Student Debt, College Tuition, and Wage Inequality*

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Abstract

We study the quantitative effects of rising college tuition and wage inequality on the rising student debt in the U.S. We build an incomplete-markets overlapping-generation (OLG) model with discrete college education choice, student debt, and delinquency choice. Solving transitional dynamics with the estimated increase in college tuition and wage inequality, we find that these sources can explain 50 percent of the observed increase in student debt in the U.S. since 1979. Importantly, the rising college costs and wage inequality explain the changes in college choice and borrowing behavior over time, successfully accounting for the dynamics of student debt held by individuals under age 30. College tuition is the critical determinant for the borrowing behavior of college students and thus the rising student debt, while wage inequality is crucial for college choice. Lastly, we find that the increasing wage inequality is welfare-improving for college graduates, but they experience significant welfare losses from the increased college costs. In net, students entering a college in 2015 enjoy the welfare gain of 2 percent of lifetime consumption.

Keywords: Student Debt, College Tuition, College Choice, Wage Inequality.

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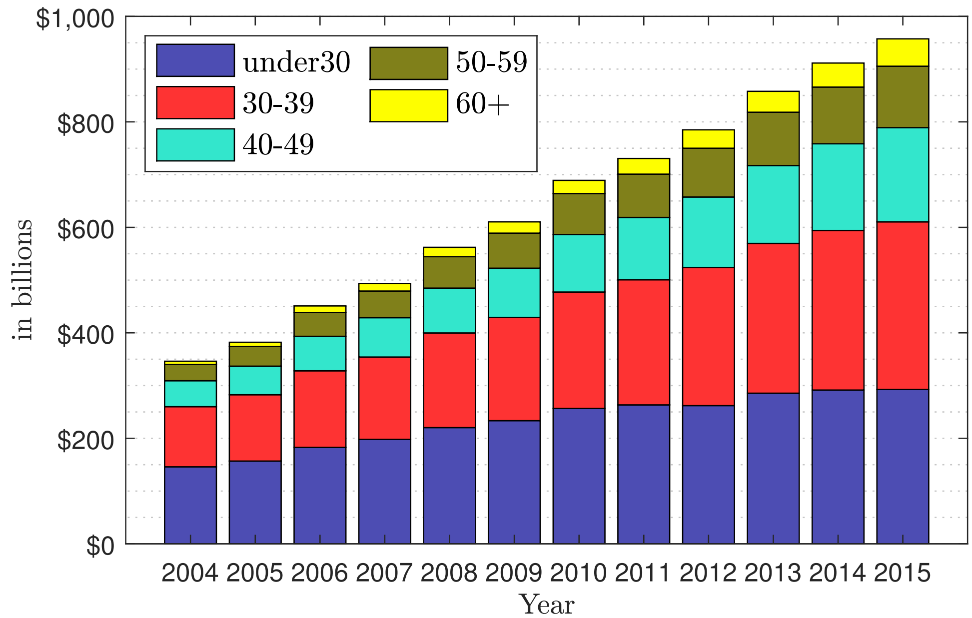
1 Introduction

Figure 1: Total student debt balances by age group



Source: New York Fed Consumer Credit Panel. Expressed in 2004 U.S. dollars.

As seen in Figure 1, the total outstanding student debt has risen sharply in the U.S. For example, the outstanding student debt has increased from 345 billion dollars in 2004 to around 1 trillion dollars in 2015. This is nearly a threefold increase in a decade, and the outstanding student debt has reached approximately 7 percent of the total GDP in 2015.[1] Now, in the U.S., the total outstanding student debt exceeds the total credit card debt and auto loans, becoming the second-largest component in households debt after the mortgage (Brown et al. (2015)).[2]

Due to an overwhelming increase in outstanding student debt, there have been discussions about whether such an increase in student debt is a concern to policymakers or not. Some people believe that it is a natural increase from the growing number of

[1] As shown in Figure B1 in Appendix B, the rise in the student debt is accompanied by the increases in both the total number of borrowers and the average amount of student debt per borrower. For example, the total number of student debt holders has doubled from 22 millions in 2004 to 44 millions in 2015, and the average student debt per borrower has increased from $\$15,106$ to $\$21,677$ dollars over the same period.

[2] Student debt grew even during the Great Recession while other consumer debts such as mortgages, credit cards, auto loans, and home equity lines of credit have declined following the Great Recession. This is mainly because student debt is not forgivable even in a consumer bankruptcy.

college educated individuals, alongside rising wage inequality and tuition, while others argue that it may reflect the deteriorated financial health of existing borrowers over time. Though understanding the sources of rising student debt is the first step forward for policy makers, there is little work done in the literature. This paper aims to fill this gap by studying how much of the increase in student debt can be explained by empirically consistent changes in college tuition and wage inequality.[3] Tuition and wage inequality are natural suspects for the increased student debt, as both are crucial for college choice and borrowing behavior and have significantly increased in the U.S. for decades along with the student debt. For example, the average yearly net tuition and fees for 4-year public and private colleges have increased from $5,000 in 1979 to $14,000 in 2015. For wage inequality, the college wage premium has doubled during the same period, and the variances of wage shock processes have also increased sharply.

To study the implications of rising college tuition and wage inequality on student debt, we build an incomplete-markets overlapping-generations (OLG) model with college education choice, student debt, and delinquency choice on student debt. Individuals born with different abilities and parental transfers decide whether they want to pursue a college degree or not. A college education is costly; individuals have to spend four years of their life studying and paying net tuition. College students can finance their education through three different sources: parental transfers, labor income, and government student loans. Individuals enter the labor market with two different 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, each period, they can choose to be delinquent on their payments due.

We discipline our model using various sources of U.S. data, including the National Longitudinal Survey of Youth (NLSY79 and NLSY97), the National Center for Education Statistics (NCES), the Panel Study of Income Dynamics (PSID), and the College

[3]Notably, rising wage inequality also affects rising net tuition. Cai and Heathcote (2019) show that rising income inequality is the key driver of the increase in the 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 network, providing top-quality universities an incentive to raise their tuition and fees.

Board. Importantly, without targeting, the calibrated model successfully explains much of the observed distribution of college completion rates, net tuition, student debt, and hours worked during college education over ability and parental transfer groups in the NLSY97. Next, using the PSID data, we estimate the wage process, allowing for time-varying college wage premia, skill-varying labor market experience premia, and time-varying variances of wage shock processes.

To understand the implications of rising college tuition and wage inequality on student debt, we solve transitional dynamics with the estimated college wage premia, variances of wage shock, and net tuition and fees. We find that changes in these sources increase the student debt from 51 billion dollars in 1979 to 420 billion dollars in 2015, explaining half of the total increase in student debt in the U.S. over this period. The rising college costs and wage inequality are broadly consistent with changes in college choice and borrowing behavior over time and account for most of the rise in student debt held by individuals under age 30. By conducting the decomposition exercise, we further find that the tuition is vital for determining the borrowing behavior of college students, while wage inequality is an important determinant for college choice.

Finally, we examine how increases in the benefits and costs of college affect welfare of college-educated individuals over time. We find that a larger wage inequality in terms of college wage premium and more dispersed wage shock leads to welfare gains for recent college educated individuals. However, these welfare gains are substantially reduced by the sharply rising college tuition. Quantitatively, a cohort that enters a college in 2015 enjoys the welfare gain of 2% of lifetime consumption, explaining why individuals pursue a college degree despite the high tuition.

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 calibration and estimation. Section 5 presents quantitative results from transitional dynamics, and Section 6 discusses the welfare implications. Finally, Section 7 concludes.

2 Related Literature

Our paper is first related to the literature that explores the implications of different student loan policies on the 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 where individuals face both earnings and interest rate risk. Ionescu (2009) further quantifies the effects of flexible repayment options and the relaxed eligibility for student loans on college enrollment, borrowing, and default rates in a heterogeneous life-cycle model with human capital. A more recent paper by Abbott et al. (2019) examines the effects of government grants and loans on the college attainment, welfare, and aggregate economy by building a general equilibrium incomplete-markets life-cycle model with intergenerational links. Though our focus lies more on the dynamics of student debt, the college choice, borrowing, and repayment behavior are essential for our analysis, and our framework builds on the models in this literature.

Central to our analysis is the interaction of college attainment, parental transfers, and borrowing. A large literature discusses the role of credit constraints and family income on schooling decisions, including Belley and Lochner (2007), Hai and Heckman (2017), Keane and Wolpin (2001), Chetty et al. (2017), and Carneiro and Heckman (2002). Using the NLSY79, Keane and Wolpin (2001) and Carneiro and Heckman (2002) find that the family income has little effect on college attendance during the early 1980s. However, by comparing the NLSY79 and NLSY97 data, Belley and Lochner (2007) show that the family income has become more important for a college attainment decision.

The private lending market is also an important component of student loans. Ionescu and Simpson (2016) and Lochner and Monge-Naranjo (2011) explore the interaction between a private lending market and government student loans. Despite its importance, our work is agnostic about the role of private loans in the dynamics of student debt. This is motivated by the following facts. First, among the total outstanding student debt, private loans only account for 6 to 7 percent. Second, the historical average of annual disbursements of non-federal loans to undergraduate students is around 10 percent of the total supply.[4] Lastly, the private lending market operates in a stark different way from government loans. In the private market, terms, eligibility, and interest rate of loans depend on the default risk of borrowers.

The interaction between student loans and labor market outcome is essential for determining the college graduate's repayment behavior with regard to student debt. The papers that study the implications of student debt on 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 the 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 the college graduates with high student debt are likely to accept jobs with higher wages but lower job satisfaction. For simplicity, and lack of data availability, our model does not explicitly account for the heterogeneous labor market outcomes such as job securities and amenities among the college-educated. However, for future research, it is important to take them into account to understand the dynamics of student debt, as they can affect the repayment behavior of student debt holders after college graduation.

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 ε and parental transfers a_0 makes a college education decision. College education takes four model periods and

[4]See Figures B2 and B3 in Appendix B. Though the fraction of private loans disbursed to undergraduate students peaks to 30% in 2007, it quickly decreases afterwards.

lasts until age $J_c = 4$.[5] Each period, an enrolled college student has to pay net tuition and devote a fixed fraction of time for studying. College education can be financed through three different sources: parental transfers a_0, labor supply n, and government student loans b. After graduation, college graduates randomly lose their skills acquired in college with a probability of ϕ_d before they enter the labor market.[6]

After college education, an individual enters the labor market with two distinct skill levels $e \in \{l, h\}$. A fraction of $1 - \phi_d$ college graduates become skilled workers $(e = h)$, while those who lose their skills after graduation and who did not go to college enter the labor market as unskilled workers $(e = l)$. Skilled workers earn the wage w^h higher than the wage earned by unskilled workers w^l. They also face higher labor market experience premia $l^h(j)$ over their working lives than that of the unskilled $l^l(j)$. Lastly, workers face idiosyncratic wage shocks 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 the fixed repayment schedule, to pay off all the student debt. Each period, workers with existing student debt can be delinquent on their payments. The remaining student debt after delinquency choice accumulates the interest r_b on it.

After retirement, individuals receive social security benefits $s^e(\varepsilon)$. Retirees do not have an option to be delinquent and must pay off any remaining student debt following a fixed payment schedule. All individuals retire at age $j = J_r$ and survive until age $j = J$.

[5]In the model, we only consider undergraduate students' borrowing and education choices. This is because student debt for graduate study accounts for a small fraction of the total debt. For example, as shown in Figure B4, the fraction of total federal student loans issued for graduate study has been decreasing since 1980, and the fraction of federal student borrowers for graduate study stays around 10 percent.

[6]This is to make the model consistent with a relatively high college drop-out rate seen in the U.S.

3.2 College education

Individuals start their lives with different initial abilities ε and parental transfers a_0. The initial ability follows a finite-state Markov chain $\varepsilon \in \{\varepsilon_1, ..., \varepsilon_{n_\varepsilon}\}$, where

$$Pr(\varepsilon' = \varepsilon_k | \varepsilon = \varepsilon_l) = \pi_{lk} \geq 0; \quad \sum_{k=1}^{n_\varepsilon} \pi_{lk} = 1.$$

The parental transfer is drawn from $a_0 \sim A(\varepsilon, \xi_a)$, where ξ_a is drawn from a standard normal distribution. Given these, individuals decide to go to college or to enter the labor market as high school graduates. Parental transfers are paid only once at the initial age for individuals who do not pursue a college degree, while those who enroll in college receive a fixed amount a_0 every period until graduation.[7]

College education takes four model periods and involves three types of costs. First, an individual has to pay net tuition $\phi(\varepsilon, a_0)$ for every education period. Here, net tuition is assumed to be a function of ability and parental transfers to be consistent with heterogeneous education costs seen in the data.[8] 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 labor supply during college education. Lastly, individuals who pursue a college degree face a psychic education cost χ_e.

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.[9] Here, b is the cumulative student debt for entire education periods, 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 amount of cost of attendance

[7]This is to reflect the fact that college students receive a larger amount of parental transfers than those who do not go to college.

[8]In the NLSY97, net education cost is higher for wealthy or high ability individuals than wealth-poor or low ability individuals. This likely reflects the fact that the quality of education varies by ability and wealth.

[9]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 is waived during college for subsidized loans, there is little difference between the two loans.

(COA) minus expected family contribution (EFC). To be consistent with this, the annualized borrowing amount $\frac{b}{J_c}$ cannot exceed ρ times the yearly net tuition, $\rho\phi(\varepsilon, a_0)$, as well as the student loan limit $\underline{b}$.[10] There is no idiosyncratic risk during college. Thus, there is no endogenous dropout. Lastly, college graduates randomly lose their skills with a probability ϕ_d and enter the labor market as unskilled workers.

The optimal college education decision is

$$e(\varepsilon, a_0) = \begin{cases} h & \text{if } V_1^h(\varepsilon, a_0) - \chi_e \geq EV_1^l(\varepsilon, a_0) \\ l & \text{otherwise.} \end{cases}$$

where $V_1^h(\varepsilon, a_0)$ is the value of an individual going to college, while $EV_1^l(\varepsilon, a_0)$ is the expected value of an individual entering the labor force as a high school graduate. Note that individuals who decide not to pursue a college degree or lose their skills after college re-draw their initial labor productivity ε from its ergodic distribution.[11] Below, we explain the maximization problem of a college student in each school year in detail.

3.2.1 Freshmen

The maximization problem of a first-year student is

$$V_1^h(\varepsilon, a_0) = \max_{c,\, n,\, b} u(c, 1 - \bar{t} - n) + \beta V_2^h(\varepsilon, a_0, b) \tag{1}$$

$$\text{s.t. } c = a_0 + (1-\tau)\pi w_l l^h(1)\tilde{\varepsilon} n - \phi(\varepsilon, a_0) + \frac{b}{J_c}$$

$$0 \leq \frac{b}{J_c} \leq \min\{\rho\phi(\varepsilon, a_0), \underline{b}\}, \quad \tilde{\varepsilon} \equiv \min\{\varepsilon, \bar{\varepsilon}\}, \quad c \geq 0, \quad n \in [0, 1-\bar{t})$$

where τ is a labor income tax rate. We assume that a college student earns an unskilled hourly wage w_l, and work experience in college does not increase labor market experi-

[10]Note that students cannot borrow to consume.

[11]As labor productivity is highly correlated with ability, for simplicity, we use them interchangeably in the model.

ence premium, $l^h(1)$.[12] Here, π is a scaling factor for labor income during college and ε can not exceed the mean of idiosyncratic shock, $\bar{\varepsilon}$. [13] Note that the maximization problems of sophomores and juniors are same as that for freshmen, except for b not being a choice variable.

3.2.2 Seniors

The maximization problem of a senior is

$$
\begin{aligned}
&V^h_{J_c}(\varepsilon_l, a_0, b) = \max_{c,n,a'} u(c, 1-\bar{t}-n) + \\
&\beta\Big[\phi_d E V^l_{J_c+1}(i=0, \varepsilon', a', b) + (1-\phi_d)\sum_{k=1}^{N_\varepsilon} \pi_{lk} V^h_{J_c+1}(i=0, \varepsilon'_k, a', b)\Big] \\
&\qquad \text{s.t. } c + a' = a_0 + (1-\tau)\pi w_l l^h(1)\tilde{\varepsilon}_l n - \phi(\varepsilon, a_0) + \frac{b}{J_c} \\
&\qquad \tilde{\varepsilon} \equiv \min\{\varepsilon, \bar{\varepsilon}\}, \quad a' \geq 0, \quad c \geq 0, \quad n \in [0, 1-\bar{t})
\end{aligned}
\tag{2}
$$

where ϕ_d is the exogenous probability of losing skills. As mentioned before, when students lose their skills, they re-draw their labor productivity. Here, i represents the number of repayments made for student debt. For example, if $i = 0$, individuals have not begun the repayment of outstanding student debt. Lastly, senior students can save in financial assets a.

[12] However, the number of years in college will be counted as labor market experience once graduated. This way, we can use age as a proxy for labor market experience for workers.

[13] These modeling assumptions are based on the following. First, without scaling labor income, college students borrow a counterfactually large amount of student loans to finance their college education. Second, ε restricted to be less than its mean helps the model explain the borrowing behavior of students in the highest ability group in the data. This assumption is also consistent with the fact that ability is not fully accounted for in labor income during college.

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

A student loan is a non-dischargeable long-term debt.[14] In the model, individuals must make a total number of n_T repayments to pay off all the debt. For each payment, individuals have to pay

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

fraction of existing debt.[15] Note that the values of λ_i increase with the number of repayments and guarantee the same repayment amount for every repayment period.

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

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

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

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

$$V_j^{e,p}(i, \varepsilon_l, a, b) = \max_{c,n,a'} u(c, 1-n) + \beta \sum_{k=1}^{N_\varepsilon} \pi_{lk} V_{j+1}^e(i+1, \varepsilon_k', a', b') \tag{3}$$

[14] Under Chapter 7 and 13 bankruptcies in the U.S., 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 the credit bureau. Government agencies that guarantee student loans make a repayment plan, including penalties on 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 the student debt after 25 years of repayments, the remaining debt can be forgiven only if a debtor has a very low income.

[15] In the U.S., debtors are required to start repaying their student debt 6 months after graduation or college drop-out.

$$\text{s.t.} \quad c + a' = (1+r)a + (1-\tau)w_e l^e(j)\varepsilon_l n - \lambda_i b$$
$$b' = (1+r_b)(1-\lambda_i)b$$
$$a' \geq 0, \quad c \geq 0, \quad n \in [0,1).$$

As these individuals make a repayment this period, the total number of repayments made increases to $i+1$ next period. Also, the interest accrues to the remaining balance of student debt after repayment.

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

$$V_j^{e,np}(i, \varepsilon_l, a, b) = \max_{c,n,a'} u(c, 1-n) + \beta \sum_{k=1}^{N_\varepsilon} \pi_{lk} V_{j+1}^e(i, \varepsilon_k', a', b') \tag{4}$$

$$\text{s.t.} \quad c + a' = (1+r)a + (1-\tau)w_e l^e(j)\varepsilon_l n$$
$$b' = (1+r_b)b$$
$$a' \geq 0, \quad c \geq 0, \quad n \in [0,1).$$

Note that the maximization problem of a worker who does not go to college ($e = l$) solves the same problem as equation (4) with $b = 0$ and $i = 0$.[16]

3.4 Retirees

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

$$V_j^e(i, \varepsilon, a, b) = \max_{c,a'} u(c, 1) + \beta V_{j+1}^e(i+1, \varepsilon, a', b') \tag{5}$$

[16] 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.

$$\text{s.t.} \quad c + a' = (1+r)a + (1-\tau)s^e(\varepsilon) - \lambda_i b$$
$$b' = (1+r_b)(1-\lambda_i)b$$
$$a' \geq 0, \quad c \geq 0$$

4 Taking the model to the data

In this section, we show how we discipline our model using the data. First, we discuss the calibration strategy. Next, we explain how we estimate wage processes. Lastly, we discuss how we estimate time-varying changes in tuition and fees that are used as an input for transitional dynamics in Section 5.

4.1 Calibration

4.1.1 Parameters set externally

Demographics Assuming a model period of one year, we calibrate the model economy to the 1979 U.S. economy.[17] 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 loan During the 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 $\phi_d = 0.4$ at graduation.[18] Similar to the Federal Student Loans Program (FSLP), we assume that the fixed loan payment period is $n_T = 15$ years.

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

[18] As mentioned before, this is to capture a relatively high college drop-out rate in the U.S. We measure the college drop out rate as one minus the graduation rate among college-enrolled students. Based on the OECD Table B5.3, the graduation rate ranges from 50 to 70%.

The interest rate on federal student loans is determined by the risk-free interest rate plus 3.1%. We choose a risk-free rate r as 3.0% such that r_b becomes 6.1%, similar to the historical average of federal student loan rates.[19] The borrowing limit $\underline{b}$ is chosen to match $\$23,000$ cumulative student loan limit over the four years of college in 2004 dollars.[20] Lastly, using the average family contribution to the paid net tuition in NLSY97, we set $\rho = 0.7$.

Preferences Individuals face a standard separable utility

$$u(c, 1-n) = \frac{c^{1-\sigma}}{1-\sigma} + \psi \frac{(1-n)^{1-\eta}}{1-\eta}. \tag{6}$$

with the coefficient of relative risk aversion σ set to 2.

Taxes and social security payments Labor income is taxed at 27% (Domeij and Heathcote (2004)). Following Kim (2021), the social security is paid proportional to the productivity shock in the last working age ε^{Jr-1}. Specifically, the social security payment function is

$$s^e(\varepsilon) = \theta_s w^e \frac{\sum_{j=1}^{J_r-1} l^e(j)}{Jr-1} \varepsilon^{Jr-1} \overline{n} \tag{7}$$

with a replacement rate $\theta_s = 0.4$ and the average hours worked in the economy $\overline{n} = 0.33$. Below, Tables 1 summarizes the parameters set externally.

4.1.2 Parameters set internally

Before we discuss the parameters that are calibrated inside the model, we introduce parametric functions for parental transfers and net tuition.

[19]The loan rate is common to both subsidized and unsubsidized loans. In 1992, the FSLP introduced a variable interest rate on student loans, which is reverted to a fixed rate of 6.8% in 2006. During this period of variable rate, the loan rate ranges between 4% and 8%. Note that, in the model with the fixed risk-free rate, there is no distinction between fixed and variable interest rates.

[20]This limit applies to the sum of subsidized and unsubsidized loans. For both loans, annual borrowing limits are $\$2,625$ for freshmen, $\$3,500$ for sophomores, and $\$5,500$ for juniors and seniors.

Table 1: 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)	0.4
n_T	Student loan payment periods (FSLP)	15
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)	$\$23,000$
$1-\rho$	Average Expected Family Contribution (NLSY97)	0.4
τ	Labor income tax rate (Domeij and Heathcote (2004))	0.26
θ_s	Replacement rate for social security benefits	0.4

Parental transfers To capture a positive relationship between ability and parental transfers, parental transfers are assumed to be the following:

$$\log a_0 = \psi_0 + \psi_1 \log(\varepsilon) + \psi_2 \xi_a \tag{8}$$

where ξ_a follows a standard normal distribution.[21]

Net tuition As mentioned before, net tuition is a function of ability and parental transfers such that we can reproduce the observed heterogeneous education costs seen in the data.

$$\phi(\varepsilon, a_0) = \phi_0 + \phi_1 \varepsilon + \phi_2 a_0 \tag{9}$$

Table 2 summarizes the parameters and moments that are calibrated inside the model. First, the time discount factor β is calibrated to match the capital to output ratio. ψ and η are calibrated to match the average hours worked and the Frisch elasticity labor supply for males. Second, we match observed college attainment rates over ability terciles

[21]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 have any individuals with low (high) ability and high (low) parental transfers in simulation. A random component is introduced to overcome this issue and allow more heterogeneity across individuals.

Table 2: Parameters set internally

Parameters	Description	Data	Model
β	Capital to output ratio	3.00	3.15
ψ	Average hours worked of male	0.33	0.33
η	Frisch elasticity of male labor supply	0.48	0.48
ψ_0	College completion rate 1T(%)	0.02	0.00
ψ_1	College completion rate 2T(%)	0.10	0.17
ψ_2	College completion rate 3T(%)	0.37	0.32
ϕ_0	College completion rate 1Q(%)	0.08	0.04
ϕ_1	College completion rate 2Q(%)	0.11	0.13
ϕ_2	College completion rate 3Q(%)	0.15	0.17
χ_e	College completion rate 4Q(%)	0.30	0.31
χ_b	Average net annual education cost	$4,937$	$4,940$
π	Total outstanding student debt to GDP	0.0075	0.078

and parental transfer quartiles in the data.[22] This implies that, in the aggregate, 16% of population is college graduated. Next, we target the 1979 average yearly net paid tuition of $4,937 in 2004 U.S. dollars, which is estimated in Section 4.2. Lastly, we target the total outstanding student debt to GDP, which amounts to 51 billion in 2004 dollars.[23]

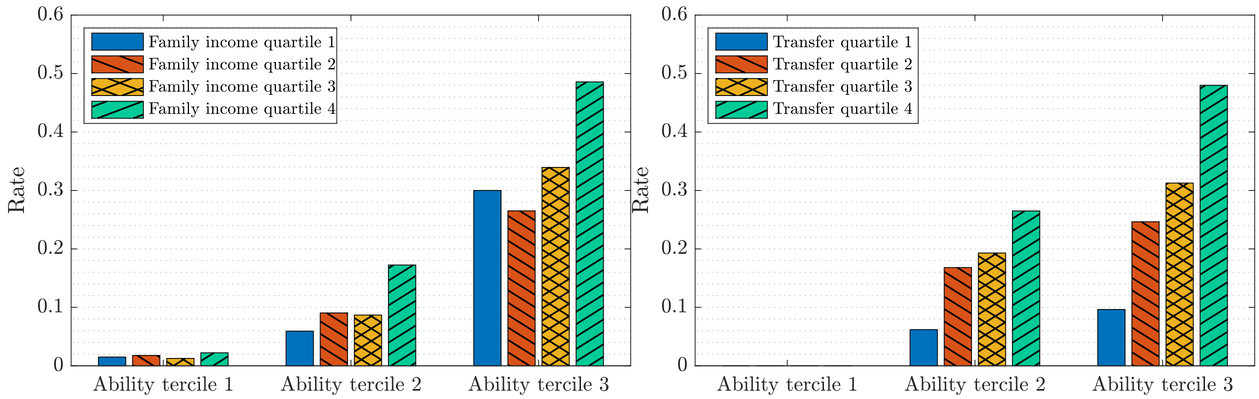
Figure 2 further compares college completion rates by ability terciles and parental transfer quartiles in the NLSY79 (left) to those in the model (right). Similar to Lochner and Monge-Naranjo (2011), it shows that the college completion rate is increasing in ability (parental transfers), conditional on parental transfers (ability).

The calibrated economy generates 11% of annual delinquency rate, which is measured as the fraction of total student debt that is more than 90 days overdue in a given year. Similarly, using the American Bankers Association data, Volkwein et al. (1998) estimate the annual delinquency rates of student debt around 17-21% through the 1980s and early 1990s. The delinquency rate is vital to determine the age composition of student debt. Figure 12 compares the age composition of student debt in the model to that in

[22]In the NLSY79, we measure ability using the Armed Forces Qualification Test (AFQT) score, which is computed by using subtestsparagraph comprehension, word knowledge, mathematics knowledge, and arithmetic reasoning, from Armed Services Vocational Aptitude Battery (ASVAB) test. Also, as the NLSY79 does not have parental transfer information, we proxy the distribution of parental transfers using that of family income. See Appendix A for more data details.

[23]For student debt, data availability is limited. As in Looney and Yannelis (2015), the earliest data for the total outstanding student debt goes back to 1984, and thus we use their 1984 value for the calibration.

Figure 2: College completion rates in 1979

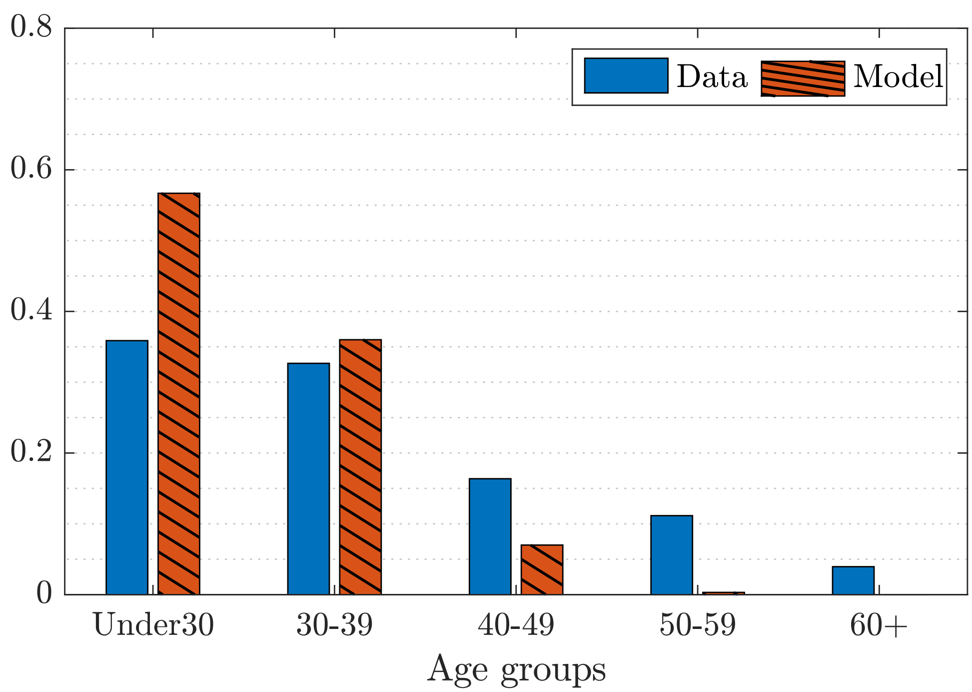


(a) Data (b) Model

Note: 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 the college completion rate as the percentage of individuals between age 14 and 22 in 1979 who completed at least 16 years of education by 1988.

the data. As you can see, without targeting, the model is broadly consistent with the declining share of student debt in age.

Figure 3: Fraction of total student debt held by different age groups

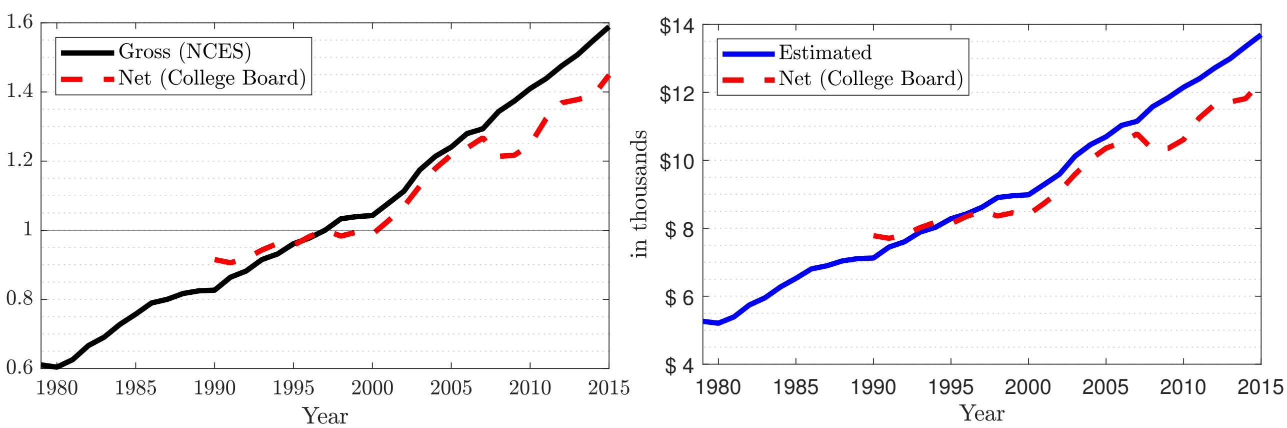


So far, we are agnostic about the model's performance on distribution of college costs and students' borrowing. This is mainly because, unlike the NLSY97 data, the NLSY79 does not provide information on student debt, parental transfers, and net tuition that are key to discipline our model. To overcome this, in Section 5, we compare model's simulated moments in 1997 in transition to the NLSY97 data moments.

4.2 Net college tuition and fees

In the quantitative analysis in Section 5, we consider three possible time-varying sources for rising student debt: 1) college wage premia, 2) variances of wage shocks, and 3) college costs. The first two sources are estimated in Section 4.3. This section explains how we estimate time-varying net college tuition and fees between 1979 and 2015, the sample periods for our quantitative exercise in Section 5.

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



(a) Tuition indices (base year = 1997)

(b) In 2004 U.S. dollars

Note: The left figure shows the tuition indices: the ratio of the average gross (black solid line) and net tuition (red dashed line) relative to the 1997 levels. The right figure compares the estimated time-varying net college tuition (blue solid line) to that in the data (red dashed line). Gross tuition data are from the NCES Digest of Education Statistics (2017 tables). Net tuition data are from the 2018 Trends in College Pricing published by the College Board. The average net tuition is calculated as the enrollment weighted average of 4-year public and 4-year private colleges tuition in the College Board.

Figure 4 (a) shows the average gross and net tuition indices between 1979 and 2015. To estimate changes in net paid tuition over these periods, we multiply the average net paid tuition $8,619 in the NLSY97 by the gross tuition index in Figure 4 (a).[24] Figure 4 (b) compares the estimated net tuition to the average net tuition measured using the NCES data. It shows that the estimated net tuition successfully reproduces the observed net tuition in College Board for available years. Importantly, as seen in Figure 4 (b), college tuition and fees have risen rapidly in the U.S., increasing from $5,000 in 1979 to $14,000 in 2015.

4.3 Wage process estimation

To introduce a realistic time-varying wage inequality into the model, we estimate the wage process using the 1968-2017 PSID data.[25] The estimation procedure in this section closely follows Kim (2021) and Heathcote et al. (2010). We first run the following OLS regression to estimate time-varying college wage premia $\frac{w^h}{w^l}$ and skill-varying labor market experience premia l^e over the sample period.[26]

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

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

[24]Due to the fact that net tuition data are only available from 1990, we use gross tuition index instead of net tuition index. However, as seen in Figure 4 (a), the gross and net tuition indices are similar to each other.

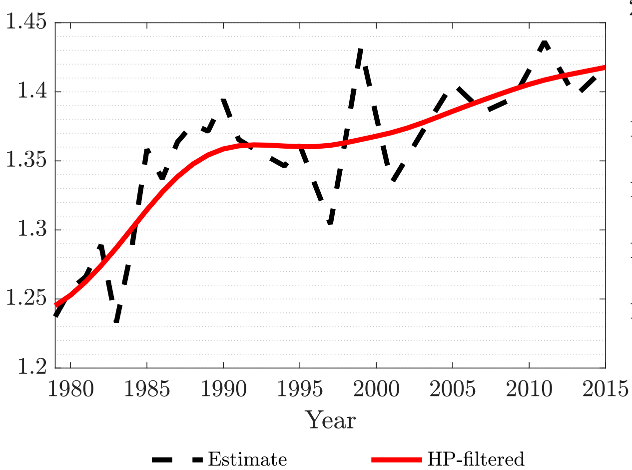
[25]We use survey data from 1968 to 2017, but only estimate the variances through 2015 because of the finite sample bias at the end of the sample period.

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

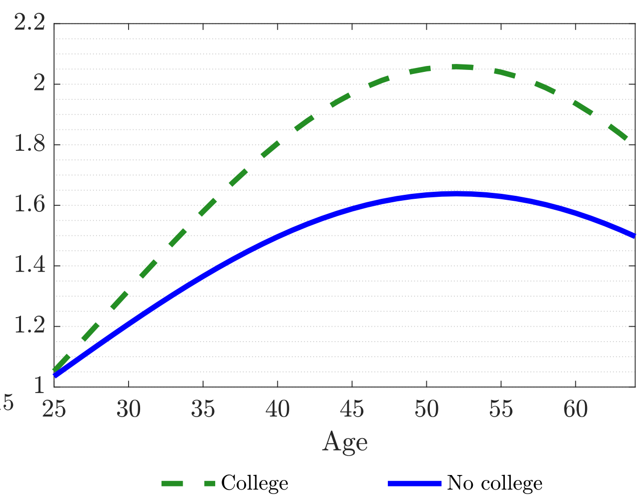
the college-educated. Here, labor market experience θ is measured as age minus years of schooling minus 6.[27] Note, $\beta_{e,2}$ and $\beta_{e,3}$ capture the education-specific labor market experience premium.

Figure 5 shows the estimated college wage premia (left) and skill-specific labor market experience premia (right).[28] First, the college wage premia have almost doubled, increasing from 1.25 in 1979 to 1.42 in 2015. Second, the wage growth is much steeper for the college-educated than for the non-college educated. For example, the labor market experience more than doubles hourly wages for college-educated workers through the first 25 years of work (dashed green line), while it only increases by 50% for non-college educated workers relative to their initial levels (solid blue line).

Figure 5: 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. The dashed black line is raw estimates and the solid red line is HP-filtered series with a smoothing parameter of 100. The right panel shows the labor market experience premia, $l^e(j) = exp(\beta_{e,3}\theta + \beta_{e,4}\theta^2)$, for college (dashed green line) and non-college graduates (solid blue line).

[27] In years missing the variable for years of schooling, I proxy years of schooling using the median of education brackets for individuals with less than a college degree. For example, if the individual responded that they finished grades 6-8, I approximate years of schooling for this individual as 7. For individuals with a college degree or more, I proxy their years of schooling as 16.

[28] Here, we only present the result for years that are used for transitional dynamics.

Next, we estimate the wage shock process. The regression residuals $\widehat{r}_{i,j,t,e}$ are assumed to be the sum of idiosyncratic wage shocks $\epsilon_{i,j,t,e}$ and measurement error $\widetilde{v}_{i,j,t,e}$.[29] Idiosyncratic shocks consist of both a persistent component η and a transitory component ϵ^v. Specifically,

$$\epsilon_{i,j,t,e} = \eta_{i,j,t,e} + \epsilon^v_{i,j,t,e}$$

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

where $\epsilon^p_{i,j,t,e} \sim N(0, \sigma^2_{p_t})$ and $\epsilon^v_{i,j,t,e} \sim N(0, \sigma^2_{v_t})$.

We estimate year-varying variances of shock $\{\sigma^2_{p_t}, \sigma^2_{v_t}\}$, the persistence of the shock $\{\rho\}$, and the variance of the initial value for the persistent shock σ^2_π using minimum distance methods.[30] We estimate $L = 102$ parameters, summarized in a vector $\mathcal{P}_{102\times 1}$.

The theoretical moment is defined as:

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

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.

[29] I use French (2004)'s estimate for the variance of a measurement error in log hourly wages of 0.02.

[30] Given that the PSID has conducted a biennial survey starting from 1997, the estimation of annual shock processes there must confront the problem of observations missing for every other year. As Heathcote et al. (2010) indicates, 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 variances for missing years by taking the weighted average of the two closest surrounding years.

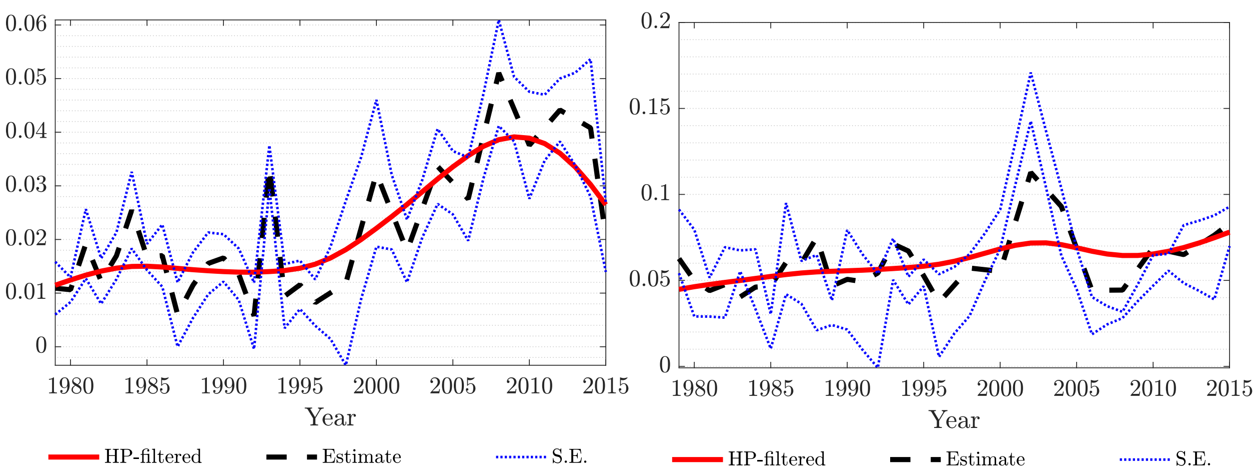
The minimum distance estimator solves

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

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.

Figure 6 shows the estimated skill-varying variances of shocks. 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.

Figure 6: Variances of persistent and transitory shocks



(a) Persistent shock (b) Transitory shock

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

5 Transition dynamics

In this section, we present the quantitative results from transition dynamics with time-varying college costs (Figure 4), college wage premia (Figures 5), and variances of wage shock (Figures 6). The realistic college choice and borrowing behavior are essential for the model to be a valid framework to study the dynamics of student debt. Thus, we first evaluate how well the model explains the observed distribution of tuition, college choice, and student loans borrowing in the NLSY97. Next, we show how much of the observed increase in student debt in the U.S. can be explained by the sources we consider. Lastly, we conduct a decomposition exercise to explore the role of each source in the dynamics of student debt, college choice, and borrowing.

5.1 Comparison of the model to the data

Table 3 compares some key moments from the data to those in the model. For the model, we take the simulated data from the year in transition that is equivalent to 1997. Note that the model is calibrated for the steady state and that all these moments in transition are not targeted. Importantly, the model successfully explains the total student debt of around 180 billion dollars in 1997 and the observed average parental transfers of $4,600 in the NLSY97.[31] In addition, the borrowing behavior of new college graduates in the model is similar to that in the data, reproducing 68% of graduating seniors holding student debt and the average cumulative student debt of $14,241 upon graduation, compared to 56% and $11,562 respecitvely in the data.

Figure 7 presents the distribution of college completion rates in 1997 over ability terciles and parental transfers quartiles, similar to Figure 2. While the model overestimates the college completion rates by the second ability group, the relatively high college completion rates for individuals with high-ability and large parental transfers are consistent with the college completion rates seen in the NLSY97.

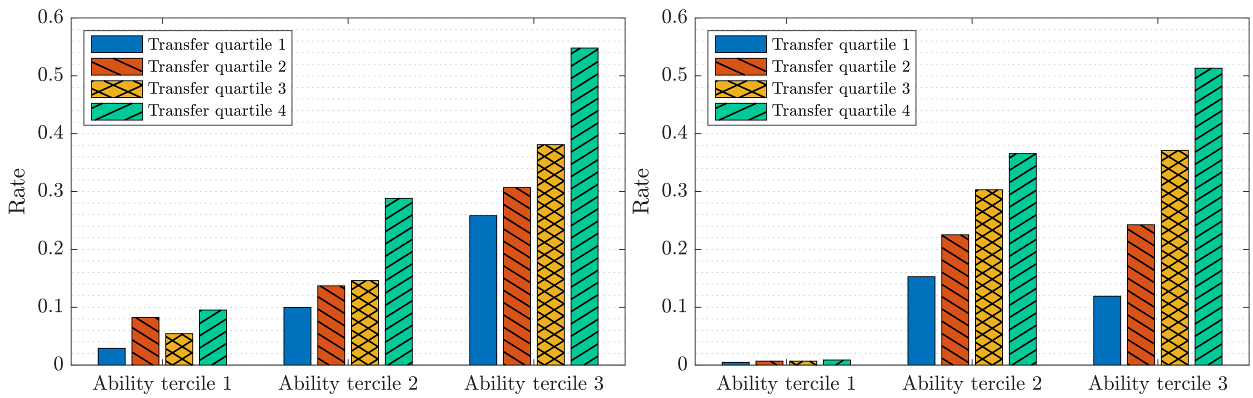
[31]Note that, in contrast to NLSY79, parental transfer information is available in the NLSY97. See Appendix A how we calculate parental transfer.

Table 3: Untargeted moments

Moment	Data	Transition(1997)
Aggregate college completion rate (%)	21	20
Total outstanding student debt (in billions)	\$179.77	\$184.60
Average parental transfers	\$4,618	\$4,454
Graduating seniors with std debt (%)	56	68
Average cumulative std debt upon graduation	\$11,562	\$14,241
Delinquency rates in 1980s-1990s(%)	17 − 20%	12%

Note: The total outstanding student debt in 1997 is obtained from Looney and Yannelis (2015), and the delinquency rates are obtained from (Volkwein et al., 1998). All other remaining moments are estimated from the NLSY97.

Figure 7: College completion rates in 1997

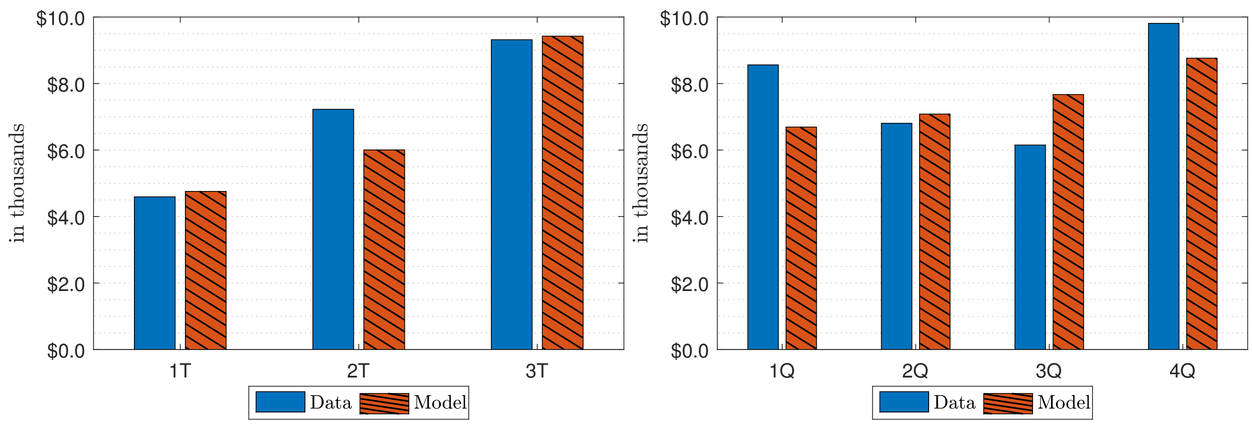


(a) Data (b) Model

Note: College completion rates by ability and parental transfers in the NLSY97 (left) and the model economy in 1997 (right). In the NLSY97, the college completion rate is measured as the percentage of individuals between age 12 and 18 in 1997 whose enrollment status is reported as either a 2-year college graduate or a 4-year university graduate by 2007, multiplied by the college drop-out rate.

In Figure 8, we compare the distribution of the average net paid tuition in the NLSY97 to that in the model across ability terciles (left) and parental transfer quartiles (right). In the NLSY97, we calculate the net paid tuition following Gordon and Hedlund (2020), using the information on financial aid from family and friends; loans from family and friends, grants and scholarship, federal and other student loans, work-study financial aid, employer assistance financial aid, other financial aid, and out of pocket spending. Importantly, the observed net paid tuition and fees are higher for the students from higher ability tercile group and the fourth parental transfer quartile group, reflecting heterogeneous costs of college education across individuals. This is driven by the fact that the students with high ability or from rich families are more likely to attend a top-quality college that charges high tuition.[32]

Figure 8: Net tuition and fees in 1997



(a) over ability terciles (b) over parental transfer quartiles

We further examine how students finance their college education in the model and the data. Figures 9 (a) and (b) present the average hours worked per week by college students over ability terciles and parental transfer quartiles. It shows that students from different ability and parental transfer groups work for similar hours per week. Figures 9 (c) and (d) show the average cumulative student debt at graduation over ability terciles and parental transfer quartiles.[33] In the NLSY97, a significant amount of student debt is held by the individuals across all ability terciles and parental transfer quartiles. Furthermore, borrowing amount is increasing in ability and parental transfers. Without targeting, the model reproduces these facts fairly well, except for the borrowing behavior of the first ability tercile group. Agents in the first ability group do not borrow in the

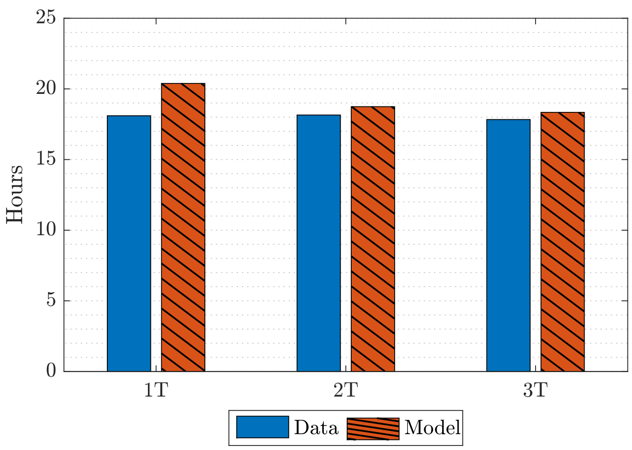
[32]Cai and Heathcote (2019) show that the increasing income inequality in the U.S. for recent decades has increased the tuition as well as households' willingness to pay for high-quality colleges.

[33]The NLSY97 reports the amount of student loans that an individual takes for each institution and academic term. For each individual, we sum all the student loans across terms, years, and institutions until graduation and divide it by the number of years enrolled in college to calculate the yearly average. To calculate the cumulative student debt at graduation, we multiply the yearly average of student loans by 4 in Figures 9 (c) and (d). See Appendix A for more details.

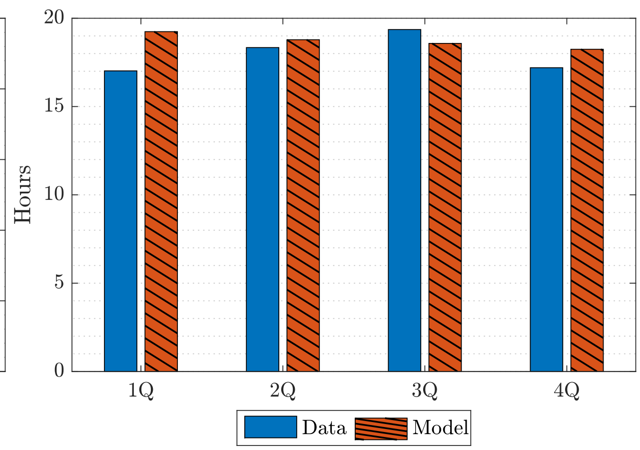
model. This is because individuals who pursue college education in this ability group are either from rich families that offer large parental transfers or pay little net tuition.

Overall, labor income is the primary financing source for college students with relatively low ability and parental transfers. This is due to the fact that these individuals can borrow less amount from the future income given the high persistence in their labor productivity. In contrast, college students with high ability and large parental transfers rely more on parental transfers and student loans to finance their education.

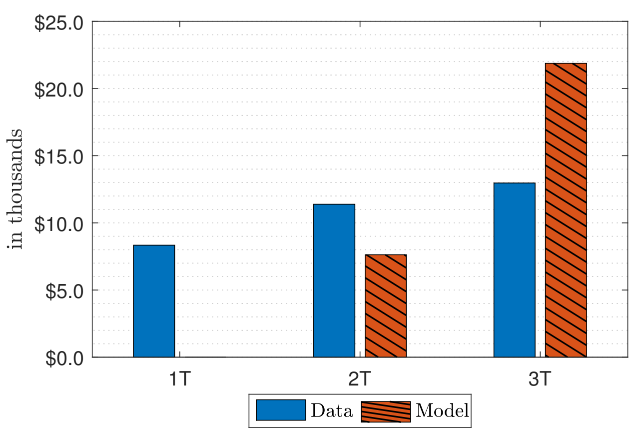
Figure 9: Distribution of labor supply and student debt over parental transfers and ability



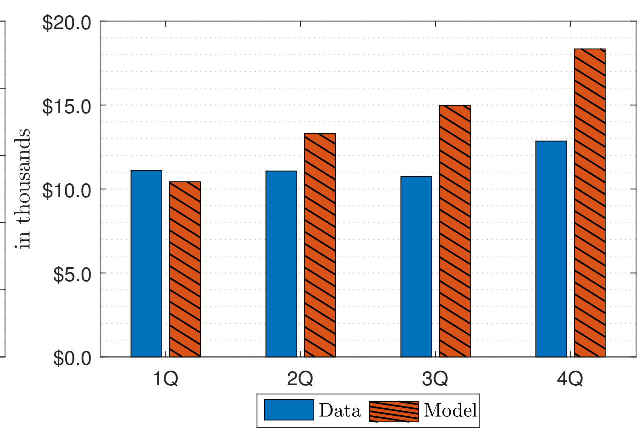
(a) Labor supply over ability tertiles



(b) Labor supply over parental transfer quartiles



(c) Average debt over ability tertiles



(d) Average debt over parental transfer quartiles

Note: The two top figures show the average hours worked per week by college students over ability terciles (left) and parental transfer quartiles (right). The bottom two figures show the average accumulated student debt until graduation by college students over ability terciles (left) and parental transfer quartiles (right).

5.2 Dynamics of student debt, college choice, and borrowing

In this section, we present the results from transitional dynamics. Figure 10 shows the dynamics of the aggregate student debt (top) and the fraction of the student debt held by individuals under age 30 over time (bottom). As shown in Figure 10 (a), the rising wage inequality and net tuition and fees increase the aggregate student debt from 51 billion dollars in 1979 to 420 billion dollars in 2015, explaining 50 percent of the observed student debt in the U.S. in 2015 (see Figure 1). Importantly, the increase in student debt in the model is largely driven by student debt held by individuals under age 30. As seen in Figure 10 (b), the amount of student debt held by these individuals increases from 30 billion dollars in 1979 to 280 billion dollars in 2015, accounting for 67 percent of the total increase in the model.

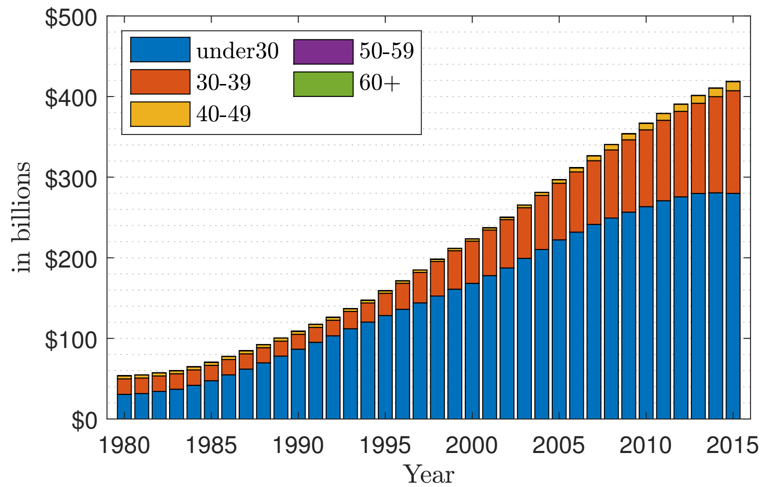
As seen in Figure 11, the rise in aggregate student debt in the model is broadly consistent with the observed dynamics of college completion rates, average cumulative student debt at graduation, and the fraction of graduating seniors with student debt. First, the time-varying wage inequality and college costs increase the college completion rates by 5 percentage points in the model from 1979 to 2015, compared to approximately 12 percentage points increase in the data.[34] Second, the model successfully explains the increase in the average cumulative student debt at the graduation. For example, the average student debt held by college graduates increases from $3,000 in 1979 to $20,000 in 2015. Lastly, though overpredicted, the model reproduces the increasing share of college students who borrow government student loans fairly well. Note that, in the model, there is no increase in parental transfers and labor income during college.[35] With rapidly increasing college costs, students cannot afford the college education without taking student loans. This leads all college students to borrow students loans in the model by 2005.

[34]In the model, the time-varying benefits of a college education are only captured by the wage inequality. However, there are other benefits for college-educated workers in the real world, such as better job security and amenities. In the absence of these, the model only reproduces half of the empirical increase in college completion rates.

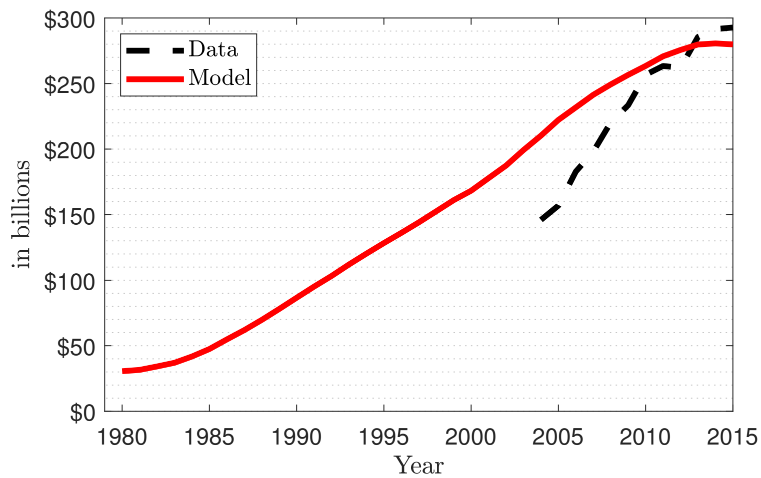
[35]College workers receive the hourly wage for unskilled workers, which is fixed over time.

In sum, the increases in college costs and wage inequality from 1979 can account for the half of the observed rise in student debt in the U.S. Also, these sources can explain much of the changes in college choice and borrowing behavior seen in the data. However, college costs and wage inequality are not enough to understand the rise in student debt held by the individuals over age 30. This implies that a significant fraction of the observed increase in student debt in the U.S is driven by the changes in the repayment behavior of existing borrowers, which is not captured by the increases in wage inequality and college costs.

Figure 10: Dynamics of student debt over the transition



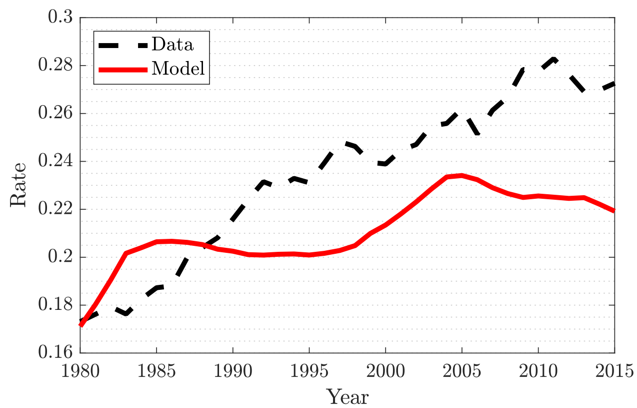
(a) Aggregate student debt (model)



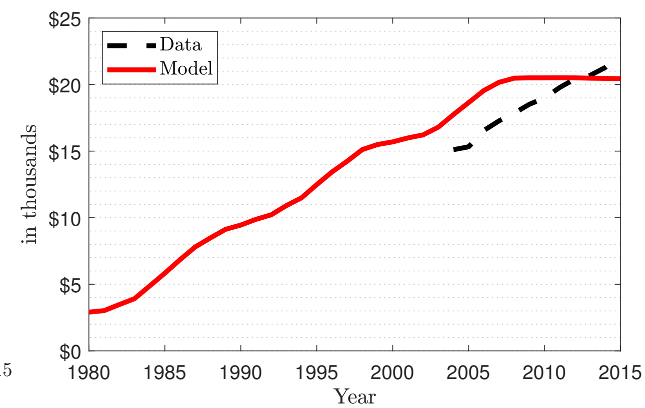
(b) Total student debt held by individuals under age 30

Note: The dynamics of aggregate student debt over the transition (top) and the dynamics of student debt held by individuals under age 30 (bottom).

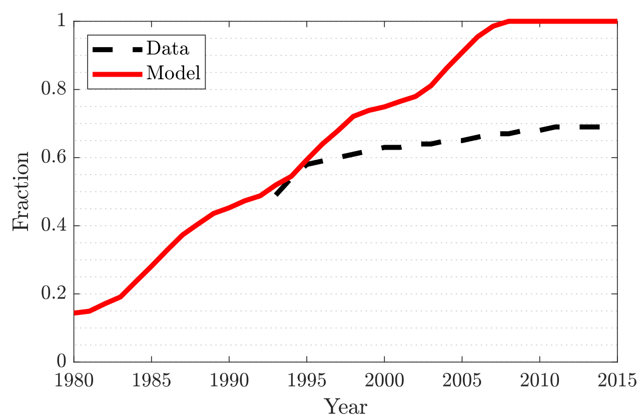
Figure 11: Changes in college choice and borrowing behavior



(a) College completion rate



(b) Average student debt at graduation



(c) Fraction of graduating seniors with student debt

Note: Figure 11 compares (a) college completion rate; (b) the annualized average student debt at the graduation; and (c) the fraction of college graduates with student debt from the model and data. For the data moments, college completion rates are from the NCES and NLSY97. Average student debt at graduation and the fraction of graduating seniors with student debt are from the National Postsecondary Student Aid Study (NPSAS).

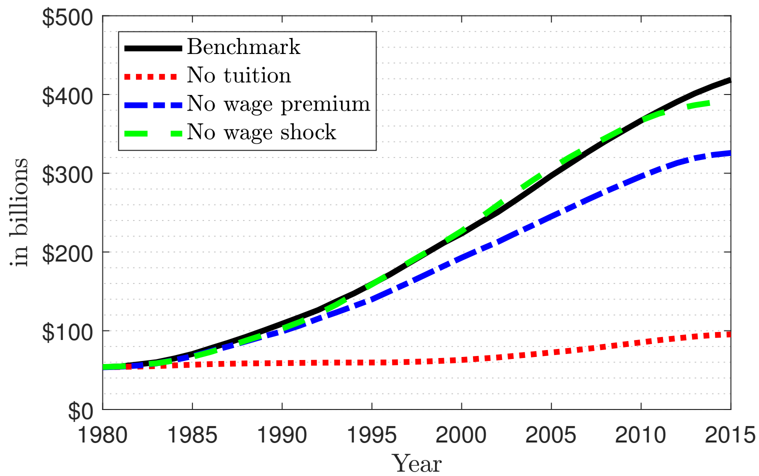
5.3 Decomposition exercise

To examine how each time-varying source affects the aggregate student debt, we conduct counter-factual experiments where we remove one of the time-varying components each time. In Figure 12, we show the dynamics of total student debt (top) and the total number of borrowers (bottom). As seen in Figure 12, the rapidly increasing college costs play a vital role in driving up the total student debt and total number of borrowers. In the absence of rising college tuition, the total student debt only increases by 100 billion dollars in 2015 instead of 400 billion dollars in the benchmark economy. Furthermore, without college becoming more expensive, the total number of borrowers only increases by 2 millions between 1979 and 2015, compared to 20 millions in the benchmark economy.

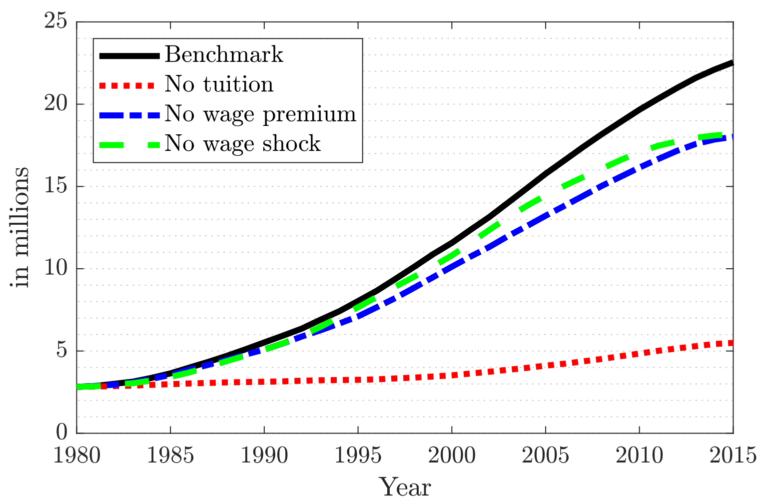
Figure 13 shows the dynamics of college completion rates, the average student debt of college graduates, and the fraction of college graduates with student debt in counterfactual experiments. First, the rising college wage premium is essential for the rising college completion rate in the model. As seen in Figure 13 (a), in the absence of the observed college benefit, individuals are less likely to pursue a college degree, especially when the costs of college are rising steep. This explains a weaker increase in total student debt and the number of borrowers in Figure 12 when college wage premia are held constant. Second, when the variances of wage shock do not rise, the college completion rate decreases. This is consistent with the findings in Kim (2021) and Heathcote et al. (2008) that, with sufficiently elastic labor supply, a rise in unobserved wage dispersion can be welfare-improving for skilled workers.[36] Third, without the rising college costs, there is a further increase in college completion rate from the benchmark level. Lastly, it is crucial to note that the borrowing behavior of college students is largely determined by the college tuition. As seen in Figures 13 (b) and (c), the rising college tuition is the

[36]This is due to the fact that income effects dominate substitution effects with the coefficient relative risk aversion greater than one. A more volatile wage shock implies a higher probability of both favorable and unfavorable wage shocks. As elastic labor supply allows households to insure themselves against downside wage risk by increasing their hours worked, the more volatile wage shock, especially for persistent component of wage shock, leads to a higher expected labor income (see Kim (2021)).

Figure 12: Decomposition of total student debt and total number of borrowers



(a) Aggregate student debt

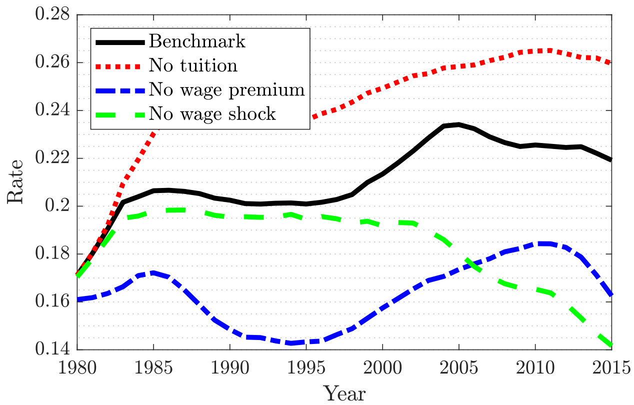


(b) Total number of borrowers

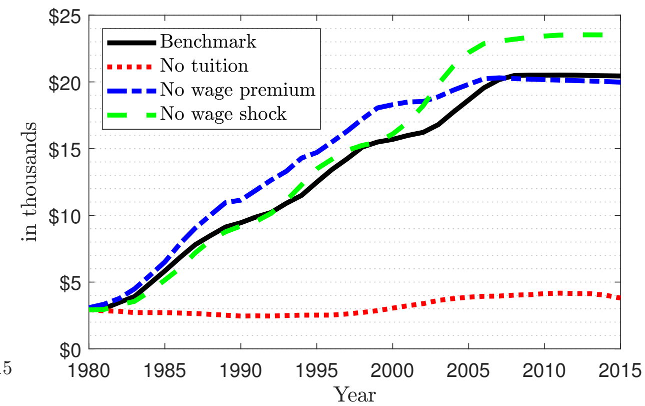
Note: Figure 12 shows the dynamics of aggregate student debt over the transition (top) and the dynamics of total number of student debt holders (bottom). The black solid line is the benchmark economy. The blue dash-dot line is the economy without time-varying college wage premia. The green dashed line is the economy without time-varying wage shock process. The red dotted line is the economy without time-varying college tuition.

main source for determining students' borrowing decisions and the amount of students loans taken for their education.

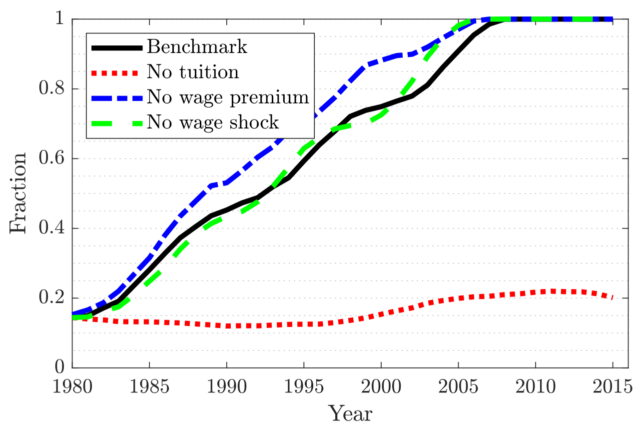
Figure 13: Changes in college choice and borrowing behavior



(a) College completion rate



(b) Average student debt at graduation



(c) Fraction of graduating seniors with student debt

Note: Figure 13 shows (a) college completion rate; (b) the annualized average student debt at the graduation; and (c) the fraction of college graduates with student debt. The black solid line is the benchmark economy. The blue dash-dot line is the economy without time-varying college wage premia. The green dashed line is the economy without time-varying wage shock process. The red dotted line is the economy without time-varying college tuition.

6 Welfare implications

The significant changes in the benefits and costs of college encourage us to conduct welfare analysis for college-educated individuals over time. We measure welfare changes by computing the percentage change in lifetime consumption required to make a cohort in the steady-state indifferent between going to college in year t and the steady-state. Defining $\{\mathbf{c}, \mathbf{n}\}$ as the distribution of lifetime sequences of consumption and hours worked, the consumption equivalent variation (CEV) welfare change for individuals who go to college in year t is the value ϑ_t that solves the following:

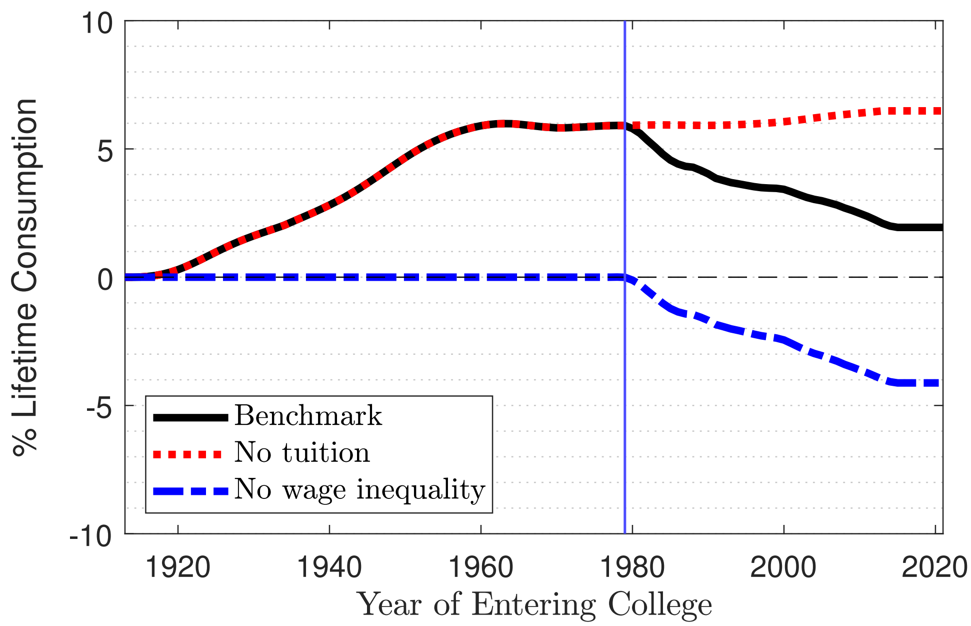
$$\int_{\mathbf{S}} \sum_{j=1}^{J} u((1+\vartheta_t)\mathbf{c}_{j,*}, 1-\mathbf{n}_{j,*})\mu_{h,*}(d\mathbf{S}) = \int_{\mathbf{S}} \sum_{j=1}^{J} u(\mathbf{c}_{j,t}, 1-\mathbf{n}_{j,t})\mu_{h,*}(d\mathbf{S}) \tag{10}$$

where $*$ indicates the steady state and $\mu_{h,*}$ is the distribution of skilled households in the steady-state. The distribution is defined over the state space $\mathbf{S}$.

Figure 14 plots the average welfare change of cohorts over the year they enter the college. For example, a cohort that enters the college in 1969 will face the steady state level of college costs and wage inequality until 1979 but will face the time-varying of these afterwards. We present welfare changes in three different economies: benchmark economy, the model without changes in wage inequality, and the other with college costs held constant over time.

Figure 14 first shows that the rising wage inequality is welfare-improving for cohorts who enter the college until 1979, relative to the initial steady state. This is expected as individuals face the same distribution of college education costs as the initial steady-state until 1979 but earn higher hourly wages after 1979. Note that, in the absence of rising college costs, the increasing wage inequality leads to a welfare gain of more than 5% of lifetime consumption in the long-run. However, the increasing college costs from 1980 sharply reduce welfare gains from rising wage inequality for those who enter the college after 1979. In net, the combined effect of rising wage inequality and college costs results in positive welfare gain of 2% of lifetime consumption, partly explaining why individuals pursue a college degree despite the high tuition.

Figure 14: Average welfare changes



Note: The average welfare change relative to the initial steady state, cohort by cohort.

7 Conclusion

This paper evaluates the quantitative effects of rising college tuition and fees and wage inequality on the growing student debt in the U.S. We build an incomplete-markets OLG model with college education choice, student debt, and delinquency choice on student debt. Solving transitional dynamics with the estimated increases in college costs and wage inequality, we find that these natural suspects can lead to 50% of the observed rise in the total student debt. These sources mainly affect the college choice and borrowing behavior of college students, accounting for a significant fraction of the increase in student debt held by individuals under age 30. However, college costs and wage inequality rarely affect the repayment behavior of existing borrowers and thus the dynamics of student debt held by individuals over age 30. Crucially, these results suggest the importance of other sources, such as financial shock that may affect the repayment behavior of borrowers, for understanding the remaining rise in the student debt in the U.S.

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A National Longitudinal Survey of Youth (NLSY79 and NLSY97)

The NLSY79 consists of 12,686 individuals whose ages are between 14 and 22 in 1979, and the NLSY97 consists of 8,984 individuals whose ages are between 12 and 18 in 1997. We only use nationally representative samples and exclude supplemental samples.[37] We drop individuals with 1) no ability information, 2) no family income information in NLSY79, 3) no parental transfer information in NLSY97, and 4) education higher than bachelor's degree. We include individuals who graduated from college by 2007. The final sample size is 4,473 for the NLSY79 and 5,039 for the NLSY97.

We measure ability using the Armed Forces Qualification Test (AFQT) score for the NLSY79 and the the Armed Forces 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. In the NLSY79, given that the college enrollment status is not available, an individual is college educated if he or she completed at least 16 years of education by 1988.[38] For the NLSY97 cohort, we define an individual as college educated if he or she is either a 2-year college graduate or a 4-year university graduate by 2007 based on the current enrollment status.

Following Abbott et al.(2019), parental transfers are measured as all transfers 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 three types of parental transfers: trans-

[37]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.

[38]The year 1988 is chosen to take into account the possible graduation year given the individuals' age in 1979.

fers from both parents (or guardians), transfers from a living mother figure (or female guardian), and transfers from a living father figure (or male guardian). We measure parental transfers for respondents who live with both parents using transfers from both parents. If respondents do not live with both parents, then we sum the amounts from both a living mother figure and a living father figure. If respondents live with parents and do not pay rent, we include the average amount of rent by age groups. We compare this parental transfers measure with the amount of family aid reported in Education section of the NLSY97 and use the maximum of the two.[39]

The Education section of the NLSY97 provides the amount of student loans that an individual borrows for every school and academic term attended in a given year. 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 the years of education and dividing it by the total number of years enrolled in college. To make data moments comparable to the model, we multiply the yearly average of student loans by 4 to get the total amount of student loans accumulated during the college education.

We estimate the weighted average net tuition following **?**. The NLSY97 provides the eight different sources individuals use to finance their education for every school and academic term attended in a given 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 ($YSCH\_26000$)
6. Employer assistance financial aid ($YSCH\_26200$)

[39] As noted in Abbott et al.(2019), the family aid in Education section are not fully consistent with the parental transfers in Income section, have many skips, and do not cover all transfers.

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

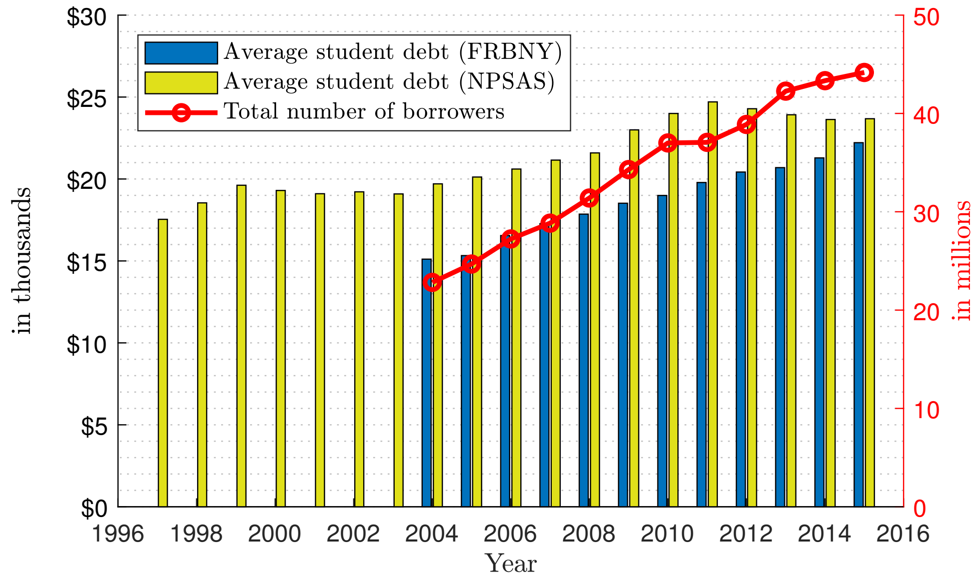
8. Out of pocket spending ($YSCH\_26500$)

Given these measures at a given year and school, we first identify whether an individual reports any changes in how he or she financed the attendance 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 full-time and 0.5 if an individual was part-time at the given term. Finally, for each school in a given year, we compute the average amount of each financing source across terms. Then, we compute the average across 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 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 tuition is obtained by subtracting the average amount of grant and scholarship from the average sticker tuition.

Lastly, in the NLSY97, we calculate the average weekly hours worked in college by dividing the annual hours worked during the 2-year or 4-year college enrolled years by 52.

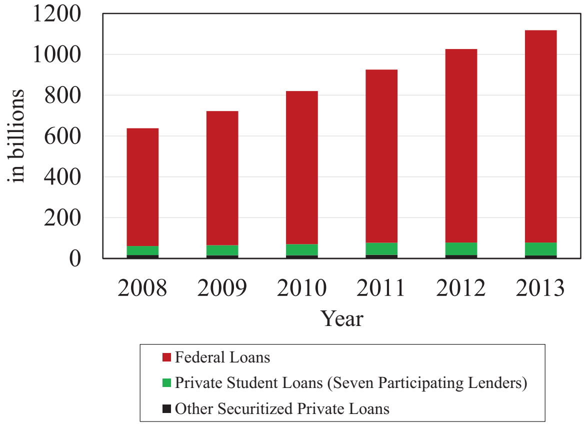
B Additional Figures and Tables

Figure B1: Number of borrowers and average student debt

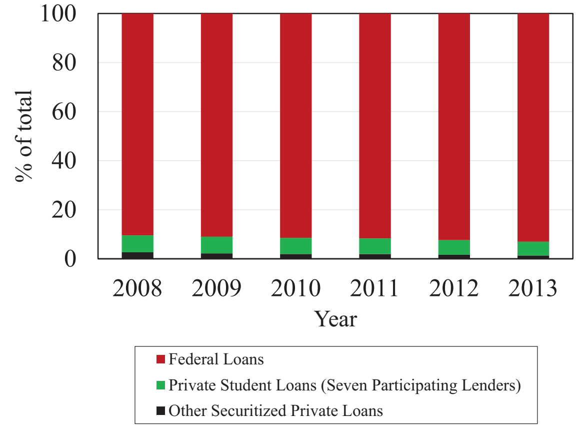


Source: The data for the average student debt per borrower is from both the National postsecondary student aid study (NPSAS) and the New York Fed Consumer Credit Panel. The total number of borrowers is from the New York Fed Consumer Credit Panel data. All the values are expressed in 2004 U.S. dollars.

Figure B2: Composition of outstanding student loans



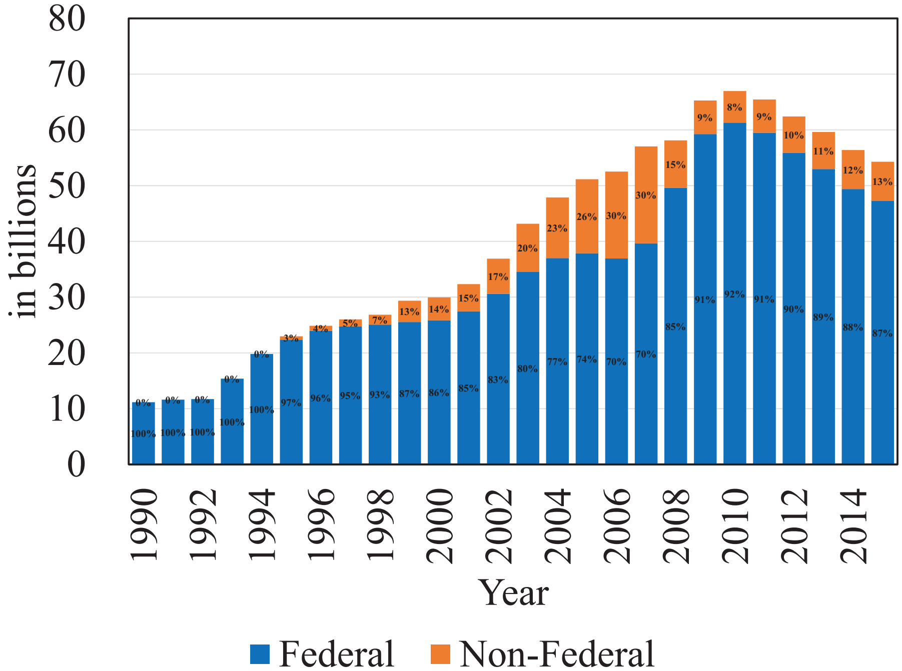
(a) In current dollars



(b) As a fraction of total debt

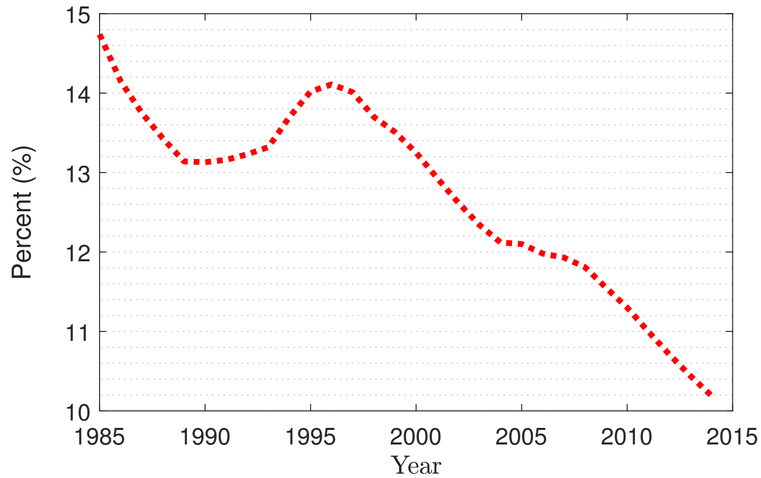
Source: The 2013 MeasureOne Private Student Loan report. Notes: In July 2012, the Department of Education and the Consumer Financial Protection Bureau (CFPB) released a study of the private education loan market based, in part, on data submitted by nine major private education lenders. The 2013 MeasureOne 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 B3: Annual amount of disbursed loans to undergraduate students

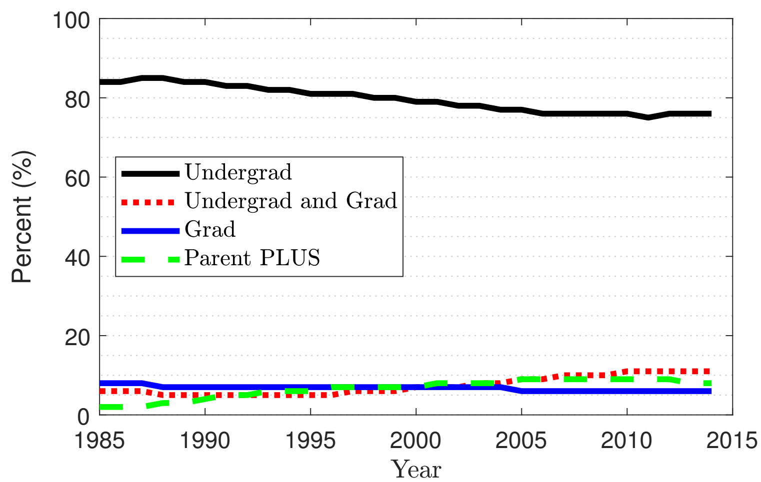


Source: College Board (2018). Expressed in 2004 U.S. dollars.

Figure B4: 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 B4 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.