulated moments over parental transfers. The red dash-dot line represents the average net tuition and fees, the black dashed line represents the effective borrowing limit, and the blue line represents the borrowing amount. The white bars represent the college completion rates, and the black circled marks indicate where the parental transfer quartile is divided. The left y-axis indicates the dollar values of moments, while the right y-axis indicates the college complication rates.

student debt balance from $45 billion in 1979 to $525 billion in 2015. This is approximately 50% of the observed increase in student debt in the U.S. Notably, these sources explain much of the dynamics of student debt until 2007. However, the aggregate student debt balance in the model starts to deviate from that in the data after 2007. This suggests that some other factors, such as the Great Recession or the 2006 reform, affect the dynamics of the U.S. student debt since 2007.[48]

Figure 11: Dynamics of student debt



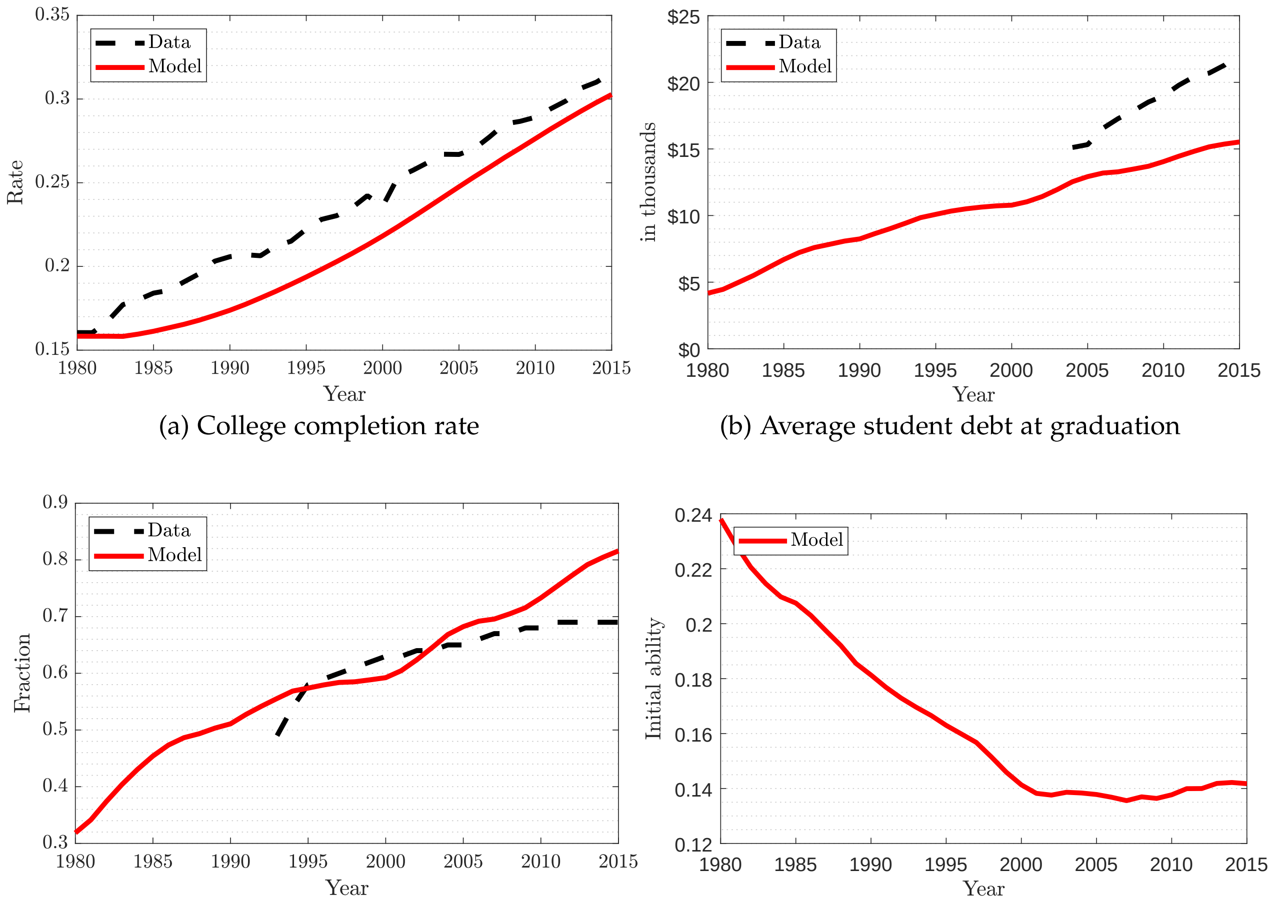
Note: In this figure, the dynamics of aggregate student debt over the transition (bars) are compared to those in the data (line).

Figure 12 further compares changes in the college completion rates, average cumulative student debt amounts at graduation, and fraction of graduating seniors with student debt in the model to those in the data. It also shows the average ability of college students in Figure 12 (d). As mentioned before, the time-varying college completion rate is reproduced by the decreasing psychic cost of education. It is noteworthy that, without targeting, the model is also broadly consistent with the increasing borrowing amount

[48]During the Great Recession, a number of individuals went back to college or graduate school. In addition, the adverse impact on the financial and labor markets increased the delinquency rates of student debt holders. Furthermore, in 2006, the Higher Education Reconciliation Act of 2005 removed the lock-in interest rate option for student debt and fixed the interest rate on student loans to 6.8%. As shown in Ionescu (2008), this reform has increased the overall delinquency rate of student debt holders.

by students and the fraction of students graduating with student debt.[49] Finally, an increasing preference for a college degree lowers the average ability of college students in the model. As we show in Section 5.5, this leads to a higher delinquency rate among borrowers.

Figure 12: Changes in college choice and borrowing behavior



(a) College completion rate

(b) Average student debt at graduation

(c) Fraction of graduating seniors with student debt

(d) Average initial ability

Source: The college completion rates are from the CPS and the NLSY79. The average student debt at graduation and the fraction of graduating seniors with student debt are from the National Postsecondary Student Aid Study (NPSAS).

[49]Note that, in 2008, the student loan limit increased to $31,000, which is omitted from the model. This may explain the gap in the borrowing amount between the model and the data in Figure 12 (b).

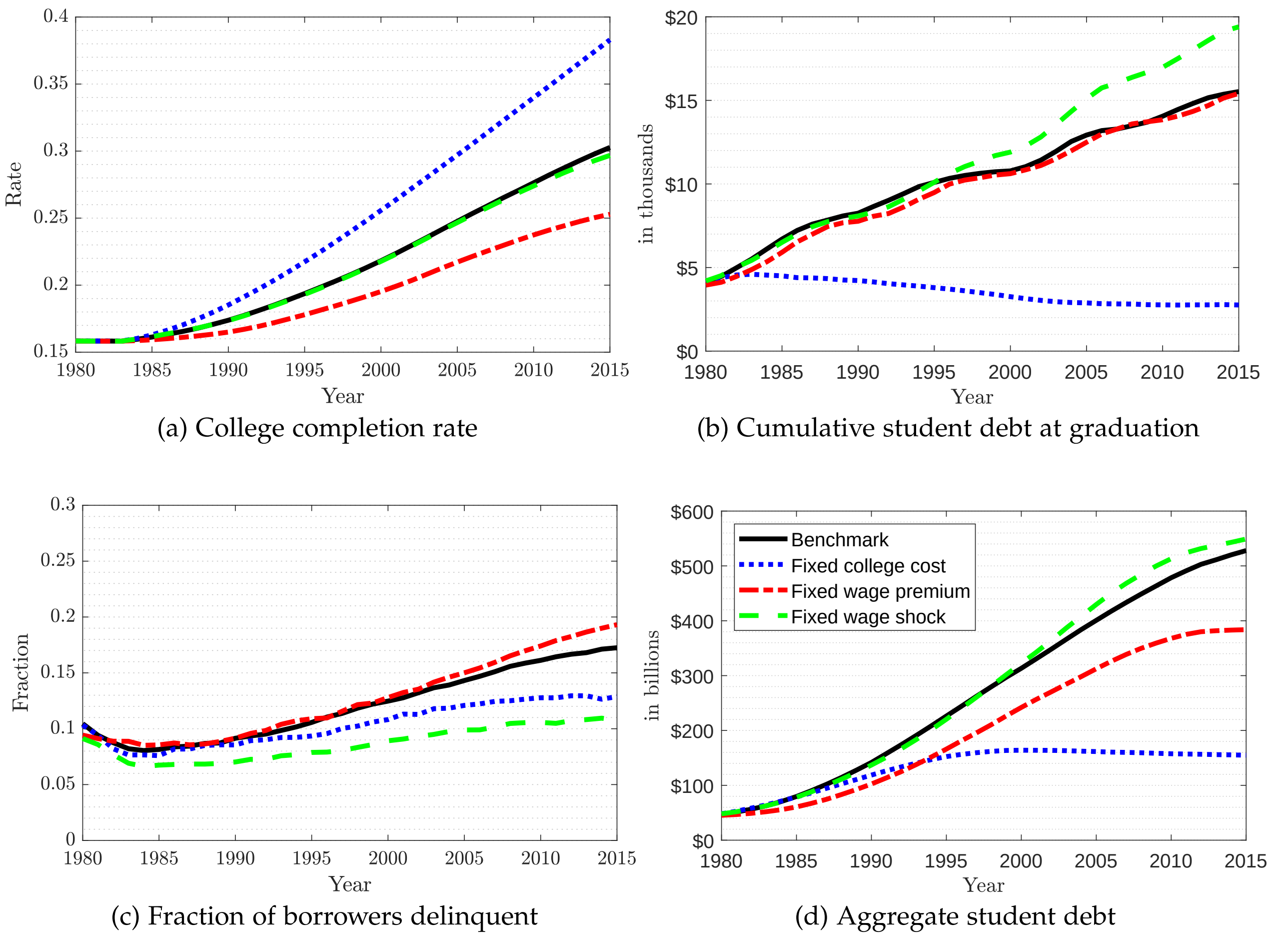
5.4 Decomposition exercise

In this section, we examine how each time-varying source affects the results by conducting counter-factual experiments in which we remove one of the time-varying components each time. We show the dynamics of college completion rates, the average cumulative student debt amounts at graduation, delinquency rates, and the aggregate student debt in Figure 13. We further summarize these changes over the transition in the benchmark and counter-factual economies in Table 5.

First, without rising college costs, the college completion rate further increases to 38%. However, students borrow less from government loans compared to the benchmark economy. The fraction of borrowers delinquent decreases by 5 percentage points as individuals carry a moderate amount of student debt over their lifetime. In net, the aggregate student debt increases by only $105 billion, despite a larger fraction of people with a college degree. Second, as expected, the increasing college wage premia is important for explaining the rising college completion rate in the model. Without it, the college completion rate only increases by two-thirds of the rise in the benchmark economy. However, the mitigated increase in college wage premia barely affects the borrowing amount by students and delinquency rates in the economy. The aggregate student debt still increases significantly by $335 billion, due to the increased college attendance costs. These results imply that the increasing college costs plays an important role in the growth of student debt in the U.S., as it determines the borrowing behavior of college students. However, as we show in Section 5.5, if individuals pay off their debt without being delinquent, the aggregate student debt increases by only half of the growth in the benchmark economy, even with all the time-varying sources.

Although the time-varying wage shock process barely affects college choice, students borrow more from government loans and borrowers are less likely to be delinquent on their payments when variances of wage shocks, especially persistent components, do not rise. This is because a more volatile wage shock process implies a higher probability of a persistent negative wage shock. When such a shock is realized, individuals have a hard time paying off their student debt as planned.

Figure 13: Decomposition exercises



(a) College completion rate

(b) Cumulative student debt at graduation

(c) Fraction of borrowers delinquent

(d) Aggregate student debt

Note: The black solid line is the benchmark economy. The blue dotted line is the economy without time-varying college costs. The red dashed line is the economy without time-varying college wage premia. The green dash-dot line is the economy without the time-varying wage shock process.

Table 5: Changes over the transition

1979–2015	Δ (a)	Δ (b)	Δ (c)	Δ (d)
Benchmark	+14%	+11.6K	+6%	+480B
Fixed college costs	+22%	-1.2K	+2%	+105B
Fixed college wage premia	+9%	+11.5K	+10%	+335B
Fixed variances of wage shock	+14%	+15.5K	+1%	+500B

Note: Table 5 shows the changes in (a) college completion rates, (b) cumulative student debt at graduation, (c) fraction of borrowers delinquent, and (d) aggregate total student debt over the transition between the benchmark model and the counter-factual economies. The letter K indicates a thousand, and the letter B indicates a million.

5.5 Delinquency choice

An increasing delinquency rate over time and individuals rolling over their student debt are crucial for explaining the rapid growth of the student debt in the U.S. To show this, in this section, we explore the implications of delinquency in the model.

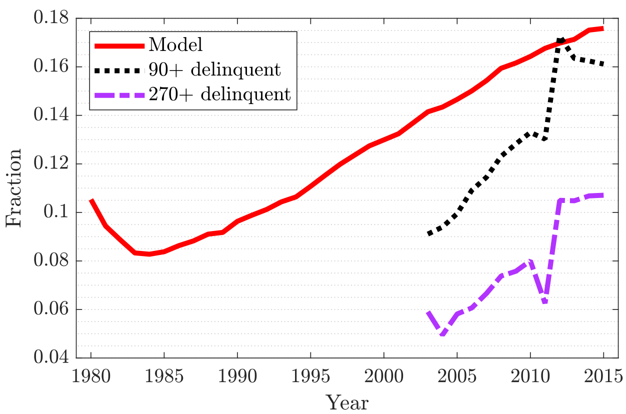
First, we present the fraction of workers who are delinquent on their payments after graduation over labor income quartiles in 1997 in Table 6. The model predicts that workers in the lower distribution of labor income face a higher chance of delaying their payments. This is in contrast to the fact that high-ability individuals, who are more likely to be in the top income distribution, are the ones borrowing the most from student loans (see Figure 8).

Table 6: Delinquency rate across earnings quartile in 1997

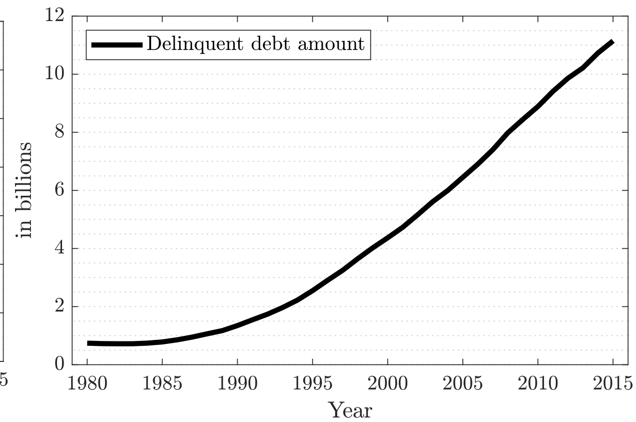
Earnings quartile	Q1	Q2	Q3	Q4
Delinquent borrowers	69.4	15.3	0.3	0.0

To show how the delinquency rate changes over time, Figure 14 exhibits the fraction of borrowers who are delinquent on their payments on the left and the fraction of student debt that is delinquent on the right. As seen in the left figure, without targeting, the model is qualitatively consistent with the observed dynamics of the aggregate delinquency rate-the fraction of borrowers who are delinquent on their payments 90 days or more.[50,51] The aggregate delinquency rate initially decreases as the college wage premia increase. However, as the residual wage dispersion increases, and the average ability of college graduates declines, the delinquency rate almost doubles between 1979 and 2015.

Figure 14: Fraction of delinquent borrowers and debt



(a) Fraction of delinquent borrowers



(b) Fraction of delinquent debt

Note: In (a), the red solid line represents the moments from the model, and the black dashed line and purple dash-dot line represent 90+ delinquent and 270+ delinquent rates from the FRBNY data, respectively.

Finally, we quantify the role of delinquency choice in the growing student debt by solving the model without a delinquency option but with all the time-varying sources. We do not re-calibrate the model to make it comparable to the benchmark economy. Importantly, without delinquency choice, the total student debt only increases by $250 billion, compared to $480 billion in the benchmark economy, as shown in Table 7. This is because, as shown in Figure 15, in the counter-factual economy without delinquency, college students reduce their borrowing from student loans, as they do not have the option to defer their payments when they experience financial hardship.

In sum, although the rising college costs encourages students to borrow a larger amount for their college education, if individuals pay off the debt following the repayment schedule without being delinquent, the aggregate student debt does not increase

[50]Despite the model period of 1 year, given that the model abstracts from additional penalties, such as wage garnishment, for 270 days or more delinquency, delinquency in the model represents 90 days or more delinquency.

[51]To compare, in Appendix C, we also solve the model with wage garnishment when borrowers are delinquent on their payments and calibrate the delinquency rate to the 270+ rate. All the quantitative results remain similar between the two models.

as much as in the benchmark economy. However, a more volatile wage shock process and the lower ability of college graduates lead a higher fraction of borrowers to delay their payments. As a result, the total student debt balance rises sharply.

Table 7: Changes in total outstanding student debt

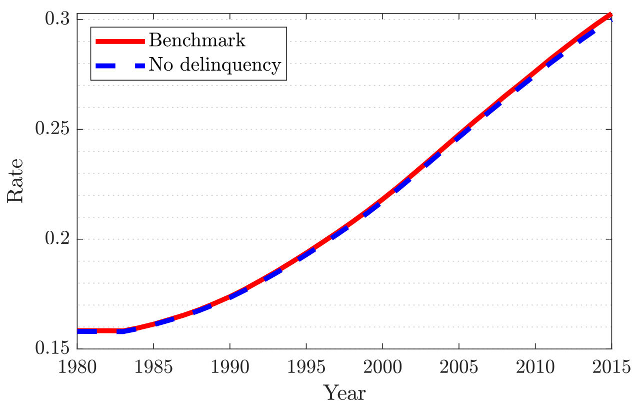
1979–2015	Δ Student debt
Benchmark	+480B
No delinquency choice	+250B

Note: The table shows the total changes in the student debt in the benchmark model and in the model without the delinquency option.

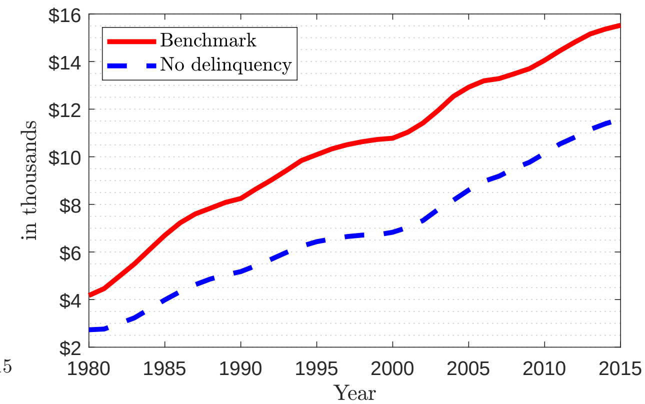
6 Conclusion

This paper examines the quantitative effects of rising college costs, wage inequality, and the delinquent behavior of borrowers on the growing student debt in the U.S. We study this by building an incomplete-markets OLG model with choices for a college education, student loans, and delinquency. Solving transitional dynamics with estimated increases in college costs and wage inequality, in addition to the increasing preference for college education over time, we find that the benchmark economy explains 50% of the observed growth in U.S. student debt between 1979 and 2015. Rising college costs largely determines the borrowing behavior of college students. The delinquency rate increases over time as the average ability of college students declines and the residual wage dispersion increases. Importantly, we find that the aggregate student debt balance only increases by half of that in the benchmark economy if borrowers can reimburse their debt without being delinquent. This suggests that increasing delinquency rates play a vital role in increasing aggregate student debt balances.

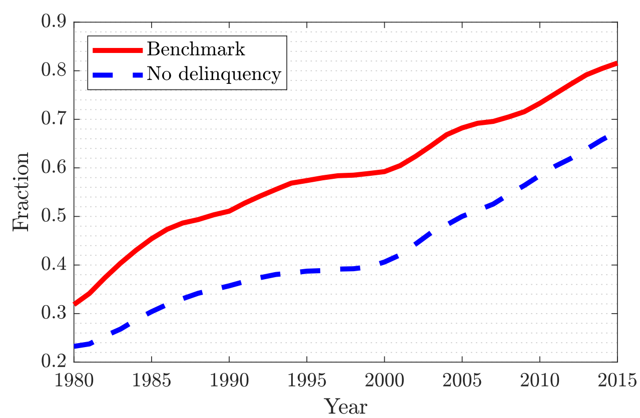
Figure 15: Changes in college choice and borrowing behavior



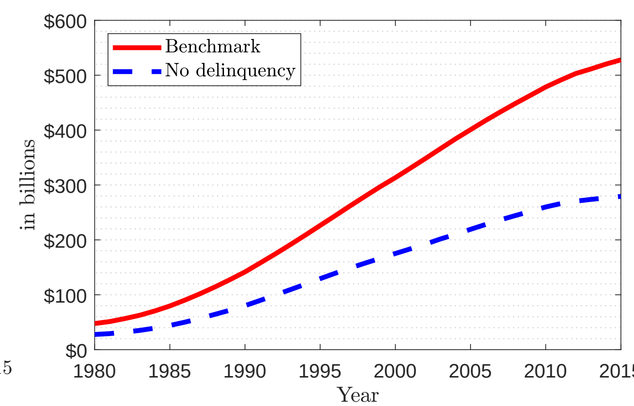
(a) College completion rate



(b) Average student debt at graduation



(c) Fraction of graduating seniors with student debt



(d) Aggregate student debt

Note: This figure shows (a) the college completion rate, (b) the average cumulative student debt at graduation, (c) the fraction of college graduates with student debt, and (d) the aggregate student debt in the benchmark economy (red solid) and no delinquency economy (blue dashed).

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A National Longitudinal Survey of Youth (NLSY79 and NLSY97)

The NLSY79 consists of 12,686 individuals between the ages of 14 and 22 in 1979, and the NLSY97 consists of 8,984 individuals between the ages of 12 and 18 in 1997. We only use the nationally representative sample and exclude the supplemental sample.[52] We drop individuals with 1) no ability information, 2) no family income information for age 16 or 17 in the NLSY79, 3) no parental transfer information in the NLSY97, and 4) the highest degree achieved higher than the bachelor's degree.[53] We use the data waves from 1979 to 1988 for the NLSY79 and from 1997 to 2008 for the NLSY97. These data waves are chosen such that the youngest cohort in each survey becomes the age 23 by the last year in the data. The final sample size is 2,159 for the NLSY79 and 4,838 for the NLSY97.

We measure the ability using the Armed Forces Qualification Test (AFQT) score for the NLSY79 and the Armed Services Vocational Aptitude Battery (ASVAB) test score for the NLSY97. The AFQT is a test that consists of arithmetic reasoning, word knowledge, paragraph comprehension, and numerical operations, and it is a part of the ASVAB test. Family income includes military income; wages, salary, and tips; net business income; net farm income; unemployment compensation; child support; AFDC payments; food stamps; other welfare and social security income; education benefits and grants; inheritance; other income (interest, dividends, rent); income from parents and other household members; and rental subsidy. An individual is measured as college educated if he or she completed at least 16 years of education.

Following Abbott et al. (2019), we measure the parental transfer as all transfers, including allowances, that an individual receives from parents or guardians when he or she is between 16 and 22 years old. The Income section of the NLSY97 reports the three

[52]Supplemental samples are designed to oversample Hispanic or Latino and black respondents living in the United States. In the NLSY79, 6,575 individuals are supplemental samples, while, in the NLSY97, 2,236 individuals are supplemental samples.

[53]For family information in the NLSY79, we use the family income for age 17 if the information is available for both age 16 and 17.

sources of parental transfers: from both parents (or guardians), from a living mother figure (or female guardian), and from a living father figure (or male guardian). We measure the parental transfers for respondents who live with both parents using transfers from both parents. If respondents do not live with both parents (or guardians), then we sum the amounts from both a living mother figure and a living father figure. If respondents live with any parent (or guardian), we include the average amount of imputed rent by age groups. We compare the estimated parental transfers with the amount of family aid, adjusted for rent payments, in the Education section of the NLSY97 and use the maximum of the two.[54]

The Education section of the NLSY97 provides the amount of student loans that an individual borrows for every school, academic term attended, and year.[55] Given that the student loan amounts include both federal and private loans, we top-code the annual amount that exceeds $35,000$ dollars. Then, we calculate the annualized average student debt by summing up the borrowed amount across terms, schools, and years of education and dividing it by the total number of full-time equivalent years in college. To calculate the cumulative student debt until graduation, we multiply the yearly average of student loans by 4.

We estimate the college education cost following Gordon and Hedlund (2020). The NLSY97 provides eight different sources of financing education for every school, academic term attended, and year:

1. Financial aid from family and friends ($YSCH\_24600$)
2. Loans from family/friends ($YSCH\_24700$)
3. Grants and scholarship ($YSCH\_25400$)
4. Federal subsidized and other student loan ($YSCH\_25600$)
5. Work study financial aid ($YSCH\_26000$)

[54]As noted in Abbott et al. (2019), the family aid in the Education section is not fully consistent with the parental transfers in Income section, has many skips, and does not cover all transfers.

[55]If it is reported as a bracket, we use the median to approximate the actual amount.

6. Employer assistance financial aid ($YSCH\_26200$)

7. Other financial aid ($YSCH\_26200$)

8. Out of pocket spending ($YSCH\_26500$)

With these measures at a given year and school, we first identify whether an individual reports any change in how he or she finances the education from the last term. If there is no change, we carry over the amount from the previous term for all eight financing sources. If an individual reports the change from the previous term but does not report a specific amount for any financing source for the current term, we update that amount to zero. Second, we assign the weight of 1 to the reported amount if an individual was a full-time student and 0.5 if an individual was a part-time student at the given term. Finally, for each school and year, we compute the average amount of each financing source across terms and schools. This gives us the individual-specific average amount per term across schools for each financing source. To get an annual value, we multiply this amount by the number of full-time equivalent terms that an individual attended schools in a given year. Then, we sum up the annual average values of eight financing sources and define it as the annual average sticker price that an individual paid for college education. The net college cost is obtained by subtracting the average amount of grant and scholarship from the average sticker price.

Lastly, in the NLSY97, we calculate the weekly average hours worked in college as follows. First, we calculate individuals' total hours of work by summing the hours of work while enrolled in 4-year or 2-year college. Then, we divide this by the number of years of college enrollment. To express it as weekly hours, we divide the annual average by 52.

B Minimum Distance Estimation

We estimate the year-varying variances of shock $\{\sigma^2_{pt}, \sigma^2_{vt}\}$, the persistence of the shock $\{\rho\}$, and the variance of the initial value for the persistent shock using minimum distance methods.[56] The theoretical moment is defined as:

$$m^j_{t,t+n}(\mathcal{P}_{102\times 1}) = E(r_{i,j,t}r_{i,j+n,t+n}),$$

which is the covariance between the wages of individuals at age j in year t and $t+n$. To calculate empirical moments, I group individuals into 50 years and 26 overlapping age groups. For example, the first age group contains all observations between 25 and 34 years old, and the second group contains those between 26 and 35 years old. The empirical moment conditions are

$$\hat{m}^j_{t,t+n} - m^j_{t,t+n}(\mathcal{P}) = 0,$$

where $\hat{m}^j_{t,t+n} = \frac{1}{I_{j,t,n}}\sum_{i=1}^{I_{j,t,n}} \widehat{r}_{i,j,t}\widehat{r}_{i,j+n,t+n}$ and $I_{j,t,n}$ is the number of observations of age j at year t existing n periods later.

The minimum distance estimator solves

$$\min_{\mathcal{P}}[\hat{\mathbf{m}} - \mathbf{m}(\mathcal{P})]'[\hat{\mathbf{m}} - \mathbf{m}(\mathcal{P})],$$

where the vectors $\hat{\mathbf{m}}$ and $\mathbf{m}$ represent empirical and theoretical moments of dimension $10,070 \times 1$. The identity matrix is used as the weighting matrix.

C A Model with Wage Garnishment

In the benchmark economy, delinquency is considered as missing payments for 90 days or more. Thus, delinquency only involves a psychic cost. However, given that the model period is one year, we solve a model with wage garnishment when defaulting in

[56]Given that the PSID has conducted a biennial survey starting from 1997, the estimation of annual shock processes must confront the problem of observations missing for every other year. As Heathcote, Storesletten and Violante (2010) indicate, although the variance for the persistent shock for the missing years can theoretically be found using the available information from adjacent years, the resulting estimates are downward-biased because of insufficient information. Therefore, I follow their approach and estimate the variances for missing years by taking the weighted average of the two closest surrounding years.

this section to be consistent with the penalty of missing payments for 270 days or more. Following Ionescu (2009), we assume that 3% of the labor income is garnished when borrowers are delinquent on their payments. Though we do not re-calibrate the model, as seen in Figure C1 (c), introducing wage garnishment brings the delinquency rate in the model close to the observed 270 days or more delinquency rate.

Figure C1 shows that the aggregate student debt increases $110 billion less than the benchmark economy. With an extra penalty on delinquency, college students rely less on government loans to finance college. Thus, on average, fewer students borrow from government loans, and they borrow less amount than the benchmark economy. Also, fewer student loans are rolled over time, reducing the increase in total student debt in the economy.

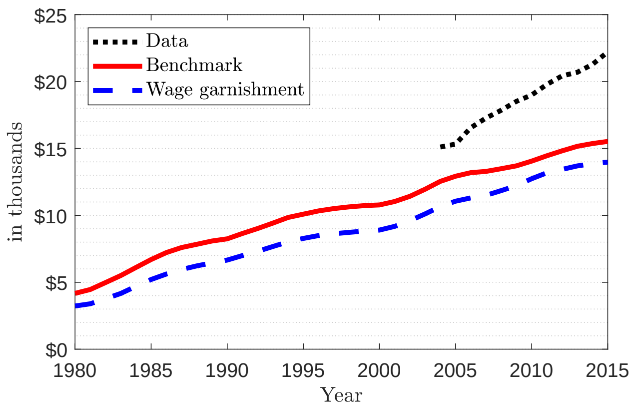
However, as seen in Table C1, when we do not allow delinquency, the aggregate student debt only increases by $210 billion, compared to $364 billion in the model with delinquency that accompanies wage garnishment. This emphasizes that even a low delinquency rate can significantly contribute to the growth of student debt in the U.S.

Table C1: Changes in total outstanding student debt

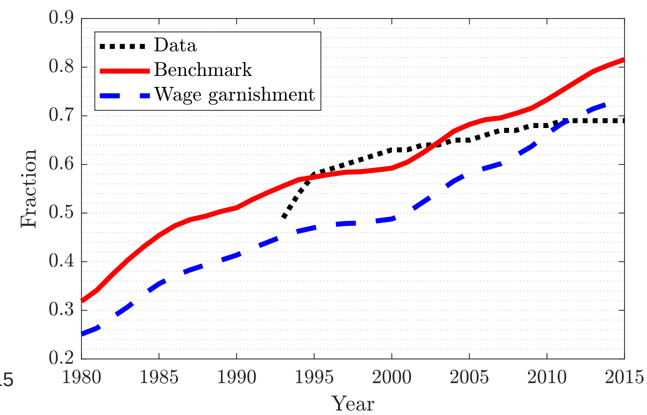
1979–2015	Δ Student debt
Wage garnishment	+364B
No delinquency choice	+210B

Note: This shows the total changes in student debt in a wage garnishment model with and without the delinquency option.

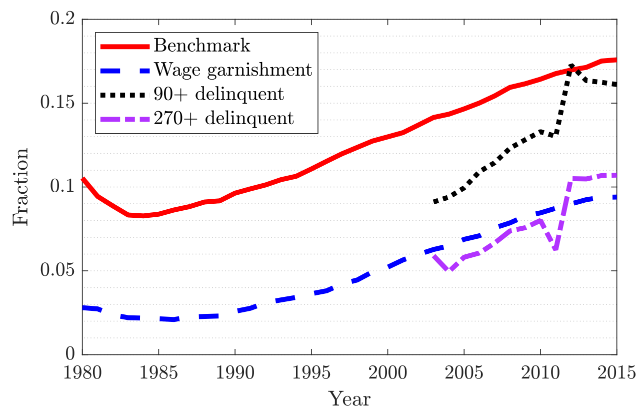
Figure C1: Benchmark v.s. Economy with Wage Garnishment



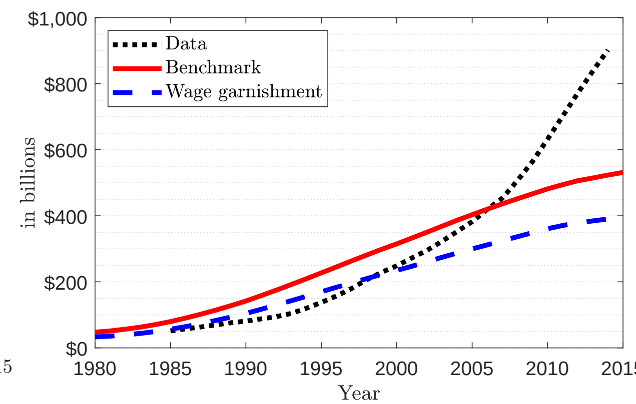
(a) Cumulative student debt at graduation



(b) Fraction of graduating seniors with student debt



(c) Fraction of delinquent borrowers

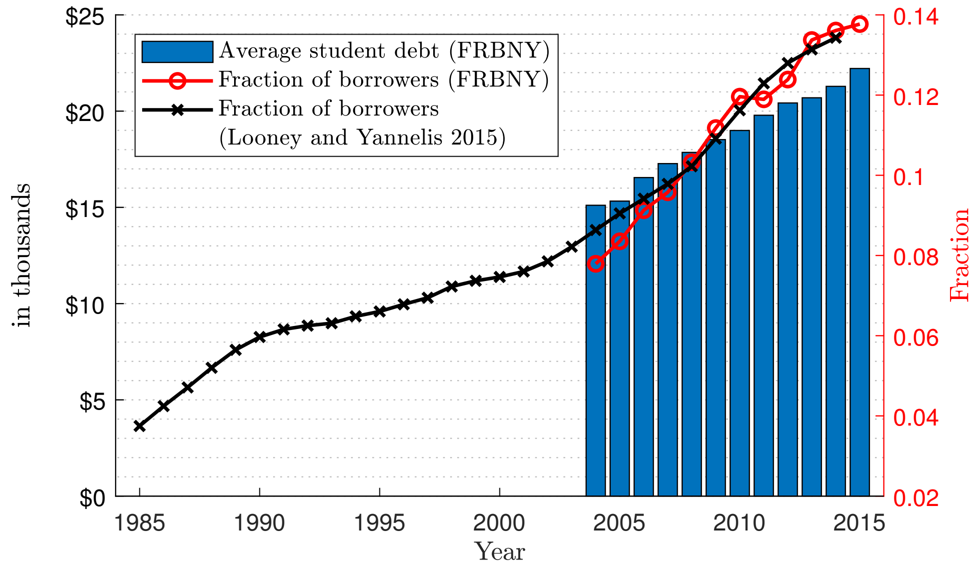


(d) Aggregate student debt

Note: This figure shows (a) cumulative student debt at graduation, (b) fraction of graduating seniors with student debt, (c) fraction of delinquent borrowers, and (d) aggregate student debt under the benchmark economy and the economy with wage garnishment. The red solid line is the benchmark economy. The blue dashed line is the economy with wage garnishment. The black dashed line and purple dash-dot line in (c) represent 90+ delinquent and 270+ delinquent rates from the FRBNY data, respectively.

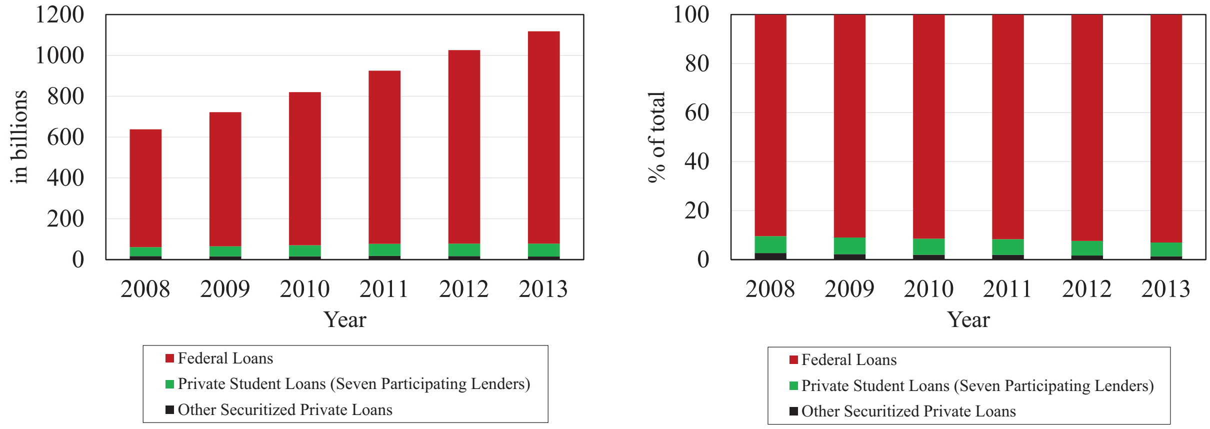
D Additional Figures and Tables

Figure D1: Average student debt and the number of borrowers



Source: The average student debt per borrower is from the National post-secondary student aid study (NPSAS) and the New York Fed Consumer Credit Panel. The total number of borrowers is from the New York Fed Consumer Credit Panel data. All the values are expressed in 2004 U.S. dollars.

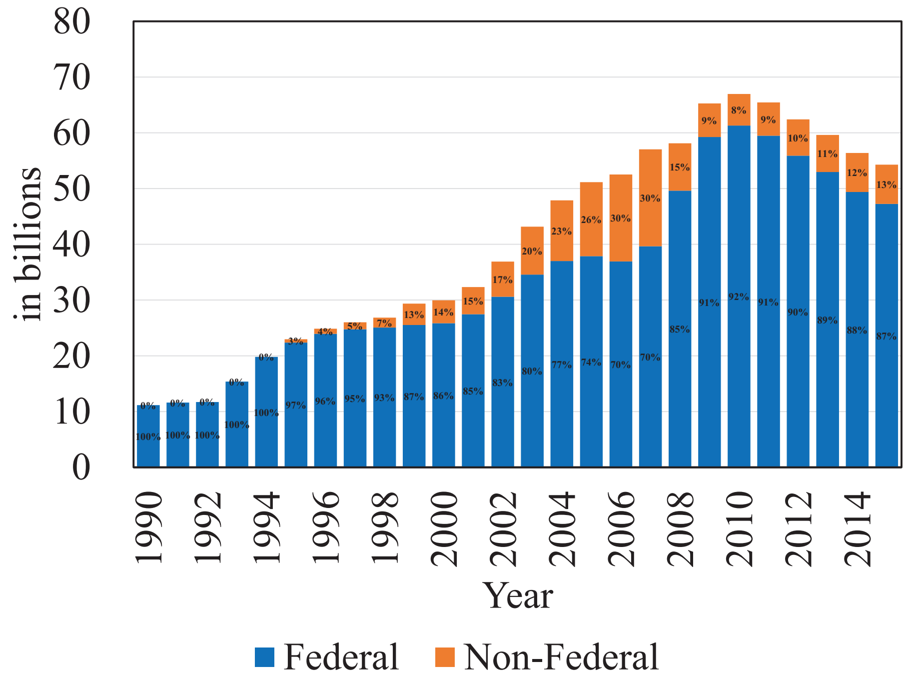
Figure D2: Composition of outstanding student loans



(a) In current dollars (b) As a fraction of total debt

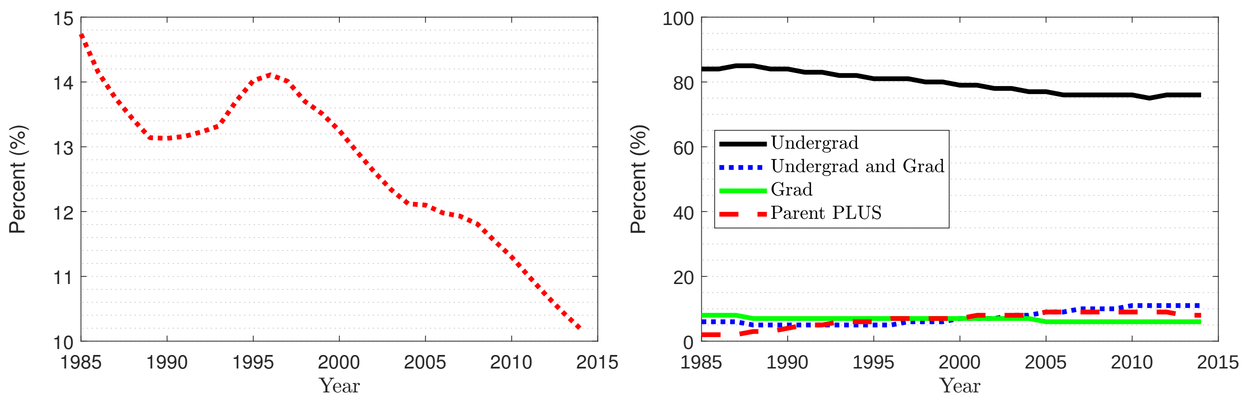
Source: The 2013 MeasureOne Private Student Loan report. Notes: In July 2012, the Department of Education and the Consumer Financial Protection Bureau (CFPB) released a study of the private education loan market based, in part, on data submitted by nine major private education lenders. The 2013 MeasureOne Private Student Loan report provides an update to and extends the CFPB study to 2013. The MeasureOne collected data from the nation's seven largest active private student lenders, including Discover Bank; The First Marblehead Corporation; PNC Bank; RBS Citizens; Sallie Mae; SunTrust Banks; and Wells Fargo Bank.

Figure D3: Annual amount of disbursed loans to undergraduate students



Source: College Board (2018). Expressed in 2004 U.S. dollars.

Figure D4: Percentages of aggregate federal student debt for graduate study and student loan borrowers by loan type



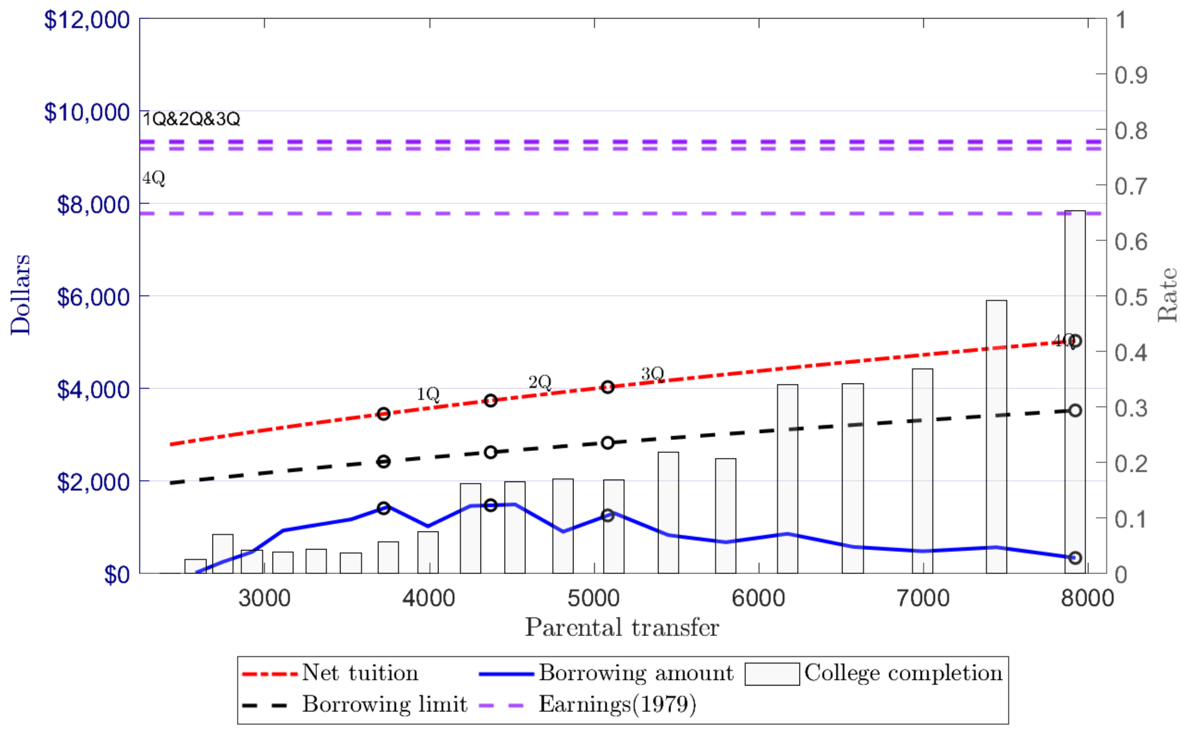
(a) Percentage of federal student loan for graduate study

(b) Percentage of federal student loan borrowers by loan type

Source: Looney and Yannelis (2015).

Note: Figure D4 shows the percentage of total outstanding federal student loan balances attributable to graduate school institutions (top) and the percentage of federal student loan borrowers by different types of federal loans (bottom). The data is taken from 4 percent of the National Student Loan Data System sample, which includes the annual information on student loans and institutions attended for about 4 million federal student loan borrowers.

Figure D5: Simulation over parental transfers



(a) 1979 economy

Note: This figure shows the 1979 simulated moments over parental transfers. The red dash-dot line represents the average net tuition and fees, the black dashed line represents the effective borrowing limit, and the blue line represents the borrowing amount. The white bars represent the college completion rates, and the black circled marks indicate where the parental transfer quartile is divided. The left y-axis indicates the dollar values of moments, while the right y-axis indicates the college complication rates.