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# Job Search under Debt: Aggregate Implications of Student Loans☆

Yan Ji

*Room 5005, Department of Finance, LS K Business Builiding Hong Kong, Clear Water Bay Hong Kong*

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ABSTRACT

A dynamic equilibrium model of schooling, borrowing, and job search is developed to quantify the aggregate implications of student loans. In my model, risk-averse agents under debt tend to search less and end up with lower-paid jobs. Calibrating the model using micro data, I show that student loans have significant effects on borrowers' job search decisions under the fixed repayment plan. The income-based repayment plan (IBR) largely alleviates the burden of debt repayment by insuring labor market outcomes, allowing borrowers to conduct a more adequate job search. In general equilibrium, IBR also increases social welfare by encouraging college attendance.



## 1. Introduction

These days Americans are more burdened by student debt than ever. Over the past decade, student loans have more than quadrupled, becoming the second largest type of consumer debt in the U.S. after mortgages (see Figure 1). The increasing student debt is accompanied by the rising default rates due to the growing number of student loan borrowers who experienced poor labor market outcomes during and soon after the recession (Looney and Yannelis, 2015). Given the intimate connection between labor market outcomes and defaults, understanding how debt repayment affects borrowers' job search strategies is crucial.

☆ Yan Ji, LSK 5005, Department of Finance, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong. Email: jiy@ust.hk. Tel: 852-23588298. I am very grateful to my advisers Robert Townsend, Alp Simsek, and Abhijit Banerjee for invaluable guidance, support, and encouragement. I have particularly benefited from the detailed comments of Daron Acemoglu, Dean Corbae, Simon Gilchrist, John Haltiwanger, Kyle Herkenhoff, Urban Jermann, Arvind Krishnamurthy, Rasmus Lentz, Benjamin Moll, Ananth Seshadri, John Shea, Gianluca Violante, and Randy Wright. I also thank Boragan Aruoba, Adrien Auclert, Jie Bai, Scott Baker, David Berger, Vivek Bhattacharya, Nicolas Crouzet, Winston Dou, Esther Duflo, Ernest Liu, Hanno Lustig, Monika Piazzesi, David Matsa, Christopher Taber, Fabrice Tourre, Constantine Yannelis and seminar participants at MIT, University of Wisconsin Madison, Stanford, Northwestern, University of Maryland, HKU, Tsinghua, HKUST, the 2017 Barcelona GSE summer forum on search and matching, the 2017 HKUST Workshop on Macroeconomics, the 2017 SED Conference, the 2018 AFR conference, and the 2018 CICM for very helpful suggestions. I thank Songyuan Teng for excellent research assistance. Any errors are my own.

*E-mail address:* yanji.mit@gmail.com

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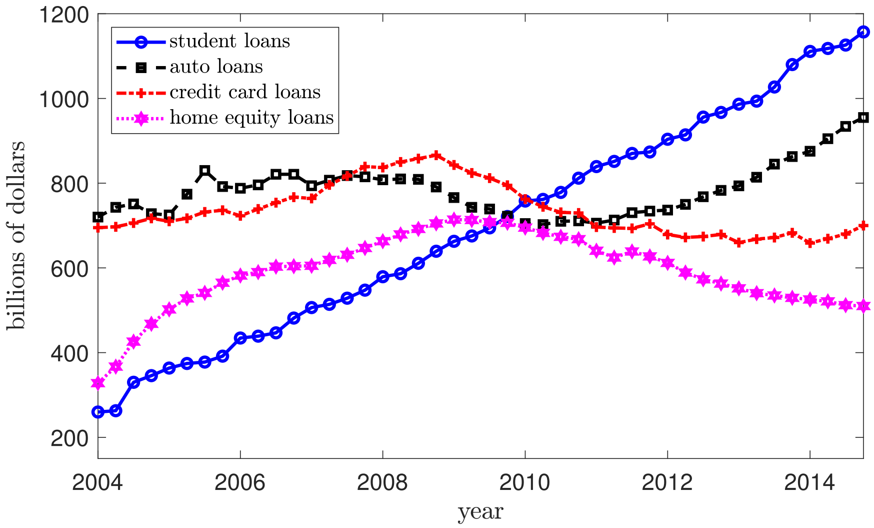


**Fig. 1.** Non-mortgage balances, 2004Q1 – 2014Q3. Note: The largest type of consumer debt, mortgage debt, had a balance of about 13 trillion in 2014 and is not plotted in this figure. Data source: Federal Reserve Bank of New York's Consumer Credit Panel (New York Fed, 2015).

The escalation of student debt has brought widespread concerns about its aggregate implications. However, measuring the aggregate effects of student loans on employment outcomes and social welfare presents a challenge. Both borrowing and job search decisions are endogenous, and depend on the job vacancies created by firms. Although we can measure the local effects of student loans using reduced-form empirical techniques, evaluating their aggregate magnitude and comparing their welfare implications across different policy regimes require an economic model. These challenges lend themselves to a structural approach. In this paper, I develop a life-cycle general equilibrium model of heterogeneous agents who finance their schooling with student loans and make decisions on consumption, loan repayment, and job search after college.

The key mechanism I propose is that risk-averse agents with debt tend to spend less time searching for a job and end up with lower-paid jobs. My main contribution lies in presenting a rich quantitative framework to evaluate the strength of this mechanism and the welfare implications of student loans under different repayment plans. I demonstrate that modeling borrowers' endogenous job search decisions plays a quantitatively important role in assessing the welfare effects of student loans. The intuition is as follows. Students with debt are more risk averse and liquidity constrained. When access to credit is tightened, the labor market offers its own version of insurance and liquidity provision by allowing borrowers to change their job search decisions. Thus neglecting this option underestimates the welfare effect of student loans as all borrowers would be forced to face some exogenously specified labor income process. This insight is related to existing work. For example, Herkenhoff (2019) and Herkenhoff et al. (2019) show that giving displaced workers access to credit significantly increases their nonemployment duration and wage income. An extensive body of literature investigates how unemployment benefits (e.g., Acemoglu and Shimer, 1999; Hansen and Imrohoroglu, 1992; Ljungqvist and Sargent, 1998) and private savings (e.g., Danforth, 1979; Lentz, 2009; Lise, 2013; Rendon, 2006) affect employment incentives.

My main quantitative exercise suggests that, under the standard fixed repayment plan, student debt repayment significantly reduces borrowers' average unemployment duration and wage income. Such a significant change in borrowers' job search outcomes is informative about the burden of debt repayment. My simulations suggest that the income-based repayment plan (IBR) largely alleviates the debt burden, motivating a more adequate job search and encouraging college studies. Quantitatively, my model implies that the IBR passed by Congress in 2009 increases the social welfare by about 1.79%, among which 0.61% is attributed to alleviating the debt burden after college and 1.18% to encouraging college attendance.

My quantitative model is an equilibrium search model (e.g., Herkenhoff, 2019; Krusell et al., 2010; Lise et al., 2016) that incorporates college entry and borrowing decisions. I explicitly model the key institutional details of the U.S. federal student loan program. There are two major repayment plans: the standard fixed repayment plan which requires borrowers to repay the same amount every month; and IBR which allows borrowers to repay based on a fraction of their income. In the model, risk-averse agents decide whether or not to enter college and finance college expenses by taking out student loans. After graduation, agents search for jobs in the labor market and receive wage offers from firms of different productivity levels. Agents decide whether to accept a wage offer or continue their search for a potentially higher-paid job.

The model implies that a higher level of debt induces agents to take less search risk by accepting a job more quickly, which is more likely to be lower paid. This is because agents are risk averse and job search risk is not perfectly insured in an incomplete market. The imperfect insurance of search risk implies a tradeoff between risks and returns, as a longer search increases both expected wage income and search risk. When debt is higher, agents become more liquidity constrained and thus consume less. Their aversion to search risk increases and they alleviate the liquidity constraint by accepting a job more hastily.

To evaluate the quantitative importance of this mechanism, I calibrate the model based on panel data from the National Longitudinal Survey of Youth 1997 (NLSY97). My calibrated model implies that the impact of student debt on labor market outcomes is quantitatively important. On average, borrowers spend 0.9 weeks fewer searching for their first jobs and earn about $1,479 less in the first year after college graduation than non-borrowers. The significant effects of student debt are also observed in the data. Running OLS regressions on the NLSY97 sample, I find that a $10,000 increase in the amount of student debt is associated with a decrease in the duration of the first unemployment spell by about 1.41 – 1.57 weeks and a decrease in the annual wage income by about 2.7% – 4.0% in the first three years after college graduation.

The significant difference in employment outcomes between borrowers and non-borrowers has twofold implications. First, neglecting borrowers' endogenous job search strategies underestimates the welfare benefit of providing student debt. My simulation suggests that if borrowers are restricted to the same income process as non-borrowers, the default rate would rise by 5.75% and the expected welfare of a newborn agent would decline by 0.59%. Second, the standard fixed repayment plan places a large burden on borrowers, which explains their job search strategies.

In fact, the government can alleviate the debt burden by restructuring debt repayment and one way to achieve it is by providing IBR. My model simulations suggest that IBR largely increases borrowers' average wage income by allowing them to optimally spend more time on their job search. Quantitatively, the expected welfare of a newborn agent increases by 1.79% and the default rate drops to zero. Intuitively, IBR offers insurance against job search risk, allowing borrowers to better smooth consumption and conduct a more adequate job search. This sort of insurance, which comes with loan repayment plans, is helpful precisely because indebted young borrowers have limited access to credit and insurance in the market.

Even though the proportional repayment under IBR generates an income-tax-like effect that reduces borrowers' labor supply, my model implies that the average labor supply under IBR is higher both because borrowers are matched with more productive jobs and because the college attendance rate is higher. My simulation further indicates that the repayment cap imposed by IBR plays an important role in limiting the income-tax-like effect on borrowers' labor supply.

Finally, I shed light on the specific channels through which IBR improves social welfare. By fixing the distribution of agents entering the labor market, I find that IBR increases social welfare by about 0.61% by insuring labor market outcomes after college whereas the remaining 1.18% welfare gains are attributed to higher college attendance. In addition, I find that both the longer repayment period and the insurance of labor market outcomes play important roles in alleviating the debt burden. If we only extend the repayment period of the fixed repayment plan from 10 years to 25 years, the increase in social welfare would be a mere 1.21% because borrowers would still need to repay their loans during unemployment, when they are highly liquidity constrained.

*Related Literature.*

Existing studies have considered how individuals' job search decisions are affected by liquidity and risk. For example, an extensive body of literature investigates how unemployment benefits and private savings affect employment incentives (e.g., Acemoglu and Shimer, 1999; Danforth, 1979; Hansen and Imrohoroglu, 1992; Lentz, 2009; Lise, 2013; Ljungqvist and Sargent, 1998; Rendon, 2006). Recently, researchers have started considering the labor market implication of other consumption smoothing mechanisms such as intra-household insurance (e.g., Guler et al., 2012; Kaplan, 2012), credit access (Herkenhoff, 2019; Herkenhoff et al., 2019), the housing market (Brown and Matsa, 2016), mortgage modifications (Herkenhoff and Ohanian, 2015; Mulligan, 2009), and default arrangements (Dobbie and Song, 2015; Herkenhoff and Ohanian, 2015). My paper contributes to this line of research by explicitly modeling and quantitatively evaluating the implications of student debt on job search behavior and the mechanism of consumption smoothing offered by different repayment plans.

This paper also contributes to the literature on student loans (see Lochner and Monge-Naranjo, 2016, for a recent survey). Much of this literature focuses on the impact of financial aid during college (e.g., Abbott et al., 2018; Keane and Wolpin, 2001; Lochner and Monge-Naranjo, 2011). However, much less is known about the impact of student loans on labor market outcomes after college. The existing evidence is mixed. For example, Zhang (2013) finds an insignificant effect of student debt on early career choice such as salary and occupation. Rothstein and Rouse (2011) and Luo and Mongey (2016) find a positive effect of student debt on initial wages after graduation. Gervais and Ziebarth (2017) and Weidner (2017) find a negative effect of student debt on initial wages. Identifying the causal effect of student debt on job search outcomes is difficult, as borrowing decisions are endogenous and may be correlated with variables that influence job search outcomes. Two of the aforementioned studies address the endogeneity concerns by exploiting quasi experimental variations. Specifically, Rothstein and Rouse (2011) exploit a "no-loans" policy in an elite university under which loans are replaced with grants. Gervais and Ziebarth (2017) explore a regression kink design in need-based federal student loans. My paper complements the empirical literature on student debt by taking a structural approach to elucidate the channels through which debt affects job search and quantify the aggregate and distributional impacts of various repayment plans.

I take a structural approach to highlight one plausible mechanism that could influence indebted students' job search decisions. Abbott et al. (2018) develop a rich general equilibrium model with heterogeneous agents to evaluate education policies. My model instead emphasizes search frictions in the labor market. In addition, I use the model to evaluate IBR, which has been argued to offer risk-sharing benefits with minimal incentive costs (Stiglitz et al., 2014). Several studies have used structural models to assess income-driven repayment plans (e.g., Dearden et al., 2008; Ionescu, 2009), but none accounts for search risk in the labor market.

This paper is also related to the burgeoning literature on the connection between household debt and labor market outcomes. Previous research has discussed three plausible mechanisms. First, household credit could affect the labor market via the aggregate demand channel (e.g., Eggertsson and Krugman, 2012; Mian and Sufi, 2014). Second, households with mortgage debt engage in risk shifting by searching for higher-paid but riskier jobs (Donaldson et al., 2016). Third, borrowers tend to work in high-paid industries (Rothstein and Rouse, 2011). My paper proposes that borrowers are less picky about jobs and more likely to earn less than non-borrowers.

## 2. Model

Time is discrete and runs forever. There are $T \geq 2$ overlapping generations. Each generation has a continuum of agents of measure one. Agents live for $T$ periods deterministically and discount the future at a constant rate $\beta$. Let $c$ and $l$ denote the consumption and labor decisions of agents who derive utility in each period from

$$u(c, l) = \frac{c^{1-\gamma}}{1-\gamma} - \phi \frac{l^{1+\sigma}}{1+\sigma}. \tag{1}$$

Because I focus on the stationary equilibrium, the cohort index is omitted and the agents' problem is described in terms of age $t$. At $t = 0$, agents decide whether or not to enter college and take out student loans. At $t = 1, \ldots, T$, agents are in the labor market, either unemployed or employed; thus $t$ also captures the number of periods in the labor market.

### 2.1. College Entry and Borrowing

As my model focuses on labor market outcomes, for tractability, I consider a static schooling problem without explicitly accounting for the consumption and savings decisions during school time. At $t = 0$, agents choose whether to attend college or to just finish high school study after randomly drawing an initial wealth $b_0$, a pecuniary cost $k$ and a psychic cost $e$ of college study.[1]

Agents can finance college study by taking out student loans. In particular, wealth-constrained agents (i.e., $b_0 < k$) borrow an amount of $k - b_0$ to cover the pecuniary cost. To capture the high dropout rate in the U.S., I assume that agents who enter college graduate with probability $\psi$. College graduates have labor productivity $z_t$; college dropouts and those who choose just to finish high school have labor productivity $z_t^{\mathrm{HS}}$. The assumption that labor productivity depends on the number of periods $t$ in the labor market instead of the number of employment periods simplifies the problem as $z_t$ and $z_t^{\mathrm{HS}}$ are homogeneous across agents within the same cohort.[2] Agents enter college if the benefit from obtaining a higher labor productivity $z_t$ outweighs the cost of college study. I postpone the mathematical formulation of college entry decisions to Subsection 2.4.

### 2.2. Labor Market

Once they enter the labor market, agents are heterogeneous in terms of their education level (college or high-school degrees), wealth $b$, debt $s$, default status $d$ (see Subsection 2.3 for its description), age $t$, and wage rate $w$ per unit of labor supply (if employed). To ease notations, I use a superscript $d$ to denote default status and a subscript $t$ to denote age. Specifically, let $U_t^d(b, s)$ be the value of an unemployed agent, $W_t^d(w, b, s)$ be the value of an employed agent, and $J_t^d(w, \rho, b, s)$ be the value of a filled job with productivity $\rho$. I use an additional superscript HS for agents with high-school degrees only. In the rest of this section, I focus on a college graduate's problem.[3]

At rate $\lambda \in (0, 1)$, an unemployed agent comes across a job vacancy whose productivity $\rho$ is randomly drawn from a cumulative distribution function (CDF) $F(\rho)$. Assuming that job vacancy has zero value to the employer, when an agent comes across a job vacancy, a match occurs provided there exists a wage rate $w$, the agent is willing to accept the job (i.e., $W_t^d(w, b, s) \geq U_t^d(b, s)$) and the firm is willing to hire the agent (i.e., $J_t^d(w, \rho, b, s) \geq 0$). The wage rate $w$ is determined through Nash bargaining:

$$w_t^d(\rho, b, s) = arg\,max_w \left[W_t^d(w, b, s) - U_t^d(b, s)\right]^{\xi} J_t^d(w, \rho, b, s)^{1-\xi}, \tag{2}$$

where $\xi$ represents the agent's bargaining power. I consider long-term wage contracts (Cahuc et al., 2006; Herkenhoff et al., 2018a; Postel-Vinay and Robin, 2002) and assume that the wage rate $w$ is fixed during the agent's employment in job $\rho$.[4] The matched job produces a flow of output $z_t \rho l$, where the labor supply $l$ is endogenously chosen given the wage rate $w$.[5] When

[1] The pecuniary cost $k$ captures the tuition fees and living expenses net of scholarships and parental transfers received during college study. Having both the pecuniary cost and the psychic cost is important to capture the borrowing and college entry patterns in the data (e.g., Heckman et al., 2006; Johnson, 2013).

[2] My quantitative analysis does not depend on homogeneous labor productivity within the same cohort. A more realistic specification is to allow agents to accumulate labor productivity during employment due to learning-by-doing or on-the-job training. However, this specification makes labor productivity an additional state variable.

[3] The problem of a high school graduate or a college dropout can be formulated similarly with the superscript HS.

[4] Even with long-term wage contracts, wages may still change when there is on-the-job search (Cahuc et al., 2006; Herkenhoff et al., 2018a; Postel-Vinay and Robin, 2002), which is not considered in my model.

[5] I consider a labor contract that specifies the wage rate but not the labor supply to follow the optimal income taxation literature (e.g., Mirrlees, 1971), as later I will analyze the income-tax-like effect of IBR on labor supply.

solving the bargaining problem (2), both firms and workers internalize the impact of the wage rate $w$ on labor supply $l$, which in turn affects the value of $W_t^d(w, b, s)$ and $J_t^d(w, \rho, b, s)$.

Job separations occur in three cases: first, agents are fired exogenously by firms at rate $\kappa > 0$; second, agents may quit jobs voluntarily at a later age $t' > t$, if $U_{t'}^d(b', s') > W_{t'}^d(w_t^d(\rho, b, s), b', s')$;[6]and third, agents retire at age $T$. After job separations, agents become unemployed and jobs disappear. An unemployed agent receives Unemployment Insurance (UI) benefits $\theta$ in every period. Agents face progressive income taxes. The after-tax income is $\tilde{E} = \varkappa E^{1-\alpha}$ (Benabou, 2002), where the pre-tax income is $E = wl$ for employed agents and $E = \theta$ for unemployed agents.[7]

### 2.3. Debt Repayment and Default

I model student debt repayment to reflect the main features of the federal student loan program, which accounts for 80% of the total volume. Most federal loans give borrowers a grace period immediately after college graduation. Thus I assume that agents only start repaying their student debt at $t_0 > 1$. Student loan borrowers can choose the fixed repayment plan or IBR.[8]The interest rate is variable before July 1, 2006, and fixed thereafter. For simplicity, I apply a fixed interest rate $r_s$ to both plans.

The fixed repayment plan requires borrowers to make the same payment $y$ in each period until age $t_{\text{FIX}}$. Thus, at age $t$, if the current amount of outstanding debt is $s$, the required payment $y$ is

$$y_t^{\text{FIX}} \equiv y(s, t; \text{FIX}) = \frac{r_s}{(1+r_s)\left[1 - 1/(1+r_s)^{t_{\text{FIX}}-t+1}\right]} s, \quad \text{for } t_0 \le t \le t_{\text{FIX}}. \tag{3}$$

In principle, the agent may not be able to make the payment if her liquid wealth is less than the required payment. When this occurs, I require the agent to repay with all of her liquid wealth $b + \tilde{E}$, i.e., the payment $y$ at age $t$ is given by $\min(y_t^{\text{FIX}}, b + \tilde{E})$.[9] Following Hubbard et al. (1995), I introduce means-tested social insurance by assuming that agents receive a government transfer $\varpi = \max\{0, \underline{c} - (b + \tilde{E} - y)\}$ when their liquid wealth net of debt repayment falls below a consumption floor $\underline{c}$with $\underline{c} > 0$.

In the U.S., borrowers are enrolled in the fixed repayment plan automatically after receiving loans. Starting from 2009, qualified borrowers can apply to be enrolled in IBR. IBR requires borrowers to repay the required amount under the fixed repayment plan or a percentage $\varrho$ of their discretionary income, whichever is smaller. Discretionary income is defined as the difference between pre-tax income $E$ and 150% of the relevant poverty guideline $pov$. Borrowers are required to make payments until the loan is paid in full or until age $t_{\text{IBR}}$. After $t_{\text{IBR}}$, the remaining balance will be forgiven by the government. To reflect these features, I specify the required payment $y$ under IBR at $t$ by:

$$y_t^{\text{IBR}} \equiv y(s, t, E, y_{t_0}^{\text{FIX}}; \text{IBR}) = \min\left\{\varrho \max(E - 1.5pov, 0), \quad y_{t_0}^{\text{FIX}}, \quad s\right\}, \quad \text{for } t_0 \le t \le t_{\text{IBR}}. \tag{4}$$

By incurring a one-time disutility $\eta$, the agent can default strategically for a stochastic number of periods, during which she is not required to make any payments. Unlike other loans, student loans are practically non-dischargeable after default and thus default simply means delayed repayment. To capture this, I assume that the agent will exit the defaulting period and continue making payments at some exogenous rate $\pi$.[10]For example, under the fixed repayment plan, if the agent defaults at age $t$, she enters the defaulting period, during which no payments are made. In each subsequent period $\tau > t$, the agent has probability $\pi$ of exiting the defaulting period. Suppose the agent exits at age $t' > t$, she will continue making payments according to formula (3) for $\tau \ge t' + 1$. Because the agent does not pay from $t$ to $t'$ and interests accrue, payments after the defaulting period will increase. To be more specific, according to formula (3), the payment $y(s, t; \text{FIX})$ at $t$ increases with the current amount of outstanding debt $s$. All else being equal, if the agent is in default from $t$ to $t'$, the outstanding amount of debt $s$ at $t' + 1$ would be larger, due to the absence of debt repayment and accrued interests, resulting in larger payments for $\tau \ge t' + 1$ according to formula (3). The payment formula (3) is specified to ensure that at $t' + 1$, the outstanding amount of debt $s$ is equal to the present value of all payments $y$ from $t' + 1$ to $t_{\text{FIX}}$, discounted by the loan interest rate $r_s$. As a result, there is no principal forgiveness under the fixed repayment plan, even when defaults occur (see column 1 of Table 4 for zero forgiveness in simulation). As in Ionescu (2009), I do not allow for repeated defaults

[6] Endogenous separations may occur due to the endogenous changes in $b$, $s$, and $z_t$ over the life cycle. In the model of Herkenhoff et al. (2018a), when the worker's value from staying with the firm is lower than her value of unemployment, the wage will be renegotiated and raised to the point where the workerâs employment value equals her unemployment value so long as the gains from trade are positive. Thus, in their model, endogenous separations occur only when the gains from trade become negative. Because endogenous separations rarely occur in my simulations, adopting the more realistic specification of Herkenhoff et al. (2018a) would not change my main quantitative results.

[7] The parameter $\varkappa$ determines the overall level of taxation. The parameter $\alpha$ determines the tax progressivity. When $\alpha = 0$, the tax system has a flat marginal tax rate $1 - \varkappa$. When $\alpha > 0$, the tax system is progressive.

[8] In the U.S., student loan borrowers can also choose the graduated or extended repayment plans, which are simply variations of the fixed repayment plan. I evaluate the implication of extending repayment in Section 4.2.

[9] In my simulations, involuntary defaults rarely occur because the highest possible monthly debt repayment is about \$450 (corresponding to a borrower with \$40,000 amount of debt), lower than the after-tax monthly UI (\$565).

[10] In reality, borrowers can rehabilitate their defaulted loans after making several eligible payments. To obtain loan rehabilitation, borrowers must agree with the U.S. Department of Education on a reasonable and affordable repayment plan. The repayment plan after default is decided case by case. Generally, a monthly payment is considered to be reasonable but still affordable if it is at least 1.0% of the current loan balance. Volkwein et al. (1998) find that two out of three defaulters reported making payments shortly after the default first occurred.

by assuming that strategic default is a one-time option.[11] I use three different letters to represent different default status: $d \in \{O, I, N\}$, where $d = O$ if the agent has the one-time option to default, $d = I$ if the agent is in the defaulting period (i.e., not making payments), and $d = N$ if the agent has no default option.

## 2.4. Value Functions

After obtaining the pecuniary cost $k$, psychic cost $e$ and wealth $b_0$, agents decide whether or not to enter college at $t = 0$. As in Herkenhoff et al. (2018a), agents enter the labor market unemployed. Thus, they enter college if the value of doing so $\psi U_1^O(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}) + (1 - \psi)U_1^{O,\text{HS}}(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}) - e$ is greater than the value of not doing so $U_1^{O,\text{HS}}(b_0, 0)$.

Once agents are in the labor market, their problems are formulated recursively. The problem at the final period $t = T$ is trivial and presented in Internet Appendix E. Below, I illustrate the recursive problem for $t = 1, \ldots, T-1$. An unemployed agent with $d = N$ has defaulted before and does not have the option to default again.

$$U_t^N(b, s) = \max_{c, \underline{\rho}} u(c, 0) + \beta\left[\lambda \int_{x \geq \underline{\rho}} W_{t+1}^N(w^N, b', s')dF(x) + [1 - \lambda(1 - F(\underline{\rho}))]U_{t+1}^N(b', s')\right] \tag{5}$$

$$\text{subject to} \quad s' = (1 + r_s)(s - y), \tag{6}$$

$$b' = (1 + r)(b + \varkappa\theta^{1-\alpha} - y) - c + \varpi, \quad \text{and} \quad b' \geq -\varsigma\theta, \tag{7}$$

where the agent optimally chooses consumption $c$ and reservation job productivity $\underline{\rho}$. With probability $\lambda$, the agent comes across a job and accepts it if the job's productivity is greater than $\underline{\rho}$. The payment $y$ at $t$ is given by formulas (3) or (4) depending on the selected repayment plan. The interest rate on deposit is $r$ and the parameter $\varsigma > 0$ represents the access to consumption loans proportional to current income. Note that the wage rate $w^N \equiv w_{t+1}^N(x, b', s')$ depends on job productivity $x$ and default status $d = N$; it is endogenously determined according to equation (2).

An unemployed agent with $d = O$ decides whether or not to default in each period by solving

$$U_t^O(b, s) = \max\left\{U_t(b, s), U_t^I(b, s) - \eta\right\}, \tag{8}$$

where $U_t(b, s)$ is the value of not defaulting and $U_t^I(b, s) - \eta$ is the value of defaulting at $t$, given by

$$U_t(b, s) = \max_{c, \underline{\rho}} u(c, 0) + \beta\left[\lambda \int_{x \geq \underline{\rho}} W_{t+1}^O(w^O, b', s')dF(x) + [1 - \lambda(1 - F(\underline{\rho}))]U_{t+1}^O(b', s')\right], \tag{9}$$

subject to constraints (6) and (7).

$$U_t^I(b, s) = \max_{c, \underline{\rho}} u(c, 0) + \beta\pi\left[\lambda \int_{x \geq \underline{\rho}} W_{t+1}^N(w^N, b', s')dF(x) + [1 - \lambda(1 - F(\underline{\rho}))]U_{t+1}^N(b', s')\right]$$

$$+ \beta(1 - \pi)\left[\lambda \int_{x \geq \underline{\rho}} W_{t+1}^I(w^I, b', s')dF(x) + [1 - \lambda(1 - F(\underline{\rho}))]U_{t+1}^I(b', s')\right], \tag{10}$$

$$\text{subject to} \quad s' = (1 + r_s)s, \tag{11}$$

$$b' = (1 + r)(b + \varkappa\theta^{1-\alpha}) - c + \varpi \quad \text{and} \quad b' \geq -\varsigma\theta, \tag{12}$$

where the default status may change from $d = I$ to $d = N$ at $t + 1$ with probability $\pi$.

Employed agents may quit their jobs voluntarily or be fired exogenously by their firms at rate $\kappa$. The default decisions involve similar recursive formulations. I thus illustrate the recursive problem with $D = N$ below and leave the other two cases to Internet Appendix C.2.

$$W_t^N(w, b, s) = \max_{c, l} u(c, l) + \beta\left[\kappa U_{t+1}^N(b', s') + (1 - \kappa)\max\{W_{t+1}^N(w, b', s'), U_{t+1}^N(b', s')\}\right] \tag{13}$$

$$\text{subject to} \quad s' = (1 + r_s)(s - y), \tag{14}$$

[11] In practice, loan rehabilitation is a one-time opportunity, and more severe punishments are imposed on borrowers who default repeatedly.

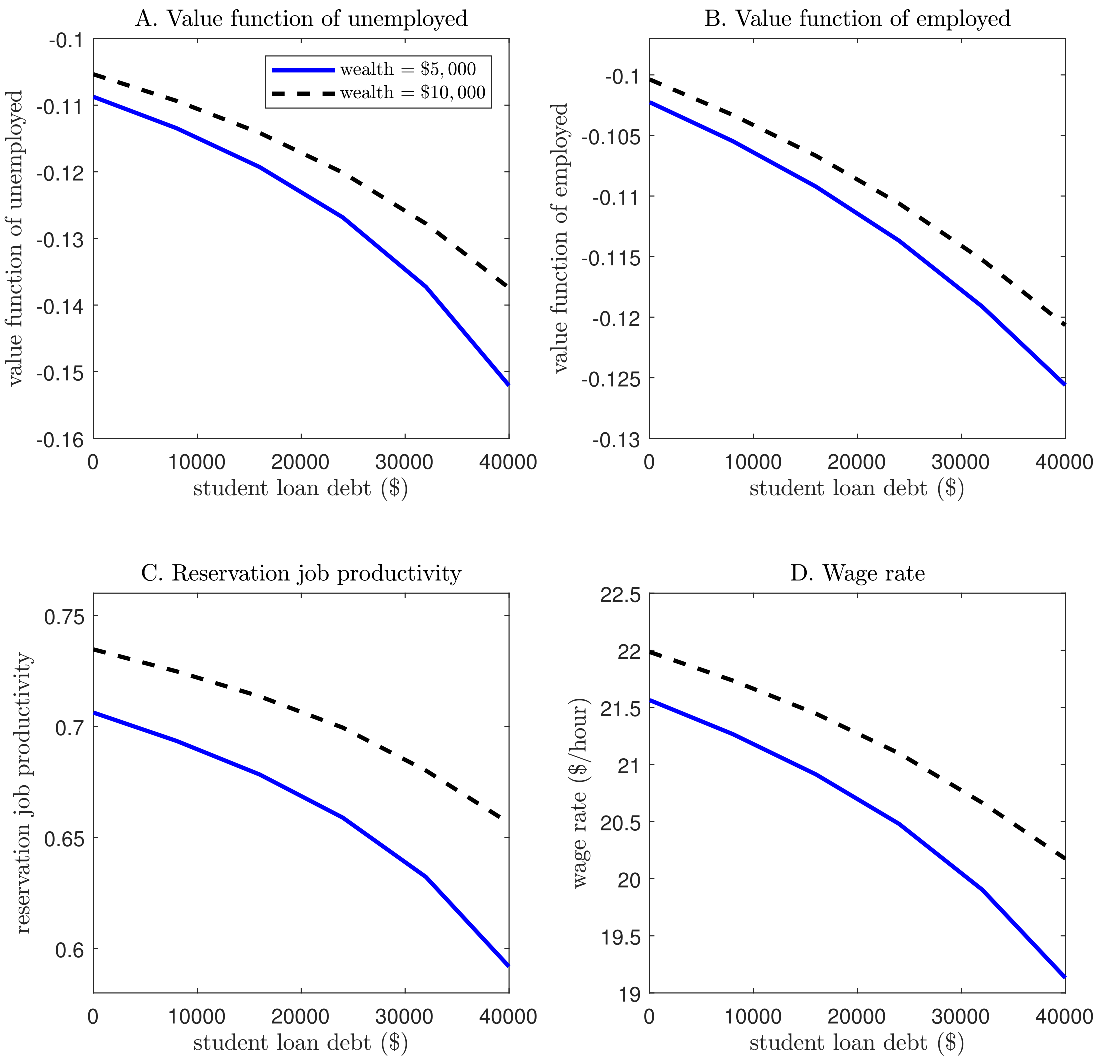


**Fig. 2.** Illustration of value functions and optimal policy functions. Note: This figure illustrates the value and policy functions based on the calibrated parameters in Table 2. I consider an agent repaying under the fixed repayment plan at age $t = 7$. The blue solid line plots the case with wealth $b = \$5,000$ and the black dashed line plots the case with $b = \$10,000$. In panel B, the wage rate is fixed at $w = \$25$ per hour. In panel D, the job productivity is fixed at $\rho = 0.8$.

$$b' = (1+r)(b + \varkappa(wl)^{1-\alpha} - y) - c + \varpi \quad \text{and} \quad b' \geq -\varsigma wl. \tag{15}$$

The employed agent's choice of $l_t^N(w, b, s)$ also determines the value of the filled job.

$$J_t^N(w, \rho, b, s) = (z_t\rho - w)l_t^N(w, b, s) + \beta(1-\kappa)J_{t+1}^N(w, \rho, b', s')\mathbb{1}_{\{W_{t+1}^N(w,b',s') \geq U_{t+1}^N(b',s')\}}, \tag{16}$$

where $\mathbb{1}$ is a function indicating whether the agent voluntarily quits her job.

Figure 2 illustrates the value functions and optimal policy functions. Panels A and B show that the values for both unemployed and employed borrowers decrease with debt and increase with wealth. Moreover, panel C shows that the reservation job productivity chosen by an unemployed borrower is lower when debt is higher, and this relationship is more pronounced when the agent's wealth is lower due to a tighter liquidity constraint. Panel D shows that, conditional on the same job productivity, the endogenously determined wage rate through bargaining is lower when debt is higher and wealth is lower as the agent's value of outside options (i.e., unemployment) becomes lower. The value and policy functions for other cases are detailed in Internet Appendix C.3.

**Table 1**
Impact of student debt on labor market outcomes after college graduation.

Panel A: Duration of first unemployment spell and unemployment exit rate

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Duration of unemployment spell | | | Unemployment exit rate | | |
| Loan amount (in $10,000) | −1.41 | −1.57 | −1.53 | 0.058 | 0.060 | 0.054 |
| t-statistic | (−2.31) | (−2.30) | (−2.19) | (2.32) | (2.14) | (2.00) |
| Demographic controls | √ | √ | √ | √ | √ | √ |
| Ability controls | | √ | √ | | √ | √ |
| Family controls | | | √ | | | √ |
| County fixed effect | √ | √ | √ | √ | √ | √ |
| Observations | 1,115 | 971 | 929 | 1,115 | 971 | 929 |
| $R^2$ | 0.0278 | 0.0311 | 0.0492 | - | - | - |

Panel B: Wage income in year $t+1$, $t+2$, and $t+3$ for college students graduating in year $t$

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | Year $t+1$ | | | Year $t+2$ | | | Year $t+3$ | |
| Loan amount (in $10,000) | −0.032 | −0.040 | −0.035 | −0.028 | −0.035 | −0.031 | −0.027 | −0.035 | −0.032 |
| t-statistic | (−2.29) | (−2.50) | (−2.06) | (−2.80) | (−3.18) | (−2.38) | (−2.25) | (−2.51) | (−1.78) |
| Demographic controls | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Ability controls | | √ | √ | | √ | √ | | √ | √ |
| Family controls | | | √ | | | √ | | | √ |
| County fixed effect | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Observations | 914 | 809 | 644 | 798 | 707 | 553 | 656 | 581 | 445 |
| $R^2$ | 0.1060 | 0.1275 | 0.1356 | 0.1391 | 0.1627 | 0.1582 | 0.1320 | 0.1658 | 0.1730 |

Note: Demographic controls include a cubic in age, gender and marriage dummies, an interaction term for married females, a set of four dummies for race (white, black, Hispanic, others), the duration of college study, a set of dummies for college major (physical science, social science, engineering, and others), and the county of residence in the graduation year. Ability controls include AFQT score, college GPA, SAT score, and ACT score. Family controls include family's adjusted gross income, parents' education, and family's net worth. t-statistics are included in brackets.

## 3. Data and Calibration

In this section, I first introduce the data and offer some suggestive evidence. Then I calibrate my model and check whether it can replicate the empirical evidence on student loans.

### 3.1. Data

My analysis is based on the panel data from NLSY97, a nationally representative survey conducted by the Bureau of Labor Statistics (BLS). In round 1, 8,984 youths were initially interviewed in 1997. These youths were born between 1980 and 1984. Follow-up surveys were conducted annually. The survey contains extensive information on each youth's labor market behavior and documents the amount of student loans borrowed during college. I focus on youths with a high school diploma or a bachelor's degree. This leaves me with a sample of 1,261 students with a bachelor's degree and 3,542 students with a high school diploma, among which 960 are college dropouts.[12]

To provide some suggestive evidence, I examine the effect of student debt on job search decisions by regressing the duration of the first unemployment spell after college graduation on the amount of student debt. The results are tabulated in panel A of Table 1. In column (1), I control for a list of demographic characteristics likely observable to potential employers. My estimate implies that a $10,000 increase in student debt is associated with an unemployment duration that is 1.41 weeks shorter. Ability likely determines both unemployment duration and student debt. In column (2), I additionally control for proxies for ability and find that an extra $10,000 debt is associated with an unemployment duration that is 1.57 weeks shorter. In column (3), I further control for proxies for family socioeconomic background. The correlation of student debt and unemployment duration remains significant. I evaluate the robustness of these results by estimating a set of Cox hazard models following the literature on UI benefits. Columns (4) – (6) show that the monthly unemployment exit hazard rate is about 5.4% – 6.0% higher for an individual with $10,000 more student debt.

I continue to examine the effect of student debt on wage income. For individuals graduating in year $t$, I construct their (log) wage income in years $t+1$, $t+2$, and $t+3$ if they are employed full time in the given year. I then run a Mincer-style regression relating (log) wage income after college graduation to debt level. Panel B shows that conditional on full-time employment, those with $10,000 more student debt are associated with a wage income that is about 2.7% – 4.0% lower in the first three years after graduation. These estimates jointly suggest that student debt repayment could possibly affect borrowers' labor market outcomes. In the remaining sections, I use my calibrated model to structurally evaluate the role of

[12] I drop youths who have served in the military or attended graduate schools because they would not be making labor market decisions in the same way as the other youths in my sample. I also drop youths who received their bachelor's degree before 1997 due to the lack of labor market information upon college graduation. Internet Appendix D presents the summary statistics and variable construction.

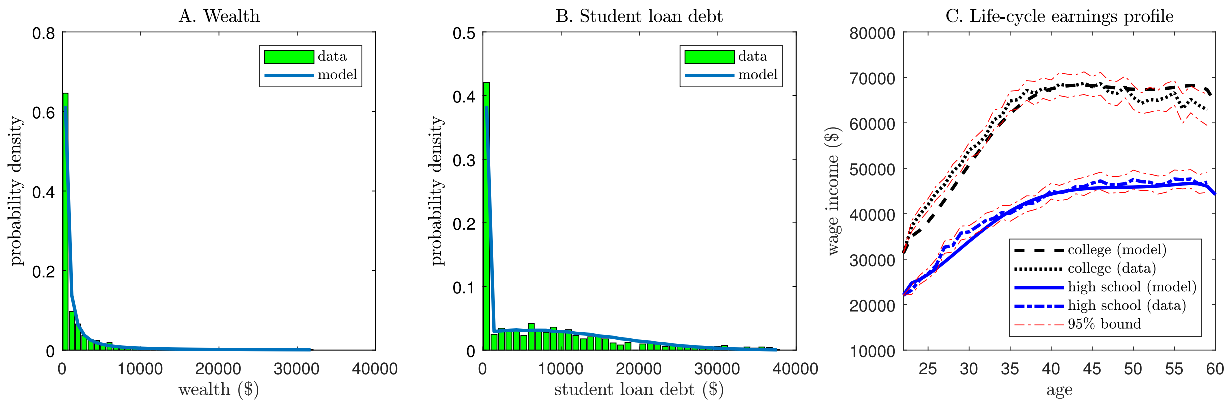


**Fig. 3.** Wealth, debt, and life-cycle earnings profiles in the model and data. Note: In panel A, the blue solid line plots the calibrated distribution of wealth in the model at $t = 0$ (before making the college entry decision) and the histogram plots the empirical distribution of wealth at age 18 in the NLSY97 data. In panel B, the blue solid line plots the endogenous distribution of student debt among borrowers right after college graduation and the histogram plots the empirical distribution of student debt in the year of college graduation in the NLSY97 data. In panel C, the blue solid and dash-dotted lines plot the life-cycle earnings profile in the model and data for high school graduates. The black dashed and dotted lines plot the life-cycle earnings profile in the model and data for college graduates. The red dash-dotted lines represent the 95% bound. The earnings in the data are from March CPS 1997 – 2008. The model-implied statistics in all three panels are the average values across 1,000 independent simulations. In each simulation, a cross section of 100,000 agents is simulated.

student debt in job search decisions. I also conduct several counterfactual experiments to shed light on the importance of different channels.

### 3.2. Calibration

I solve the model numerically (see Internet Appendix E). The model is calibrated using the data between 1997 – 2008. Because IBR was only introduced in 2009, my calibration assumes that all agents are enrolled in the fixed repayment plan.[13] Each period represents one month. The agent's productivity is a cubic function of labor market experience $t$ (Bagger et al., 2014).

$$z_t = \mu_0 + \mu_1 t + \mu_2 t^2 + \mu_3 t^3, \tag{17}$$

$$z_t^{HS} = \mu_0^{HS} + \mu_1^{HS} t + \mu_2^{HS} t^2 + \mu_3^{HS} t^3. \tag{18}$$

The distribution of initial wealth is parameterized with a Pareto distribution with scale parameter $\zeta$ and shape parameter $\varphi$. The pecuniary cost $k$ is parameterized to follow a truncated normal distribution (bounded below by zero) with mean $\mu_k$ and variance $\sigma_k^2$. The psychic cost $e$ follows a normal distribution with mean $\mu_e$ and variance $\sigma_e^2$. The job productivity is drawn from a Beta distribution with parameters $f_1$ and $f_2$ (Jarosch, 2015; Lise et al., 2016).

*Externally Determined Parameters.*

A set of parameters are externally determined (see panel A of Table 2). The two parameters $(\zeta, \varphi)$ governing the initial wealth distribution are estimated directly using maximum likelihood estimation to match the empirical wealth distribution of youth at age 18 in my sample (see panel A of Figure 3). I set $\gamma = 2$ following Herkenhoff (2019). The tax parameters $\varkappa = 1.66$ and $\alpha = 0.11$ are calibrated using the coefficients obtained from regressing log individual after-tax earnings on log individual pre-tax earnings.[14] The average tax rate implied by the model is 33.26%. I set $\sigma = 2.59$, which implies that the tax-modified Frisch elasticity is $(1-\alpha)/(\sigma+\alpha) = 0.33$, broadly consistent with microeconomic evidence (see Keane, 2011).

I set the monthly risk-free rate $r = 0.37\%$, corresponding to the average real interest rate in the U.S. between 1997 – 2008. I set the monthly discount rate $\beta = 0.997$. I set $T = 468$, which corresponds to a real-life working age of 22 to 60. In my sample, there are 2,221 college attendants among which 960 fail to earn a bachelor's degree. I thus set the college completion rate $\psi = 0.568$.

I set $\theta = \$700$, which means that yearly UI benefits are roughly equal to 40% of the average six-month wage income.[15] Combining AFDC, food stamps, and WIC, the average monthly benefit in my sample is \$200. Since the consumption

[13] During my sample period, student loan borrowers had the option to enroll in the old income-contingent plan. However, enrollment was below 1% due to the high repayment rate.

[14] The pre-tax earnings data are obtained from March CPS 1997 – 2008. I use the NBER's TAXSIM program to compute after-tax earnings as earnings minus all federal and state taxes.

[15] In the U.S., UI benefits generally pay eligible workers between 40% – 50% of their previous pay for six months. In my model, unemployed agents receive UI benefits every month. Therefore, I choose a relatively low value of UI benefits to account for this discrepancy. The average six-month wage income is \$22,213 in my model. Thus I set $\theta = \$22,213 \times 0.4/12 \approx \$700$.

**Table 2**
Calibration and parameter choice.

| Panel A: Externally determined parameters | | | | | |
|---|---|---|---|---|---|
| Parameter | Description | Value | Parameter | Description | Value |
| $\zeta$ | Initial wealth distribution (scale) | 223.0 | $\varphi$ | Initial wealth distribution (shape) | 1.52 |
| $\gamma$ | Risk aversion | 2 | $\underline{c}$ | Consumption floor ($) | 400 |
| $\varkappa$ | Overall tax level | 1.66 | $\varsigma$ | Consumption loans | 0.185 |
| $\alpha$ | Progressive tax rate | 0.11 | $t_0$ | Grace period | 7 |
| $\sigma$ | Elasticity of labor supply | 2.59 | $t_{\mathrm{FIX}}$ | Repayment period (FIX) | 126 |
| $r$ | Risk-free deposit rate (%) | 0.37 | $t_{\mathrm{IBR}}$ | Repayment period (IBR) | 306 |
| $\beta$ | Discount factor | 0.997 | $\varrho$ | IBR repayment rate | 0.15 |
| $T$ | Number of periods working | 468 | $pov$ | Monthly poverty guideline ($) | 870 |
| $\psi$ | College completion rate | 0.568 | $\pi$ | Duration of default | 0.083 |
| $\theta$ | UI benefits ($) | 700 | $r_s$ | Student loan interest rate (%) | 0.53 |
| | | | Panel B: Internally calibrated parameters | | |
| Parameter | Description | Value | Moment description | Data | Model |
| $\mu_k$ | Mean of pecuniary cost ($) | 8,348 | Average debt among borrowers ($) | 11,873 | 11,873 |
| $\sigma_k$ | Std. dev. of pecuniary cost ($) | 12,836 | Std. dev. of debt among borrowers ($) | 8,633 | 7,832 |
| $\mu_e$ | Mean of psychic cost | 0.0215 | Fraction of agents attending college (%) | 46.2 | 46.2 |
| $\sigma_e$ | Std. dev. of psychic cost | 0.0533 | Fraction of student loan borrowers (%) | 61.6 | 61.6 |
| $\eta$ | Disutility of default | $3.93 \times 10^{-3}$ | Two-year cohort default rate (%) | 9.26 | 9.54 |
| $\kappa$ | Job separation rate | 0.018 | Monthly E2U rate (%) | 1.8 | 1.8 |
| $\lambda$ | Job contact rate | 0.6 | Monthly U2E rate (%) | 28.8 | 28.4 |
| $f_1$ | Job productivity distribution | 1.4 | UI on unemployment duration (week) | 0.3 – 2 | 0.77 |
| $f_2$ | Job productivity distribution | 0.8 | UI on reservation wage (%) | 4.0 | 4.0 |
| | | | Credit on unemployment duration (week) | 0.33 – 0.53 | 0.39 |
| | | | Credit on reemployment wage (%) | 0.61 – 1.34 | 1.36 |
| $\xi$ | Workers' bargaining power | 0.4 | Wage growth rate of young workers (%) | 6.2 | 5.6 |
| $\phi$ | Labor supply scaling factor | $3.65 \times 10^{-5}$ | Average labor supply (hours per year) | 1,754 | 1,766 |
| $\mu_0^{\mathrm{HS}}, \mu_0$ | Constant term in productivity | 21.04, 29.66 | | | |
| $\mu_1^{\mathrm{HS}}, \mu_1$ | Linear term in productivity | 0.18, 0.26 | Life-cycle wage income | See panel C of Figure 3 | |
| $\mu_2^{\mathrm{HS}}, \mu_2$ | Square term in productivity | $-7.40 \times 10^{-4}$, $-1.14 \times 10^{-3}$ | | | |
| $\mu_3^{\mathrm{HS}}, \mu_3$ | Cubic term in productivity | $1.01 \times 10^{-6}$, $1.59 \times 10^{-6}$ | | | |

Note: The mean of psychic cost $\mu_e$ and the disutility of default $\eta$ correspond to 2.7% and 0.1% of life-time consumption respectively. The model-implied moments reported in panel B are the average values across 1,000 independent simulations. In each simulation, a cross section of 100,000 agents is simulated. The sensitivity of each parameter to each moment is shown in Internet Appendix A.1.

floor also includes nonentitlement programs, such as housing assistance (Hubbard et al., 1995), I set the monthly consumption floor $\underline{c} = \$400$.[16] Kaplan and Violante (2014) estimate that the median ratio of credit limit to income is 18.5% for household members aged 22 to 59. I thus set $\varsigma = 0.185$.[17]

The parameters $t_0$, $t_{\text{FIX}}$, $t_{\text{IBR}}$, $\varrho$, $pov$, $\pi$, and $r_s$ are chosen to capture a realistic setting for federal student loan borrowers. I set $t_0 = 7$ as the non-repayment grace period is six months for most federal student loans. Under the standard fixed repayment plan, borrowers must repay all loans in 10 years. Thus I set $t_{\text{FIX}} = 126$. IBR passed by Congress in 2009 requires borrowers to repay 15% of their discretionary income every month for 25 years or until the loan is paid in full. Thus I set $t_{\text{IBR}} = 306$ and $\varrho = 0.15$. I set the poverty guideline, $pov = \$870$ per month, based on the average individual poverty guideline in the U.S. between 1997 – 2008. Following Ionescu (2009), I set $\pi = 0.083$ so that borrowers on average spend one year in default status. Ionescu (2009) estimates that the annualized markup set by the government for subsidized loans issued before 2006 is about 2% over the treasury bill rate. I thus set the monthly interest rate on student loans $r_s = 0.53\%$.

*Internally Calibrated Parameters.* The remaining parameters are calibrated by matching relevant moments (see panel B of Table 2). The two parameters $(\mu_k, \sigma_k)$ capturing the pecuniary costs of college study are calibrated to match the mean and standard deviation of student debt among borrowers (see panel B of Figure 3).[18] The two parameters $(\mu_e, \sigma_e)$ capturing the psychic costs are calibrated to match the college attendance rate and fraction of borrowers. The disutility of default $\eta$ is calibrated to match the two-year cohort default rate of student loan borrowers (Yannelis, 2015).

The exogenous job separation rate $\kappa$ is identified by the transition rate from employment to unemployment. The job contact rate $\lambda$ is identified by the transition rate from unemployment to employment. In the data, the monthly employment-to-unemployment rate is 1.8% and the monthly unemployment-to-employment rate is 28.8%. This implies that the average unemployment duration is about 15 weeks and the unemployment rate is about 6%, roughly in line with BLS statistics.

The distribution of job productivity is central to the quantitative implications of student debt on labor market outcomes because it determines the option value of staying unemployed. I rely on existing micro estimates for the effect of UI benefits and credit access to calibrate the parameters $f_1$ and $f_2$. Existing estimates in the empirical UI literature suggest that a 10% increase in the UI replacement rate increases the reservation wage by 4% (Feldstein and Poterba, 1984) and unemployment duration by 0.3 to 2 weeks (see Card et al., 2015; Nakajima, 2012, for a summary of empirical and quantitative estimates).[19] In the model, the UI benefits are calibrated to reflect a 40% replacement rate. Thus, increasing the replacement rate by 10% corresponds to a 25% increase in the amount of UI benefits. Consistent with the data, the model implies that increasing UI benefits by this amount would increase the reservation wage by 4% and the unemployment duration by 0.77 weeks on average. Different from UI benefits, consumer credit must be repaid, rolled over, or defaulted upon, which alters the set of admissible jobs for which individuals could search. Therefore, I also benchmark the calibration to the estimates in the consumer credit literature. In particular, using administrative data from TransUnion and the Longitudinal Employer-Household Dynamics (LEHD), Herkenhoff et al. (2019) find that increasing credit limits by 10% of prior annual earnings would increase the amount of time displaced workers take to find a job by 0.33 weeks (OLS estimate) to 0.53 weeks (IV estimate). Among those who find a job, the replacement earnings increase by 0.61% (OLS estimate) to 1.34% (IV estimate). My model-implied estimates are roughly in line with the estimates of Herkenhoff et al. (2019) (see Internet Appendices A.2 and C.1 for details). This enhances the credibility of the quantitative exercise since student debt affects unemployed borrowers' job search decisions through a mechanism similar to UI benefits and access to credit.

The bargaining parameter $\xi$ governs wages out of unemployment. I calibrate its value so that the average yearly wage growth rate of young workers aged between 23 to 32 is 5.6%, roughly in line with the data. The parameter $\phi$ is a scale factor of labor supply, which is calibrated to match the average number of hours worked in each year. The eight parameters governing labor productivity in equations (17) – (18) are chosen to match the average wage income in each year for high school and college graduates aged between 22 and 60. Because the NLSY97 does not provide such lengthy individual labor market histories, I construct the life-cycle earnings profile using March CPS 1997 – 2008 data (see panel C of Figure 3).[20]

As a validation test, I check whether the effects of student debt implied by the model are consistent with those implied by OLS regressions in Table 1. Using the estimated model, I simulate the same number of college graduates for one life cycle 1,000 times. I run similar regressions for each simulated dataset to construct the mean and standard errors of the estimates. Table 3 shows that the model-implied estimates are comparable to the data.

[16] Hubbard et al. (1995) estimate an annual consumption floor of \$7,000 for a family of three members in 1984. Adjusting for the GDP deflator, the individual consumption floor is about \$360 in 2008 dollars.

[17] I perform robustness checks for different values of risk aversion $\gamma$, elasticity of labor supply $\sigma$, consumption floor $\underline{c}$, credit limit $\varsigma$, and initial endowments in Internet Appendix F.

[18] My estimate suggests that the average total college cost is about \$8,348. IPEDS documents that during 2001-2004, the annual tuition for a four-year college program was between \$989 and \$2,520 depending on state category (Johnson, 2013). This implies a total four-year college tuition of \$3,956-\$10,080.

[19] The main quantitative results are robust if the model is calibrated to match a 2% increase in the reservation wage in response to a 10% increase in UI replacement (see Internet Appendix F.6). Several existing studies document insignificant effects of UI benefits on reemployment wages (Card et al., 2007; Lalive, 2007). Nekoei and Weber (2017) estimate a positive effect of UI benefits on reemployment wages by exploiting an age-based regression discontinuity in Austria. The lack of evidence on reemployment wages could be due to the existence of countervailing forces (Ljungqvist and Sargent, 1998; Nekoei and Weber, 2017; Pissarides, 1992) or because unemployed workers do not perform a more extensive search when UI increases or because their established labor market credentials make wage effects less salient.

[20] Following Rubinstein and Weiss (2006), I pool the CPS data from different years and cohorts. The pooled data analysis is valid under stationary conditions, which would be violated if the wage structure underwent major changes or the cohort quality changed substantially during this period.

**Table 3**
Model-implied regression estimates.

| | First unemployment spell | | Wage income | | |
|---|---|---|---|---|---|
| Model | Duration | Exit rate | Year 1 | Year 2 | Year 3 |
| Loan amount (in $10,000) | −0.74 | 0.059 | −0.048 | −0.049 | −0.048 |
| t-statistic | (−2.75) | (2.40) | (−11.75) | (−13.71) | (−11.57) |
| Data | | | | | |
| Loan amount (in $10,000) | −1.53 | 0.054 | −0.035 | −0.031 | −0.032 |
| t-statistic | (−2.19) | (2.00) | (−2.06) | (−2.38) | (−1.78) |
| Chow test p-value | 0.38 | 0.82 | 0.90 | 0.73 | 0.75 |

Note: The coefficients and t-statistics of the data are obtained from Table 1. In the model, I simulate the same number of college graduates for one life cycle. I then run similar regressions to construct the mean and standard errors of the regression coefficients. Finally, I calculate the p-value of the Chow test, where the null is no structural break between the actual and simulated data. The numbers reported here represent the mean, standard errors, and Chow test p-value averaged across 1,000 independent simulations. The Chow test shows formally that the regression estimates from the model are statistically similar to those in the data at the 5% significance level.

## 4. Evaluating the Implications of Student Loans

I now use the estimated model to conduct quantitative analyses. I first study the effect of student debt on labor market outcomes in partial equilibrium to illustrate the economic mechanism. I then conduct counterfactual analyses in general equilibrium to shed light on the welfare implications of student loans extended under various repayment plans to understand and quantify the implications of IBR through different channels. Finally, I evaluate the importance of providing student loans and allowing borrowers to endogenously choose their job search strategies.

### *4.1. The Effect of Student Debt on Labor Market Outcomes*

In this subsection, I focus on the effect of student debt on labor market outcomes. To illustrate the economic mechanism of IBR, I conduct a partial equilibrium analysis where the distribution of agents entering the labor market at $t = 1$ and the tax parameters ($\varkappa$ and $\alpha$) are fixed.

*Fixed Repayment Plan.*

I begin by investigating the effect of student debt on labor market outcomes when borrowers repay under the standard 10-year fixed repayment plan. Focusing on college graduates, panel A of Figure 4 shows that unemployed borrowers tend to be less picky in their job search. At age 22, unemployed borrowers accept jobs with productivity above 0.643 (see the blue solid line), whereas unemployed non-borrowers have reservation productivity of 0.676 (see the red dash-dotted line). Due to the lower reservation productivity, unemployed borrowers on average spend 0.9 fewer weeks searching for their first job at age 22 than unemployed non-borrowers (see panel B). As a result, unemployed borrowers are on average matched with less productive jobs, leading to a lower wage income. Panel C shows that employed borrowers earn about $1,479 less than employed non-borrowers at age 22 and the wage difference is persistent. Employed borrowers also work less due to the lower wage rate. At age 22, they work 1,650 hours per year on average, whereas employed non-borrowers work about 1,668 hours per year.

Intuitively, borrowers are less picky in their job search because search risk is not perfectly insured. Marginally raising the reservation productivity increases both expected wage income and search risk, generating a tradeoff between risks and returns. When debt is higher, agents consume less and thus become more risk averse.[21] When that happens, they avoid search risk by setting a lower reservation productivity. In a perfect credit market, the quantitative effect on reservation productivity is small because debt represents just over one percent of lifetime earnings. However, as agents have limited access to credit in my model, the low income during unemployment gives borrowers a strong incentive to accept a job quickly, implicitly transferring future wealth to the current period. In other words, the labor market offers its own version of insurance and credit provision through borrowers' endogenous job choices to minimize the effect of student debt.

There should be no difference in reservation productivity between borrowers and non-borrowers after debt has been paid off at age 32. However, panel A shows that the differences persist until age 45. This is because between the ages of 22 and 32, borrowers accumulate significantly less wealth than non-borrowers due to their lower wage income and the need to repay their debt (see Figure 5). Thus, although borrowers will have paid off their debt after age 32, they would still be less wealthy than non-borrowers, making them less picky in their job search (Rendon, 2006).

*Income-Based Repayment Plan.*

The significant difference in labor market outcomes between borrowers and non-borrowers has two major implications. First, borrowers' endogenous adjustment of reservation productivity offers an important self-insurance channel to alleviate

[21] A lower consumption increases risk aversion if the utility function has decreasing absolute risk aversion (DARA), which is empirically relevant. Note that the utility function (1) in my model has constant relative risk aversion (CRRA), and thus decreasing absolute risk aversion. In Internet Appendix C.4, I show that DARA utility is important in generating the negative relationship between debt and reservation wage in a simple search model.

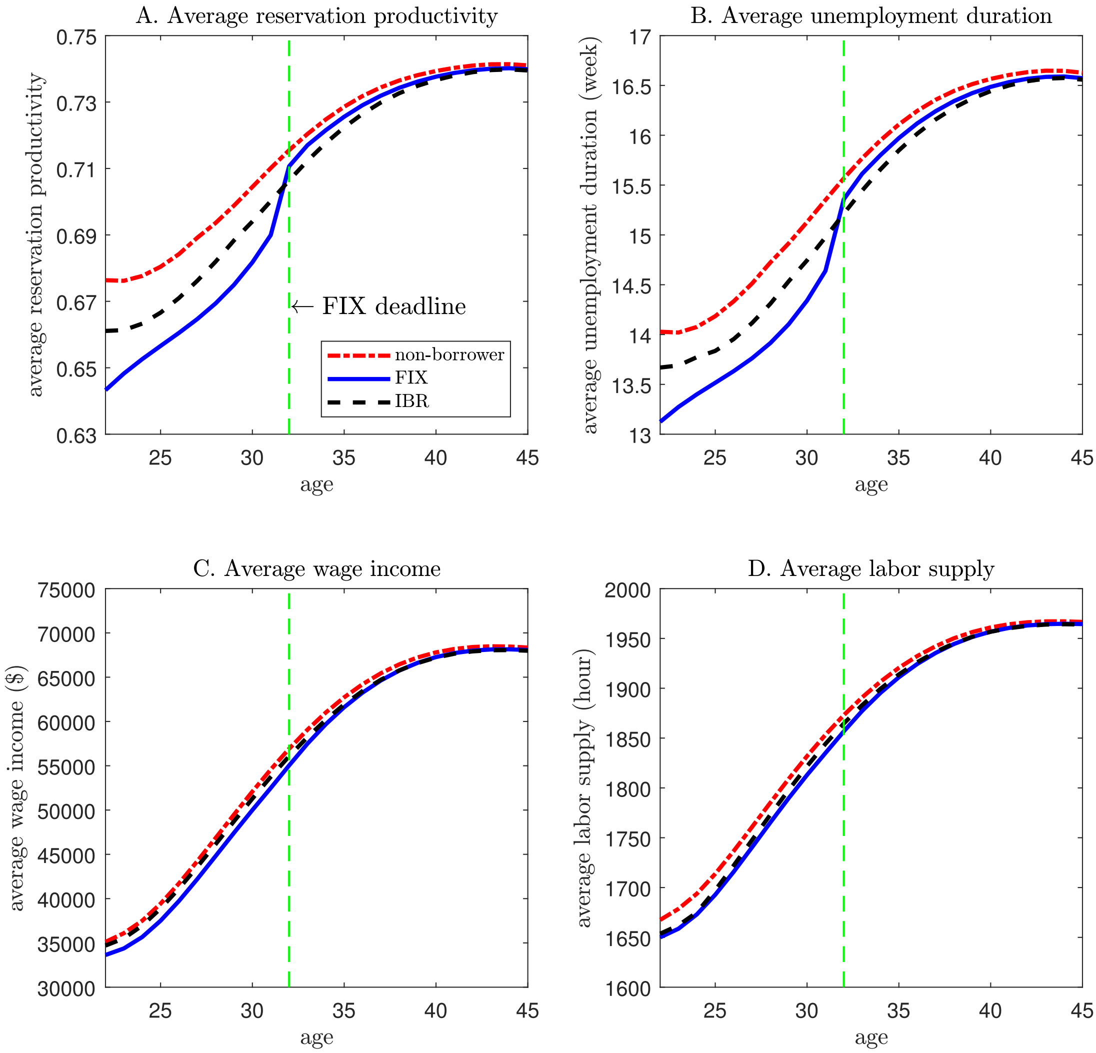


**Fig. 4.** Simulated life-cycle dynamics for different groups of agents. Note: Panels A and B plot the average reservation productivity and unemployment duration of unemployed agents between the ages of 22 and 45. Panels C and D plot the average wage income and labor supply of employed agents. I require the agents to be employed for at least nine months in a given year when computing the average wage income and labor supply. In each panel, the blue solid line plots the average corresponding statistic for borrowers under the fixed repayment plan; the black dashed line refers to borrowers under IBR; and the red dash-dotted line refers to non-borrowers. The vertical dashed line represents the last month of debt payment under the fixed repayment plan. The evaluation of IBR is conducted in partial equilibrium, where the distribution of agents entering the labor market at $t = 1$ and the tax parameters ($\varkappa$ and $\alpha$) are the same as those under the fixed repayment plan. In all three panels, the curves represent the average values across 1,000 independent simulations. In each simulation, a cross section of 100,000 agents is simulated.

the debt burden. Second, the large difference in reservation productivity reflects the extent to which the burden of debt repayment reduces welfare. Therefore, we can get a sense of the welfare implications from different repayment plans by looking at how borrowers adjust their job search strategies.

I thus evaluate what would happen to labor market outcomes if student loan borrowers are automatically enrolled in IBR immediately after college graduation without knowing that the plan exists before making the decision on college attendance.[22]The black dashed lines in Figure 4 plot the simulation results of borrowers under IBR. My model suggests that at age 22, borrowers under IBR on average spend 0.55 weeks more on their job search than borrowers under the fixed repayment plan (see panel B) and their average wage income is about $1,064 higher (see panel C). Although borrowers under IBR still receive less wage income than non-borrowers, my results indicate that IBR significantly alleviates the debt burden relative to the fixed repayment plan.

[22] The exercise here ensures that making IBR available does not change the composition of borrowers. In Subsection 4.2, I analyze the implication of IBR in general equilibrium.

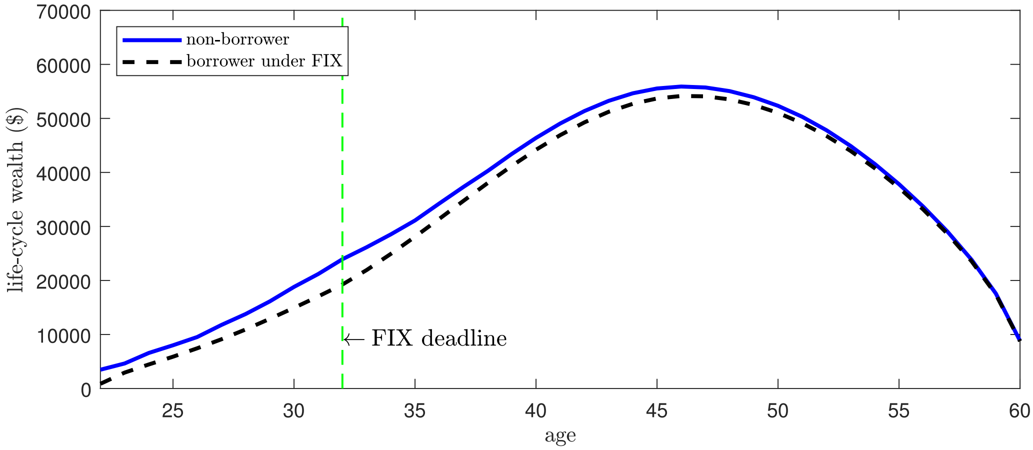


**Fig. 5.** Average wealth of non-borrowers and borrowers under the fixed repayment plan. Note: This figure reports the average wealth of non-borrowers and borrowers under the fixed repayment plan across 1,000 independent simulations. In each simulation, I simulate a cross section of 100,000 agents. The blue solid line plots the average wealth of non-borrowers and the black dashed line plots the average wealth of borrowers under the fixed repayment plan from age 22 to age 60. The vertical dashed line represents the last month of debt repayment under the fixed repayment plan.

Intuitively, recent college graduates would be either unemployed or starting their jobs with modest earnings, as captured by the hump-shaped life-cycle earnings profile. Under the standard fixed repayment plan, student loans are due when borrowers are least able to pay, which forces them to significantly lower their reservation productivity, so they are more likely to end up with lower-paid jobs. IBR offers insurance of job search outcomes, allowing borrowers to better smooth consumption and conduct a more adequate job search.[23]

IBR generates two countervailing effects on labor supply. First, a higher reservation productivity allows borrowers to be matched with more productive jobs, which generates a substitution effect that increases their labor supply. Second, IBR imposes an income-tax-like effect that reduces borrowers' labor supply, as a fraction of their earnings is used to repay outstanding debt. My simulation suggests that the labor supply of employed borrowers under IBR is higher than that under the fixed repayment plan (see panel D), indicating that the income-tax-like effect is not important under my calibration. I provide more discussions on this issue in the next section by dissecting the specific repayment terms of IBR.

### *4.2. General Equilibrium Implications of Various Repayment Plans*

In this subsection, I shed light on the general equilibrium implications of various student debt repayment plans. In Table 4, column (1) reports the baseline calibration in which borrowers repay under the standard 10-year fixed repayment plan. Columns (2) – (5) report the simulation results of several counterfactual experiments assuming that borrowers repay under different repayment plans. In these experiments, I focus on the stationary equilibrium, taking into account the general equilibrium effect by allowing agents to internalize the change in the economic environment and thereby endogenously adjust their borrowing and college entry decisions. I also adjust the economy's overall tax level $\varkappa$ to keep the government's budget constraint balanced (see Internet Appendix B).

*Baseline IBR.* Column (4) presents the simulation results of the baseline IBR. It is shown that offering IBR increases the college entry rate from 46.24% to 50.46% due to increased borrowing of student loans. The fraction of borrowers increases from 61.62% to 64.88%, and among borrowers, the average amount of debt increases from $11,873 to $12,965. College attendance and borrowing increase as agents anticipate a lower burden from debt repayment once IBR is offered.

IBR also increases the average annual wage income and output by $734 ($\$33,482 - \$32,748$) and $728 ($\$36,469 - \$35,741$) between the ages of 22 and 31. This is both because of the increase in college entry rate and the longer job search. Labor supply increases from 1,624 hours per year to 1,626 hours per year. IBR largely reduces the two-year cohort default rate from 9.54% to zero by allowing enrolled borrowers to postpone debt repayment when income is low. A few borrowers cannot fully pay off their outstanding balance within the 25-year repayment period. On average, about 14.90% of the outstanding debt is forgiven by IBR for each borrower. Because of the higher wage income under IBR, the tax parameter $\varkappa$ is increased to maintain a balanced budget, and as a result, the average tax rate decreases by 0.45% ($32.81\% - 33.26\%$). Internet Appendix B.1 shows that the welfare of offering IBR would be lower if we do not adjust the tax parameter.

Providing IBR increases the expected welfare of a newborn agent by 1.79%. I further quantify the distributional implications of IBR for different groups of agents. My simulation implies that IBR increases the expected welfare of borrowers by 2.92%. For borrowers who dropped out of college, the welfare gains are even higher (3.27%). The largest welfare gains are 9.91%, obtained by those non-borrowers who become borrowers once IBR is offered. These non-borrowers have relatively

[23] This result is related to Golosov et al. (2013)'s insight that insuring against search risk would allow agents to search for higher-paid jobs.

**Table 4**
General equilibrium implications of student debt under various repayment plans.

| | (1) Various versions of FIX | (2) | (3) | (4) Various versions of IBR | (5) | (6) |
|---|---|---|---|---|---|---|
| | Baseline | 25-year repayment | No repay for unemployed | Baseline | No cap for repayment | Partial equilibrium |
| College attendance rate (%) | 46.24 | 48.74 | 49.99 | 50.46 | 49.72 | 46.24 |
| Fraction of borrowers (%) | 61.62 | 63.65 | 64.56 | 64.88 | 64.36 | 61.62 |
| Average debt among borrowers ($) | 11,873 | 12,633 | 12,904 | 12,965 | 12,919 | 11,873 |
| Average wage income (age 22 – 31, $) | 32,748 | 33,192 | 33,531 | 33,482 | 33,059 | 33,062 |
| Average output (age 22 – 31, $) | 35,741 | 36,178 | 36,530 | 36,469 | 36,062 | 36,010 |
| Average labor supply (age 22 – 31, hours) | 1,624 | 1,634 | 1,641 | 1,626 | 1,599 | 1,620 |
| Default rate (%) | 9.54 | 3.42 | 0 | 0 | 0 | 0 |
| Fraction of debt forgiven (%) | 0 | 0 | 0.08 | 14.90 | 1.87 | 16.51 |
| Average tax rate (%) | 33.26 | 32.96 | 32.81 | 32.81 | 32.98 | 33.23 |
| Welfare implications | | | | | | |
| Overall welfare (%) | - | 1.21 | 2.01 | 1.79 | 0.52 | 0.61 |
| Borrowers (all) (%) | - | 2.26 | 3.75 | 2.92 | −0.11 | 2.10 |
| Borrowers (college graduates) (%) | - | 2.30 | 3.72 | 2.56 | −0.26 | 1.73 |
| Borrowers (college dropouts) (%) | - | 2.23 | 3.78 | 3.27 | 0.03 | 2.44 |
| Non-borrowers become borrowers (%) | - | 8.45 | 11.27 | 9.91 | 4.97 | - |

Note: Column (1) presents the statistics in the baseline calibration where all borrowers repay under the 10-year standard fixed repayment plan according to formula (3). Column (2) refers to the experiment of extending the repayment period of the fixed repayment plan to 25 years (i.e., setting $t_{\text{FIX}} = 306$ in formula). Column (3) quantifies the role of no repayment during unemployment by assuming that unemployed borrowers do not repay but employed borrowers repay as in the 25-year fixed repayment plan. Column (4) refers to the experiment where all borrowers repay under the baseline IBR according to formula (4). Column (5) quantifies the role of repayment cap by allowing the monthly repayment under IBR to exceed that under the fixed repayment plan, i.e., formula (4) is modified to $y_t^{\text{IBR}} \equiv \min\{\varrho \max(E - 1.5pov, 0), \quad s\}$. Column (6) quantifies the effect of IBR on insuring labor market outcomes after college by assuming that college entry and borrowing decisions are the same as those under the fixed repayment plan. The welfare implication refers to the percentage change in lifetime consumption relative to the baseline calibration (i.e., column 1) for different groups of agents. All statistics reported in the table are the average values across 1,000 independent simulations. In each simulation, a cross section of 100,000 agents is simulated. The simulation results without adjusting tax parameters are reported in Internet Appendix B.1.

low wealth and are unwilling to borrow large amounts of loans to attend college under the fixed repayment plan. After IBR is offered, they choose to attend college by taking on student debt. The potential to receive a college degree significantly increases their expected wage income, resulting in large welfare gains.

*The Role of Repayment Cap.*

In column (5), I study the role of repayment cap in the IBR formula. In particular, I assume that borrowers' payment under IBR can exceed the required payment under the fixed repayment plan by modifying formula (4) to $y_t^{\text{IBR}} \equiv \min\{\varrho \max(E - 1.5pov, 0), \quad s\}$ for $t_0 \le t \le t_{\text{IBR}}$. Comparing columns (4) and (5), it is shown that removing the repayment cap reduces the positive impact of IBR on college attendance rate, borrowing, wage income, and output. Because of the larger repayment, the fraction of debt forgiven per borrower reduces from 14.90% to 1.87% of the outstanding debt.

Importantly, providing IBR without the repayment cap reduces yearly labor supply by 25 hours compared with the standard fixed repayment plan (1,599 hours - 1,624 hours), suggesting that the negative impact of the income-tax-like repayment rate on labor supply dominates the positive impact of a higher reservation productivity. Labor supply under the baseline IBR (i.e., column 4) is higher than that under the baseline fixed repayment plan (i.e., column 1) because the repayment cap in the IBR formula is often binding. A binding repayment cap largely alleviates the negative impact of the income-tax-like repayment rate on labor supply since it delinks current payments and current wage income.

The welfare gains of average borrowers are −0.11% due to the low debt forgiveness and the distortion of labor supply in the absence of the repayment cap. This further suggests that the welfare gains from IBR are mainly coming through principal reduction for borrowers. The overall welfare increases by 0.52% primarily due to the large welfare gains of non-borrowers who borrow to enter college after IBR is offered (4.97%).

*Understanding Specific Channels of IBR.*

I now turn to the evaluation of specific channels of IBR. As discussed above, by insuring labor market outcomes, IBR increases social welfare not only by directly alleviating debt repayment after college but also by indirectly encouraging college entry and borrowing before college. To separately study the two channels, in column (6), I run a counterfactual experiment similar to Figure 4, where the distribution of agents entering the labor market at $t = 1$ is fixed. Comparing columns (1) and (6), it is shown that alleviating debt repayment after college alone increases the average wage income, output, and welfare by about \$314 (\$33,062 − \$32,748), \$269 (\$36,010 − \$35,741), and 0.61% relative to the baseline fixed repayment plan.[24] The difference between columns (4) and (6) is informative about the impact of IBR through promoting college attendance, which increases welfare by 1.18% (1.79% − 0.61%).

One important feature of IBR is that it extends the repayment period from 10 years to 25 years, in addition to providing insurance of labor market outcomes. Thus, to understand the importance of insurance, it is useful to benchmark the effect of IBR with an extended 25-year fixed repayment plan. Column (2) shows that simply extending the fixed repayment plan from 10 years to 25 years would increase the average college attendance rate by 2.50% (48.74% − 46.24%), wage income by \$444 (\$33,192 − \$32,748) and overall welfare by 1.21%. Comparing columns (2) and (4), it is shown that the insurance provided by IBR still plays an important role conditional on the same repayment period. This is primarily because IBR allows borrowers to not repay during unemployment, when liquidity is most needed.

To formally show the importance of liquidity provision during unemployment, in column (3), I consider a 25-year fixed repayment plan but allow borrowers to not repay during unemployment. Comparing columns (3) and (4), we can see that allowing borrowers to not repay during unemployment increases welfare by 2.01%, higher than that under the baseline IBR. The average yearly labor supply is also 15 hours more (1,641 hours - 1,626 hours) due to the absence of the income-tax-like repayment rate. These results suggest that there is room for developing better repayment plans than IBR to further promote social welfare. While solving the optimal repayment plan is beyond the scope of this paper, my analysis implies that liquidity provision during unemployment and a longer repayment period are crucial elements in designing the optimal policies.

### 4.3. Student Debt Provision and Endogenous Job Search: Quantitative Evaluation

My previous analyses indicate that IBR increases welfare relative to the standard 10-year fixed repayment plan, and borrowers change their job search decisions significantly for consumption smoothing and self-insurance. But what is the welfare implication of providing student loans in the first place? And to what extent does the insurance offered by the labor market increase welfare? I attempt to shed light on these issues in this subsection.

I first conduct a counterfactual experiment in which agents cannot take out student loans to enter college. Comparing column (1) of Table 4 and the "No student debt" row of Table 5, it is shown that college attendance rate reduces significantly from 46.24% to 17.80% in the absence of student loans. The average wage income, output, and labor supply all decrease because agents are less productive in general. The expected welfare of a newborn agent is reduced by 7.92%.

To evaluate the welfare implication of endogenous job search, I conduct a counterfactual experiment in which borrowers must choose the same reservation productivity as non-borrowers of identical characteristics. Comparing column (1) of

[24] The average yearly labor supply in column (6) is 1,620 hours, lower than that under the baseline fixed repayment plan (i.e., 1,624 hours in column 1). This is primarily because of the lower labor supply of borrowers who dropped out of college (1,564 hours in the experiment of column 6 versus 1,576 hours under the baseline fixed repayment plan). In fact, the average yearly labor supply of borrowers who graduated from college is 1,741 hours in the experiment of column (6), higher than that under the baseline fixed repayment plan (1,735 hours).

**Table 5**
Quantitative evaluation of student debt provision and endogenous job search.

| | College rate (%) | Fraction of borrowers(%) | Average debt ($) | Wage income ($) | Output ($) | Labor (hours) | Default rate (%) | Average tax rate (%) |
|---|---|---|---|---|---|---|---|---|
| No student debt | 17.80 | 0.00 | 0 | 30,189 | 32,886 | 1,572 | 0 | 36.42 |
| No search | 44.55 | 60.17 | 11,399 | 32,693 | 35,819 | 1,624 | 15.29 | 33.43 |
| | Overall welfare (%) | Welfare of borrowers (%) | | | Borrowers become | | | |
| | | all | college graduates | college dropouts | non-borrowers (%) | | | |
| No student debt | −7.92 | - | - | - | −12.69 | | | |
| No search | −0.59 | −1.14 | −1.59 | −0.72 | −4.30 | | | |

Note: The first row “No search” refers to the experiment where borrowers’ reservation productivity is forced to be the same as that of non-borrowers of the same age and wealth. The second row “No student debt” refers to the experiment where agents cannot take out student loans when entering college. All statistics reported in the table are the average values across 1,000 independent simulations. In each simulation, a cross section of 100,000 agents is simulated. The simulation results without adjusting tax parameters are reported in Internet Appendix B.1.

Table 4 and the “No search” row of Table 5, it is shown that college attendance drops by about 1.69% (44.55% – 46.24%), as the burden of debt repayment increases when borrowers cannot adjust their job search strategies. As a result, the default rate increases by 5.75% (15.29% – 9.54%) and the overall welfare declines by about 0.59%.

Overall, these two counterfactuals imply that providing student loans significantly increases welfare even when the fixed repayment plan is adopted. Although borrowers are less choosy and more likely to work in lower-paid jobs, the change in job search strategies is itself an optimal response to the burden of debt repayment. Thus forcing borrowers to search for the same jobs as non-borrowers would reduce the former’s welfare. On the other hand, the significant difference in job search strategies between borrowers and non-borrowers also reflects the large burden of debt repayment under the fixed repayment plan. The net positive welfare effect of IBR is thus reflected by the significant increase in borrowers’ reservation productivity, which is again an optimal response to the reduced burden of debt repayment. Allowing borrowers to change their job search strategies essentially makes income risk endogenous, which creates an important self-insurance channel when the credit and insurance markets fail them. Indeed, my simulation results indicate that the endogenous adjustment of job search strategies plays a quantitatively important role in assessing the welfare implications of student loans.

## 5. Conclusions

A structural model with college entry, borrowing, and job search is developed to evaluate the implications of student debt on labor market outcomes. My calibrated model suggests that student loans have significant effects on borrowers’ unemployment duration and wage income under the fixed repayment plan. The key reason is that, when the credit and insurance markets are imperfect, borrowers optimally respond to liquidity constraints and uninsured income risks by adjusting their job search strategies. Thus ignoring the adjustment of job search strategies would underestimate the welfare benefit of student debt. The significant change in borrowers’ job search strategies also reflects the burden of debt repayment under the fixed repayment plan due to its inflexible repayment schedule. My simulations suggest that IBR largely alleviates the debt burden and motivates a more adequate job search. In addition to providing insurance against job search risk, IBR also increases social welfare by encouraging students to take out loans and attend college.

Alternative mechanisms through which student debt affects labor market outcomes may well exist. For example, the debt burden may affect borrowers’ incentives to accumulate human capital through learning and investment in skills on the job (Heckman et al., 1998; Herkenhoff et al., 2018a), which may create long-run effects on labor market outcomes. The debt burden may also affect the types of jobs that borrowers search for (Rothstein and Rouse, 2011), their decisions to start a business (Herkenhoff et al., 2018b), or the assortative matching between workers and jobs (Herkenhoff et al., 2019; Lise et al., 2016; Lise and Robin, 2017). These potentially important questions are beyond the scope of this paper and are left for future research.

## Appendix A

## Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jmoneco.2020.05.002

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