Job Search under Debt: Aggregate Implications of Student Loans

Yan Ji

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Abstract

I develop and estimate a dynamic equilibrium model of schooling, borrowing, and job search. In my model, risk-averse agents under debt tend to search less and end up with lower-paid jobs. I use the model to quantify the aggregate implications of student loans. Estimating 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 job search risks. In general equilibrium, IBR also increases social welfare through more college attendance and more job postings.

JEL codes: D61, D86, I22, I28, J31, J64.

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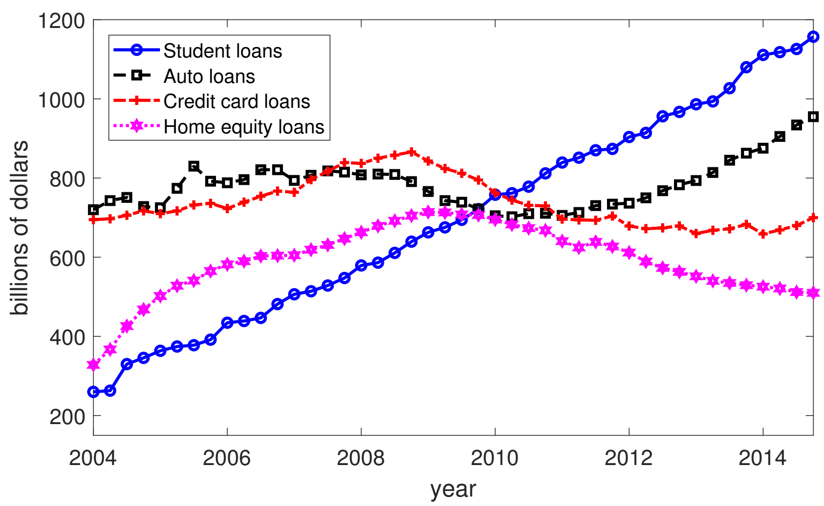
1 Introduction

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. (see Figure 1), surpassed only by mortgages. The growing number of borrowers experienced poor labor market outcomes during and soon after the recession, leading default rates skyrocketed (Looney and Yannelis, 2015). The rising student debt and default have brought more widespread concerns about the aggregate implications of student loans. Debt repayment presumably affects students' job search decisions after college. Given the intimate connection between labor market outcomes and defaults, understanding borrowers' job search strategies is crucial.



Note: The largest type of consumer debt, mortgage debt, has a balance of about 13 trillion in 2014 and is not plotted in this figure. Data source: Federal Reserve Bank of New York Consumer Credit Panel.

Figure 1: Non-mortgage balances, 2004Q1-2014Q4.

Measuring the aggregate implications of student loans on employment outcomes and social welfare presents a challenge. Both borrowing and job search decisions are endogenous, and they both depend on the job vacancies opened by firms. Although we can measure the local effects of student loans using reduced-form empirical techniques, evaluating their aggregate magnitudes and comparing their welfare implications across different policy regimes require estimating 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 can finance their schooling with student loans and make consumption, loan repayment, and job search decisions after college.

The key mechanism I propose is that risk-averse agents under debt tend to search less and end up with lower-paid jobs. My main contribution is to present a rich quantitative framework to evaluate the strength of this mechanism and the welfare implication of student loans under different repayment plans. To my knowledge, my paper is the first to highlight and quantify this mechanism in the context of student debt. I demonstrate that modelling borrowers' endogenous job search decisions plays a quantitatively important role in assessing the welfare effects of student loans. The intuition is as follows. Students under debt are more risk averse and liquidity constrained. When the ability to have more credit access is limited, the labor market offers its own version of insurance and liquidity provision by allowing borrowers to change their job search decisions. Thus ruling out this option underestimates the welfare effect of student loans as all borrowers are forced to face some exogenously specified labor income processes. This insight is related to existing work. For example, Herkenhoff (2015) and Herkenhoff, Phillips and Cohen-Cole (2016) show that allowing displaced workers to access credit significantly increases their unemployment duration and wage income.

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 strategies is informative about the burden of debt repayment. Counterfactual simulations suggest that IBR largely alleviates the debt burden, motivating more adequate job search and generating a distributional effect toward benefiting more indebted borrowers. In addition to providing insurance against job search risks, IBR also increases social welfare through more college attendance and more job postings. Quantitatively, my model implies that closing the student loan program would lead to a welfare loss of 5.45%. The IBR passed by Congress in 2009 increases the welfare of a newborn agent by about 0.42% on average.

My quantitative model incorporates college entry and borrowing decisions into an equilibrium life-cycle search model (e.g., Krusell, Mukoyama and Sahin, 2010; Herkenhoff, 2015; Lise, Meghir and Robin, 2016). 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 to enter college and finance college expenses by borrowing student debt. After graduation, agents search for jobs in the labor market by drawing wage offers from firms of different productivity. Agents decide whether to accept the wage offer or continue job search for a potentially higher-paid job.

The model implies that a higher level of debt induces the agent to take fewer search risks by accepting a job quicker, which is more likely to be lower paid. The key reason underlying this result is that agents are risk averse and job search risks are not perfectly insured in an incomplete market. The imperfect insurance of search risks implies a tradeoff between risks and returns, as searching longer increases both expected wage income and search risks. When debt is higher, agents become more risk averse and liquidity constrained due to lower consumption, which pushes them to avoid search risks by accepting a job quicker.

To evaluate the quantitative importance of this mechanism, I estimate the quantitative model based on panel data from National Longitudinal Survey of Youth 1997 (NLSY97) using the Method of Simulated Moments (MSM). The model is able to capture the positive correlation between talent and debt, endogenous student debt distribution, and various labor market characteristics observed in the data.

My first key result is to demonstrate, through the lens of the model, that the effect of student debt on labor market outcomes is quantitatively important. Specifically, I use the estimated model to evaluate the effect of student debt under the fixed repayment plan. My model suggests that borrowers tend to accept jobs with lower productivity. On average, compared to non-borrowers, borrowers spend 2.7 weeks fewer when searching for their first jobs and earn about $3,400 less in the first year after college graduation. These effects are persistent for 15 years with declining magnitude over time.

The significant effects of student debt are also observed in the data. Exploring the NLSY97 sample using OLS regressions, I find that a $10,000 increase in the amount of student debt reduces the duration of the first unemployment spell by about 2 weeks and reduces the annual wage income by about $2,000 in the first three years after college graduation. These effects remain robust after controlling for parental wealth, parental education, gender, race, test scores, marital status, the cubic age polynomials, and county fixed effects. Since regressions based on model-simulated data imply effects comparable in magnitude, the credibility of using the model to conduct policy evaluation is increased.

It is worth noting that the negative effect of student debt on borrowers' wage income does not imply that providing student debt reduces social welfare. A relevant comparison is to evaluate what would happen if borrowers were not allowed to borrow in the first place. In fact, by running a counterfactual experiment, my model suggests that completely eliminating the student loan program will reduce the expected welfare of a newborn agent by about 5.45% due to the significant drop in the college attendance rate.

The significant difference in employment outcomes between borrowers and non-borrowers has twofold implications. First, ruling out borrowers' endogenous job search strategies largely underestimates the welfare benefit of providing student debt. My counterfactual simulation suggests that if borrowers are restricted to face the same income process as non-borrowers, the default rate increases by 2.73% and the expected welfare of a newborn agent declines by about 0.30%. Second, the burden of debt repayment under the standard fixed repayment plan is large, and this is why borrowers significantly change their job search strategies.

My second key result shows that the government can further improve employment outcomes and increase the welfare gain of providing student loans by restructuring debt repayment. Specifically, I use the model to evaluate the consequence of introducing IBR, an income-dependent repayment plan passed by Congress in 2009. My model suggests that IBR largely increases borrowers' average wage income by allowing them to optimally spend more time on job search. Quantitatively, when 20% of student loan borrowers switch to IBR, as in 2016 data, the expected welfare of a newborn agent increases by 0.42%.

Intuitively, under the fixed repayment plan, there is a mismatch in the timing of a well-paying job and loan repayment. College graduates enter the labor market with low earnings ability, and student loans are due when borrowers have the least capacity to pay. IBR offers insurance to job search risks, allowing borrowers to better smooth consumption and conduct more adequate job search. This sort of insurance embedded in loan repayment plans is helpful precisely because of the failure in the credit and insurance market, as indebted young borrowers have limited credit access.

My third key result sheds light on the general equilibrium implication of IBR. By alleviating the burden of debt repayment after college, IBR also encourages more agents to attend college by borrowing student debt. When the pool of workers becomes more educated, firms also make more profits and start to post more job vacancies. These two general equilibrium effects further increase social welfare. Through several counterfactual experiments, I separately quantify the three channels through which IBR increases welfare. I find that the effects of better job search and insurance, more college entry and borrowing, and more job postings are 0.13%, 018%, and 0.11%, respectively. Note that although IBR also generates an adverse incentive effect that reduces labor supply, my simulation results indicate that this effect is much smaller compared to its insurance benefit.

Related Literature Existing studies have considered how individuals' job search decisions are affected by liquidity and risks. For example, an extensive body of literature investigates how unemployment benefits and private savings affect employment incentives (e.g., Danforth, 1979; Hansen and Imrohoroglu, 1992; Ljungqvist and Sargent, 1998; Acemoglu and Shimer, 1999; Lentz and Tranas, 2005; Silvio, 2006; Lentz, 2009; Lise, 2013). Recently, researchers have started considering the labor market implication of other consumption smoothing mechanisms such as intra-household insurance (e.g., Kaplan, 2012; Guler, Guvenen and Violante, 2012), credit access (Herkenhoff, 2015; Herkenhoff, Phillips and Cohen-Cole, 2016), housing market (Brown and Matsa, 2016), mortgage modifications (Mulligan, 2009; Herkenhoff and Ohanian, 2015; Bernstein, 2016), and default arrangements (Dobbie and Song, 2015; Herkenhoff and Ohanian, 2015). My paper contributes to this research agenda by explicitly modeling and quantitatively evaluating the implication of student debt on job search behavior and the consumption smoothing mechanism offered by different repayment plans.

This paper contributes to the large literature on student loans (see Lochner and Monge-Naranjo, 2016, for a recent survey). An extensive body of this literature focuses on the impact of financial aid during college (e.g., Keane and Wolpin, 2001; Abbott et al., 2016). However, much less is known about the impact of student loans on labor market outcomes after college. Rothstein and Rouse (2011) find that indebted students from a highly selective university receive higher initial wages as they are more likely to work in high-paid industries. Recently, Gervais and Ziebarth (2016) explore a regression kink design in need-based federal student loans and find a negative effect of student loans on earnings. Using data from NLSY97 and Baccalaureate and Beyond, Weidner (2016) finds that indebted students tend to accept jobs quicker and select jobs in unrelated fields, leading to lower wage income. In this paper, I take a structural approach to highlight one plausible mechanism that could influence indebted students' job search decisions. Abbott et al. (2016) develop a rich general equilibrium model with heterogeneous agents to evaluate education policies. My model focuses less on college participation but more on job search decisions. Instead of analyzing further expansions of government-sponsored loan limits, I use the model to evaluate IBR, which has been argued to offer risk-sharing benefits with minimal incentive costs (Stiglitz, Higgins and Chapman, 2014). My analyses elucidate the channels through which income contingency influences social welfare. There are studies using structural models to assess income-driven repayment plans (e.g., Dearden et al., 2008; Ionescu, 2009; Ionescu and Ionescu, 2014), but none of them account for search risks in the labor market, which is the focus of my paper.[1]

This paper also relates to the burgeoning literature on the connection between household debt and labor market outcomes. To my knowledge, 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; Jones, Midrigan and Philippon, 2016; Midrigan, Pastorino and Kehoe, 2018). Second, households with mortgage debt engage in risk shifting by searching for higher-paid but riskier jobs because they are protected by limited liability (Donaldson, Piacentino and Thakor, 2016). Third, borrowers tend to work in high-paid industries (Rothstein and Rouse, 2011; Luo and Mongey, 2016). My paper proposes that borrowers are less picky and more likely to have lower earnings.

The rest of the paper is organized as follows. Section 2 develops a model. Section 3 describes the data and estimates the model. Section 4 presents the quantitative results. Section 5 provides several robustness checks. Finally, Section 6 concludes.

[1] An exception is from Luo and Mongey (2016), who develop a partial equilibrium model to account for search risks, but they focus on the tradeoff between wage and non-wage benefits.

2 Model

There is a continuum of agents of measure one in each cohort who live for T periods. As each cohort has unit measure, T is also the population size. In each period, the oldest cohort of agents dies at age T and a new cohort of agents is born with initial wealth b_0 and talent a randomly drawn from the cumulative distribution function $\mho(a, b_0)$.

Agents have per-period utility $u(c, l)$ and discount factor β,

$$u(c,l) = \frac{c^{1-\gamma}}{1-\gamma} - \phi\frac{l^{1+\sigma}}{1+\sigma}, \tag{2.1}$$

where c and l are consumption and labor supply. In the following, I describe the agent's problem using age index t.

2.1 College Entry and Borrowing

At $t = 0$, the agent decides whether to enter college after drawing a pecuniary cost k and a (non-pecuniary) psychic cost e randomly from cumulative distributions $\Pi(k)$ and $\Upsilon(e)$. 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 observed in data (e.g., Johnson, 2013).

Agents who are wealth constrained (i.e., $b_0 < k$) can borrow an amount of $k - b_0$ student loan debt to pay the pecuniary cost. As a result, the agent who graduates from college has initial debt $s_1 = \max\{k - b_0, 0\}$. At $t = 1$, the agent enters the labor market as an unemployed worker, and her labor productivity z depends on her talent a, education level $(n = 0, n = 1)$, and age t. Specifically, the agent's labor productivity is determined by

$$z(a, n, t) = a g_n(t), \tag{2.2}$$

where $g_n(t)$ is a deterministic trend that depends on education levels.[2] Following Bagger et al. (2014), I assume the deterministic trend $g_n(t)$ to be cubic,

$$g_n(t) = \mu_{n,0} + \mu_{n,1}t + \mu_{n,2}t^2 + \mu_{n,3}t^3. \tag{2.3}$$

Parameters $\mu_{n,0}$, $\mu_{n,1}$, $\mu_{n,2}$, and $\mu_{n,3}$ depend on education levels and are estimated to

[2] My model does not address the issues of on-the-job investment in skills emphasized by Heckman, Lochner and Taber (1998). Investigating the implication of student debt on on-the-job human capital accumulation is an interesting topic that is left for future research.

match the life-cycle earnings profile of high school and college graduates. The assumption that labor productivity depends on age instead of the number of periods in employment simplifies the problem as z_t is homogeneous within the same cohort conditional on talent.

2.2 Labor Market

Job vacancies are created by firms of heterogeneous productivity ρ. Following the standard in the search literature, each firm only creates one job vacancy, thus I do not distinguish between firms and jobs. Job search is a random matching process. Unemployed agents meet with job vacancies at the endogenous rate λ^u. Upon a meeting, job productivity is randomly drawn from an endogenous distribution $V(\rho)$. When a worker is matched with a job, they jointly produce a flow of output using the following production technology:

$$F = z(a, n, t)\rho l. \tag{2.4}$$

To simplify notations, I denote $\Omega = (b, s, a, n, d, t)$ as the worker's characteristic, while d records default status described below. Denote $W(\Omega, \rho, w)$ as the value of an employed agent Ω at wage rate w in job ρ, $U(\Omega)$ as the value of an unemployed agent Ω, and $J(\Omega, w, \rho)$ as the value of a filled job ρ that pays wage rate w. The value of a vacancy is zero due to the free entry condition. When an agent and a job meet each other, a match is formed if there exists a wage rate w, such that the worker is willing to accept the job and the firm is willing to hire the worker. Thus the participation constraints are

$$W(\Omega, w, \rho) \geq U(\Omega) \text{ and } J(\Omega, w, \rho) \geq 0. \tag{2.5}$$

Matches break up at an exogenous rate κ. After job separations, workers flow into unemployment and jobs disappear. An unemployed worker receives UI benefits θ in every period. The wage income is given by the wage rate w specified in the contract multiplied by the units of labor supply l. Upon forming a worker-firm match, the wage rate is determined through Nash bargaining:

$$w^u(\Omega, \rho) = \underset{w}{\text{argmax}}[W(\Omega, w, \rho) - U(\Omega)]^{\xi} J(\Omega, w, \rho)^{1-\xi}, \tag{2.6}$$

where ξ represents the worker's bargaining power.[3] Adopting Nash bargaining to determine wages facilitates the comparison with other search-matching models because Nash bargaining

[3] I consider a contract in which workers and firms bargain only over wage rates but not labor supply. I adopt this bargaining protocol because the number of hours is hard to verify due to a moral hazard problem, a key friction emphasized in the optimal income taxation literature (e.g., Mirrlees, 1971).

is the most common assumption under risk neutrality (see Krusell, Mukoyama and Sahin, 2010, for a related discussion on this issue).

One concern of applying Nash bargaining to model wage determination is that the change in student debt could change the wage rate that maximizes the bargaining problem (2.6). This confounds the mechanism I hope to quantify, which is how student debt affects wage income by affecting job search decisions. In my estimated model, the wage rate derived from Nash bargaining is not very responsive to the level of debt due to the existence of two countervailing forces in problem (2.6) (see Appendix A.4). On the one hand, a greater debt repayment reduces the value of the outside option $U(\Omega)$ more than the reduction in $W(\Omega, w, \rho)$ because the marginal value of liquidity is higher during unemployment. This increases worker's surplus from the match, $W(\Omega, w, \rho) - U(\Omega)$, reducing the wage rate for the worker. On the other hand, a greater debt repayment increases the marginal value of liquidity for the worker at the current job due to the reduction in consumption. This increases the sensitivity of the worker's employment value with respect to the wage rate, $\partial W(\Omega, w, \rho)/\partial w$, increasing the wage rate for the worker.[4]

Agents face progressive income taxes. Following Benabou (2002); Heathcote, Storesletten and Violante (2014), I model after-tax income $\tilde{E}$ as:

$$\tilde{E} = \begin{cases} (\varkappa - \Delta\varkappa)(wl)^{1-\tau} & \text{if employed,} \\ (\varkappa - \Delta\varkappa)\theta^{1-\tau} & \text{if unemployed,} \end{cases} \tag{2.7}$$

where wl is the pre-tax wage income, and θ is the unemployment benefits which are taxable in the U.S. The fiscal parameters $\varkappa$, $\Delta\varkappa$, and τ are set to approximate the U.S. income tax system. The parameter $\varkappa$ determines the overall level of taxation. The parameter τ determines the rate of progressivity because it reflects the elasticity of after-tax income with respect to pre-tax income. When $\tau = 0$, the tax system has a flat marginal tax rate $1 - \varkappa + \Delta\varkappa$, and when $\tau > 0$, the tax system is progressive. The parameter $\Delta\varkappa$ is a free parameter, which is normalized to be zero in my estimation. When evaluating different student loan policies, $\Delta\varkappa$ is adjusted to reflect the change in overall level of taxation to keep the government's budget balanced.

On-The-Job Search Employed workers can conduct on-the-job search and meet with other firms at the endogenous rate λ^e. To model the wage determination during on-the-job search,

[4] The impact of the bargaining channel could be large when the level of student debt is very high, which is not the case in my estimation sample. This result is also consistent with Krusell, Mukoyama and Sahin (2010)'s finding that wage differentials created by the heterogeneity of asset and Nash bargaining are small. In principle, the strength of the bargaining channel also depends on the worker's bargaining parameter ξ. When $\xi = 1$, the wage rate is always equal to the marginal product of labor $z\rho$ irrespective of the debt level.

I adopt the sequential auction framework pioneered by Postel-Vinay and Robin (2002) and further developed by Dey and Flinn (2005) and Cahuc, Postel-Vinay and Robin (2006). The firm's participation constraint (2.5) implies that the highest wage rate that firm ρ can offer to worker Ω is its marginal product of labor, $z\rho$. Because $W(\Omega, w, \rho)$ is increasing in the wage rate, $W(\Omega, z\rho, \rho)$ is the highest value that firm ρ can offer to worker Ω. I define this as the the maximal employment value in firm ρ.

Definition 1. *The maximal employment value offered by firm ρ, denoted by $\overline{W}(\Omega, \rho, i)$, is the value of worker Ω being employed by firm ρ when the wage rate is set equal to the marginal product of labor $z\rho$,*

$$\overline{W}(\Omega, \rho) = W(\Omega, z\rho, \rho). \tag{2.8}$$

The marginal product of labor increases with job productivity ρ, thus more productive firms can offer higher wage rates to workers. This implies that the maximal employment value that a worker can obtain, $\overline{W}(\Omega, \rho)$, increases with ρ. Because on-the-job search is modeled based on Bertrand competition, the job with higher productivity will keep the worker. Therefore, on-the-job search may trigger job-to-job transitions or wage renegotiations, depending on the relative productivity of the two jobs competing for the worker.

To elaborate, consider a worker Ω in a job with productivity ρ' and wage w', poached by a new job with productivity ρ. If the maximal employment value of the new job ρ is smaller than the current job's value, i.e., $\overline{W}(\Omega, \rho) < W(\Omega, w', \rho')$, then the worker will discard the new job offer and stay with the current job with the old wage w'.

If the new job can offer a higher job value, then the two jobs will compete to bid up the wage rate. The job with higher productivity is able to overbid the other job and thus keep the worker. There are two cases:

First, if $\rho > \rho'$, the worker currently employed at job ρ' will transfer to job ρ and the old job ρ' will become the negotiation benchmark due to Bertrand competition. This grants the worker an outside option value that is equal to the maximal employment value of ρ'. The new wage rate will be set according to

$$w^e(\Omega, \rho, \rho') = \underset{w}{\operatorname{argmax}}[W(\Omega, w, \rho) - \overline{W}(\Omega, \rho')]^{\xi} J(\Omega, w, \rho)^{1-\xi}, \tag{2.9}$$

where the worker's outside option is captured by the old job's productivity ρ'.

Second, if $\rho \leq \rho'$, the worker will stay with the current employer ρ', but job ρ will be used as the new negotiation benchmark for a wage rise. This grants the worker an outside option value that is equal to the maximal employment value of ρ. The new wage rate will be set to

$$w^e(\Omega, \rho', \rho) = \underset{w}{\operatorname{argmax}}[W(\Omega, w, \rho') - \overline{W}(\Omega, \rho)]^{\xi} J(\Omega, w, \rho')^{1-\xi}. \tag{2.10}$$

Reservation Productivity Equation (2.9) nests equation (2.6), if we treat an unemployed agent Ω as being employed in a fictitious job $\rho_u(\Omega)$, such that $\overline{W}(\Omega, \rho_u(\Omega)) = U(\Omega)$. Hence, the negotiation benchmark for an unemployed agent is $\rho_u(\Omega)$ and the wage rate satisfies

$$w^u(\Omega, \rho) = w^e(\Omega, \rho, \rho_u(\Omega)). \tag{2.11}$$

In fact, $\rho_u(\Omega)$ can be considered as the reservation productivity for an unemployed agent Ω searching for a job, because she is indifferent between being employed at job $\rho_u(\Omega)$ or staying unemployed. On the other hand, job $\rho_u(\Omega)$ is also indifferent about hiring because it is offering the worker the maximal employment value. I define this formally as follows:

Definition 2. *The reservation productivity for an unemployed agent Ω is a fictitious job with productivity $\rho_u(\Omega)$ such that the agent is indifferent between accepting the job or staying unemployed, i.e.,*

$$\overline{W}(\Omega, \rho_u(\Omega)) = U(\Omega). \tag{2.12}$$

An increase in student debt s reduces the reservation productivity by making the agent more risk averse and liquidity constrained, inducing the agent to search for a shorter time. In Appendix B, I derive this mechanism analytically in a partial equilibrium search model.

2.3 Student Loans and Social Insurance

I model student debt repayment to reflect features of the federal student loan program, which accounts for 80% of the total volume. Most federal loans allow borrowers to postpone payments during the grace period immediately after college graduation. Thus I assume that agents start to make student debt repayment in period $t_0 > 1$. Student loan borrowers can choose the fixed repayment plan or IBR.[5] The interest rate is variable before July 1, 2006, and fixed thereafter. I consider a fixed interest rate r^s for simplicity, applied to both plans.

The fixed repayment plan requires borrowers to make the same payment y_t^{FIX} in each period until time t^{FIX}. Hence, the per-period payment is given by:

$$y_t^{\text{FIX}} = \frac{r^s}{(1+r^s)\left[1 - \frac{1}{(1+r^s)^{t^{\text{FIX}}-(t-t_0)}}\right]} s_t, \quad \text{for } t_0 \le t \le t^{\text{FIX}}. \tag{2.13}$$

A realistic IBR requires borrowers to repay the required payment under the fixed repayment plan or a fraction ϱ of their discretionary income, whichever is smaller. Discretionary income

[5] In the U.S., student loan borrowers are also allowed to choose graduated repayment plan and extended repayment plan. These plans are variations of the standard fixed repayment plan.

is defined as the difference between pre-tax income income and 150% of the poverty guideline. Borrowers are required to make payments until the loan is paid in full or time t^{IBR}. After t^{IBR}, the remaining balance will be forgiven by the government.[6] To reflect these features, I model the per-period payment under IBR by:

$$y_t^{\text{IBR}} = \min\left(\varrho \max(w_t l_t - 1.5pov, 0), \quad y_1^{FIX}, \quad s_t\right), \quad \text{for } t_0 \leq t \leq t^{\text{IBR}}. \tag{2.14}$$

Unlike other loans, student loans are practically non-dischargeable after default. I use the variable $d = 0^-, 0^+, 1$ to represent default status. I assume that borrowers who have never defaulted ($d = 0^-$) have the option to enter default by incurring disutility η. Therefore, defaults may happen voluntarily or involuntarily, both of which would change the agent's default status from $d = 0^-$ to $d = 1$. A voluntary default refers to the default event in which the agent chooses not to repay even though her cash-on-hand $b_t + \tilde{E}_t$ (wealth plus after-tax income) is higher than the required repayment, i.e., $b_t + \tilde{E}_t \geq y_t^{\text{FIX}}$(or y_t^{IBR}). An involuntary default happens when her cash-on-hand is not enough to make the payment.

During the period of default ($d = 1$), borrowers are not required to make any payments. In reality, borrowers can get rehabilitation on their defaulted loans after consequently making several eligible payments. I thus assume that borrowers return to non-default status ($d = 0^+$) with probability π in each period during default. Then, borrowers continue making payments y_t^{FIX} under the fixed repayment plan.[7] Note that because interest accrues, default delays the repayment but payments after the default period will increase, reflecting what happens in reality.

I do not allow repeated voluntary defaults given the complexity of the current setup.[8] Thus I assume that borrowers do not have the option to default if $d = 0^+$ and $b_t + \tilde{E}_t \geq y_t^{\text{FIX}}$. However, borrowers may still default involuntarily when their income falls short, in which case they repay all cash-on-hand. Summarizing the different cases above, the repayment at

[6]IBR is different from the first attempt at income contingent loans in the U.S. in 1971-the Yale Tuition Postponement Option (TPO). The main difference is that under IBR, borrowers do not need to repay more than the amount borrowed. However, there is cross-subsidization under TPO as participants are required to make payments until the debt of an entire "cohort" is repaid.

[7]To obtain loan rehabilitation, borrowers must agree with the U.S. Department of Education on a reasonable and affordable repayment plan. The repayment plans after default are set case by case. Generally, a monthly payment is considered to be reasonable and affordable if it is at least 1.0% of the current loan balance, which is roughly the payment required by the fixed repayment plan. Volkwein et al. (1998) find that two out of three defaulters reported making payments shortly after the official default first occurred.

[8]In practice, loan rehabilitation is a one-time opportunity, and more severe punishments are imposed on borrowers who default repeatedly. Allowing repeated default in my model leads to a technical issue, because this essentially allows the agent to delay debt repayment forever.

time t is given by

$$y_t = \begin{cases} \min\left(y_t^{\text{FIX}}(\text{or } y_t^{\text{IBR}}), b_t + \tilde{E}_t\right) & \text{if } d = 0^+, 0^- \\ 0 & \text{if } d = 1. \end{cases} \tag{2.15}$$

Following Hubbard, Skinner and Zeldes (1995), I introduce means-tested social insurance. Agents receive a government transfer ϖ_t when their after-tax income net of debt repayment falls below $\underline{c}$. i.e.,

$$\varpi_t = \max\left(0, \underline{c} - (b_t + \tilde{E}_t - y_t)\right). \tag{2.16}$$

Essentially, we can think of $\underline{c}$ as a consumption floor to ensure that agents do not have extremely large marginal value of consumption after involuntary defaults.

2.4 Value Functions

Denote $U(\Omega)$ as the value of an unemployed worker of type Ω in the labor market. After drawing the pecuniary cost k and the psychic cost e, the agent decides whether to enter college at $t = 0$. If the agent chooses to enter college, she would get an initial value U^{C} at $t = 1$ given by

$$U^{\text{C}} = U(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}, a, 1, 0^-, 1) - e. \tag{2.17}$$

If instead the agent chooses not to enter college at $t = 1$, she would get an initial value U^{HS} at $t = 1$ given by

$$U^{\text{HS}} = U(b_0, 0, a, 0, 0^-, 1). \tag{2.18}$$

Thus at $t = 0$, the agent enters college if $U^{\text{C}} > U^{\text{HS}}$. My modeling of college study does not consider the dynamics during college. This makes the college entry decision very tractable. The welfare implications of my model are not affected much by this modeling simplification because the dynamic gains and losses during college study can be largely absorbed by a flexible distribution of e estimated to account for the cross-sectional variations in college entry decisions in the data.

Instead of using the wage rate w as a state variable for an employed worker, the discussions in Section 2.2 suggest that the negotiation benchmark's productivity is a natural state variable. Therefore, the state variables are worker characteristic Ω, job productivity ρ, and the negotiation benchmark's productivity ρ'. The value of an employed worker and the value of a job immediately after search and matching can be written as $W(\Omega, \rho, \rho')$ and $J(\Omega, \rho, \rho')$.

An unemployed worker with $d_t = 0^+$ has defaulted before and does not have the option to default again. She optimally chooses consumption c_t, labor supply l_t, and reservation job's productivity ρ_u. With probability λ^u, she meets a job and gets employed if the job's productivity is greater than the reservation productivity. For expositional purposes, I isolate default status d from Ω and define $\hat{\Omega} = (b, s, a, n, t)$. The recursive equation is:

$$
\begin{aligned}
U(\hat{\Omega}_t, 0^+) = \max_{c_t, l_t, \rho_u} \quad & u(c_t, l_t) + \beta \Bigg[\lambda^u \int\limits_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 0^+, x, \rho_u) \mathrm{d}V(x) \\
& + [1 - \lambda^u + \lambda^u V(\rho_u)] U(\hat{\Omega}_{t+1}, 0^+) \Bigg] \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)\theta^{1-\tau} - y_t] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma\theta,
\end{aligned}
\tag{2.19}
$$

where r is the interest rate on deposit and $\mathbb{1}$ is an indicator function. $\varsigma > 0$ represents the access to consumption loans proportional to current income.

With $d_t = 0^-$, the agent has the option to default by incurring disutility η:

$$
\begin{aligned}
U(\hat{\Omega}_t, 0^-) = \max_{c_t, l_t, \rho_u, d_{t+1}} \quad & u(c_t, l_t) + \beta \mathbb{1}_{d_{t+1}=0^-} \Bigg[\lambda^u \int\limits_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 0^-, x, \rho_u) \mathrm{d}V(x) \\
& + [1 - \lambda^u + \lambda^u V(\rho_u)] U(\hat{\Omega}_{t+1}, 0^-) \Bigg] \\
+ \beta \mathbb{1}_{d_{t+1}=1} & \Bigg[-\eta + \lambda^u \int\limits_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 1, x, \rho_u) \mathrm{d}V(x) + [1 - \lambda^u + \lambda^u V(\rho_u)] U(\hat{\Omega}_{t+1}, 1) \Bigg], \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)\theta^{1-\tau} - y_t] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma\theta,
\end{aligned}
\tag{2.20}
$$

With $d_t = 1$, the agent is in default at t and moves to $d = 0^+$ with probability π at $t+1$:

$$
\begin{aligned}
U(\hat{\Omega}_t, 1) = \max_{c_t, l_t, \rho_u} \quad & u(c_t, l_t) + \beta\pi \left[\lambda^u \int\limits_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 0^+, x, \rho_u) \mathrm{d}V(x) \right. \\
& \left. + [1 - \lambda^u + \lambda^u V(\rho_u)] U(\hat{\Omega}_{t+1}, 0^+) \right] \\
+\beta(1-\pi) & \left[\lambda^u \int\limits_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 1, x, \rho_u) \mathrm{d}V(x) + [1 - \lambda^u + \lambda^u V(\rho_u)] U(\hat{\Omega}_{t+1}, 1) \right], \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)\theta^{1-\tau}] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s) s_t, \\
& b_{t+1} \geq -\varsigma\theta,
\end{aligned}
\tag{2.21}
$$

Employed workers contact other jobs at the rate λ^e through on-the-job search. The default decisions of employed workers involve similar recursive formulations as those of unemployed workers. I thus illustrate the recursive problem with $d_t = 0^+$ below and leave the other two cases in Appendix A.5.

$$
\begin{aligned}
W(\hat{\Omega}_t, 0^+, \rho, \rho') = \max_{c_t, l_t} \quad & u(c_t, l_t) + \beta(1-\kappa) \left[[1 - \lambda^e + \lambda^e V(\rho')] W(\hat{\Omega}_{t+1}, 0^+, \rho, \rho') \right. \\
+\lambda^e & \left. \left(\int\limits_{x \geq \rho} W(\hat{\Omega}_{t+1}, 0^+, x, \rho) \mathrm{d}V(x) + \int\limits_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 0^+, \rho, x) \mathrm{d}V(x) \right) \right] + \beta\kappa U(\hat{\Omega}_{t+1}, 0^+), \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)(w^e(\Omega_t, \rho, \rho') l_t)^{1-\tau} - y_t] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma w^e(\Omega_t, \rho, \rho') l_t,
\end{aligned}
\tag{2.22}
$$

From the firm's perspective, the value of a filled job is,

$$
\begin{aligned}
J(\Omega_t, \rho, \rho') = & [z(a, n, t)\rho - w^e(\Omega_t, \rho, \rho')] l(\Omega_t, \rho, \rho') \\
& + \beta(1-\kappa) \left[\lambda^e \int\limits_{\rho' < x < \rho} J(\Omega_{t+1}, \rho, x) \mathrm{d}V(x) + [1 - \lambda^e + \lambda^e V(\rho')] J(\Omega_{t+1}, \rho, \rho') \right].
\end{aligned}
\tag{2.23}
$$

2.5 Stationary Competitive Equilibrium

To close the model, I describe the equilibrium conditions that determine the endogenous job contact rates, vacancy distribution, and tax rates. Denote $\phi^u(\Omega)$ as the PDF of unemployed workers searching for jobs and $\phi^e(\Omega, \rho, \rho')$ as the PDF of employed workers matched with job ρ and negotiation benchmark ρ'. Because I focus on the stationary equilibrium, all these distributions are time invariant.

Matching Following Lise and Robin (2017), I assume that unemployed agents have search intensity q^u and employed agents have search intensity q^e.[9] Denote Q as the aggregate level of search intensity contributed by both unemployed and employed agents:

$$Q = q^u \overline{u} T \int \phi^u(\Omega) \mathrm{d}\Omega + q^e (1 - \overline{u}) T \iiint \phi^e(\Omega, \rho, \rho') \mathrm{d}\Omega \mathrm{d}\rho \mathrm{d}\rho', \tag{2.24}$$

where $\overline{u}$ is the equilibrium unemployment rate.

The total number of meetings M is determined by a Cobb-Douglas matching function,

$$M = \chi Q^{\omega} N^{1-\omega}, \tag{2.25}$$

where χ and ω are two parameters governing the matching efficiency. N is the endogenous number of vacancies created by firms. From a firm's perspective, the probability of contacting a worker is

$$h = M/N. \tag{2.26}$$

The job contact rates for unemployed workers and employed workers are

$$\lambda^u = q^u M/Q; \quad \lambda^e = q^e M/Q. \tag{2.27}$$

Free Entry Condition The equilibrium number of vacancies N and unemployment rate $\overline{u}$ are determined by the free entry condition. Following Lise, Meghir and Robin (2016), I assume that the firm pays a cost ν to create a vacancy whose productivity ρ is randomly drawn from a CDF $F(\rho)$. Vacancies last for one period; thus if the created vacancy is not filled by a worker in the current period, the vacancy will be destroyed. This implies that the equilibrium vacancy distribution $V(\rho)$ is the same as $F(\rho)$. The equilibrium number of vacancies N is determined by the free entry condition, which requires the cost of vacancy

[9] The assumption that search intensities are different during unemployment and employment is standard in the search literature. For example, Postel-Vinay and Robin (2002) estimate a model with on-the-job search and find that job contact rates are uniformly higher during unemployment across a wide range of occupations. In my model, search intensity is exogenously specified. With endogenous search intensity, indebted unemployed workers would search more and exit unemployment faster. This gives indebted workers another degree of freedom to adjust their job search strategies, which will to some extent alleviate the burden of debt repayment quantitatively. Qualitatively, introducing endogenous search intensity would not affect the model's prediction on workers' reservation productivity.

creation being equal to its expected value,

$$\nu = \frac{hT}{Q}\left[\overline{u}q^u \iint\limits_{\rho''>\rho_u} J(\Omega,\rho'',\rho_u)\phi^u(\Omega)\mathrm{d}\Omega\mathrm{d}F(\rho'') + (1-\overline{u})q^e \iiint\limits_{\rho''>\rho} J(\Omega,\rho'',\rho)\left(\int \phi^e(\Omega,\rho,\rho')\mathrm{d}\rho'\right)\mathrm{d}\Omega\mathrm{d}\rho\mathrm{d}F(\rho'')\right]. \tag{2.28}$$

Equation (2.28) states that a new vacancy meets an agent with probability h. Conditional on a meeting, the vacancy may meet an unemployed or employed worker. In equilibrium, the flows in and out of unemployment balance each other out. The unemployment rate $\overline{u}$ is determined by:

$$(1-\overline{u})\kappa = \overline{u}\lambda^u \int [1 - V(\rho_u(\Omega))]\phi^u(\Omega)\mathrm{d}\Omega. \tag{2.29}$$

Government Budget Constraint The overall debt forgiveness for student loan borrowers in each cohort is determined by the difference in the present value of debt borrowed at age $t = 1$ and the present value of debt repaid by retirement age T. Thus

$$\mathrm{FGV} = \int\limits_{t=1} s\phi^u(\Omega)\mathrm{d}\Omega - \frac{1}{(1+r^s)^T}\left[\overline{u}\int\limits_{t=T} s\phi^u(\Omega)\mathrm{d}\Omega + (1-\overline{u})\iiint\limits_{t=T} s\phi^e(\Omega,\rho,\rho')\mathrm{d}\Omega\mathrm{d}\rho\mathrm{d}\rho'\right]. \tag{2.30}$$

I assume that the tax revenue is collected to finance UI benefits, the means-tested social insurance, a non-valued public consumption good G, and student debt forgiveness FGV:

$$(1-\overline{u})T\iiint \left[wl - (\varkappa - \Delta\varkappa)(wl)^{1-\tau} - \varpi\right]\phi^e(\Omega,\rho,\rho')d\Omega\mathrm{d}\rho\mathrm{d}\rho' = \overline{u}T\int \left[(\varkappa - \Delta\varkappa)\theta^{1-\tau} + \varpi\right]\phi^u(\Omega)\mathrm{d}\Omega + G + \mathrm{FGV}, \tag{2.31}$$

where w, l, and ϖ are agent-specific wage, labor supply, and social insurance benefits.

Equilibrium Definition Below I define the stationary competitive equilibrium.

Definition 3. *The stationary competitive equilibrium consists of stationary distributions of unemployed agents, $\phi^u(\Omega)$, employed agents $\phi^e(\Omega,\rho,\rho')$, vacancies $V(\rho)$, the number of vacancies N, and unemployment rate $\overline{u}$, such that:*

(1). *The job contact rates for agents and firms are determined by the Cobb-Douglas meeting technology according to (2.24-2.27).*

(2). *All unemployed agents Ω make consumption and default decisions by solving problems (2.19-2.21) depending on their default status.*

(3). *All employed agents Ω at job ρ with negotiation benchmark ρ' receive wage income and make consumption, labor supply, and default decisions by solving problems (2.22) and (A.3-A.4) depending on their default status.*

(4). *Wage rates, $w^e(\Omega, \rho, \rho')$ and $w^{e,d}(\Omega, \rho, \rho')$, are determined by Nash bargaining specified in (2.9-2.11).*

(5). *All agents receive social insurance benefits ϖ determined by equation (2.16).*

(6). *The equilibrium number of vacancies N and the vacancy distribution $V(\rho)$ are determined by the free entry condition (2.28).*

(7). *The equilibrium unemployment rate $\overline{u}$ is determined to balance flows in and out of unemployment, as specified in (2.29).*

(8). *The adjustment in overall level of taxation, $\Delta\varkappa$, is determined to satisfy the government's budget constraint (2.31).*

3 Data, Estimation, and Validation Tests

I estimate the model based on U.S. data during the period 1997-2008. In this section, I first introduce the data. Then I present the estimation procedures of my quantitative model. Finally, I check the external validity of the model.

3.1 Data

My empirical analysis uses panel data from NLSY97. This is a nationally representative survey conducted by the Bureau of Labor Statistics. In round 1, 8,984 youths were initially interviewed in 1997. Follow-up surveys were conducted annually. Youths were born between 1980 and 1984. Their ages ranged from 12 to 18 in round 1 and were 26 to 32 in round 15. The survey contains extensive information on each youth's labor market behavior and documents the amount of student loans borrowed during college, which makes NLSY97 an ideal data set for studying the implications of student debt on job search decisions.

My analyses focus on high school and college graduates. I do not include college dropouts because it is not clear when they enter the labor market. I drop youths who have ever served in the military or attended graduate schools because they are not in the same position as the other youths in my sample when it comes to making labor market decisions. I also drop youths who received the bachelor's degree before 1997 due to the lack of labor market information upon college graduation. This leaves me with a sample of 1,721 high school graduates and 1,261 college graduates. I construct the variables used in structural estimation following the steps illustrated in Appendix C.

3.2 Estimation

Each period represents one month. Because my estimation sample period is 1997-2008 and IBR was introduced in 2009, I estimate the model by restricting all agents to the fixed repayment plan.[10]

My estimation consists of three steps. First, I specify the parametric functional forms for several distributions in order to identify the model and match the data. Second, I determine the values of a set of parameters without running simulations. These parameters' values are either separately estimated or taken from existing literature. Finally, I discuss the identification of the model's remaining parameters and estimate their values using MSM.

3.2.1 Parametrization

I assume that the marginal distribution of initial wealth follows a flexible generalized Pareto distribution with location parameter $\underline{b}$, scale parameter ζ, and shape parameter φ:

$$\mho_{b_0}(b_0) = \frac{1}{\zeta}\left(1 + \varphi\frac{b_0 - \underline{b}}{\zeta}\right)^{-\frac{1+\varphi}{\varphi}}. \tag{3.1}$$

The marginal distribution of talent follows a flexible beta distribution with parameters f_1^a and f_2^a. To capture the potential correlation between initial wealth and talent, I use the Frank copula, where the single parameter ϑ governs the dependence between the CDF of the marginal distribution of wealth, $\mho_{b_0}(b_0)$, and the CDF of talent, $\mho_a(a)$[11]:

$$C(x_1, x_2) = \mathbb{P}(\mho_{b_0}(b_0) \leq x_1, \mho_a(a) \leq x_2) = -\frac{1}{\vartheta}\log\left[1 + \frac{(e^{-\vartheta x_1} - 1)(e^{-\vartheta x_2} - 1)}{e^{-\vartheta} - 1}\right]. \tag{3.2}$$

I assume that the pecuniary cost k and psychic cost e of college entry are drawn from a (truncated) normal distribution with parameters (μ_k, σ_k^2) and (μ_e, σ_e^2). Because pecuniary

[10]During my sample period, student loan borrowers have the option to enroll in the old income-contingent plan (ICR). However, the enrollment rate was below 1% due to the high repayment ratios.

[11]The use of the Frank copula allows me to estimate the parameters governing the marginal distribution of wealth separately using MLE. The parameters governing the marginal distribution of talent along with the parameter ϑ are estimated with other internally estimated parameters using MSM.

costs of college entry are non-negative, I set $k = 0$ for negative draws. Following Lise, Meghir and Robin (2016) and Jarosch (2015), I assume that job productivity follows a flexible Beta distribution on support $[0, 1]$ with parameters f_1^ρ, f_2^ρ.

3.2.2 Externally Determined Parameters

Table 1 presents the values for externally determined parameters. The three parameters governing the initial wealth distribution, $(\underline{b}, \zeta, \varphi)$, are estimated directly using MLE to match the empirical distribution of wealth (see panel A of Figure 2).

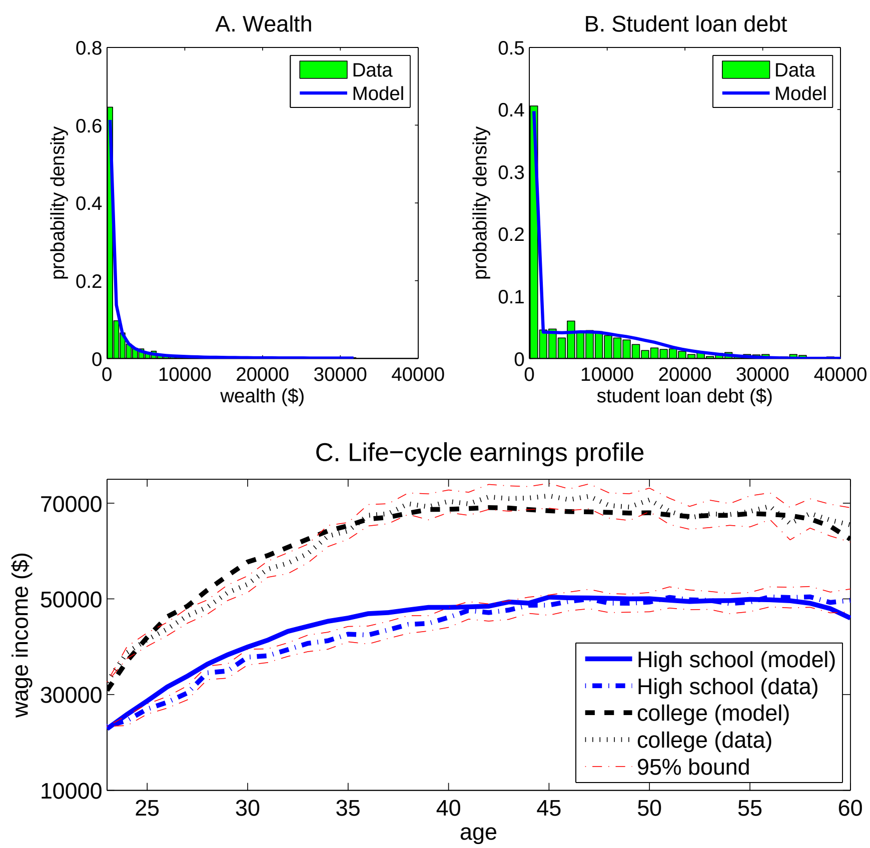


Figure 2: Comparing initial wealth, student debt, and life-cycle earnings profiles between model and data.

The parameter $\Delta\varkappa$ is normalized to be zero in my estimation. The parameters $\varkappa$ and τ are identified using the regression coefficients obtained from regressing log individual after-tax earnings $\tilde{E}_i$ on log individual pre-tax earnings E_i:

$$\log(\tilde{E}_i) = \log(\varkappa) + (1 - \tau)\log(E_i) + \varepsilon_i. \tag{3.3}$$

Table 1: Parameters determined outside the model.

Parameters	Symbol	Value	Parameters	Symbol	Value
Location parameter	$\underline{b}$	0	Risk-free deposit rate	r	0.37%
Scale parameter	ζ	223.0	Student loan interest rate	r^s	0.53%
Shape parameter	φ	1.52	Discount factor	β	0.997
Overall tax level	$\varkappa$	2.17	Overall tax level shifter	$\Delta\varkappa$	0
Rate of tax progressivity	τ	0.11	Bargaining parameter	ξ	0.72
Risk aversion	γ	3	UI benefits	θ	\$650
Elasticity of labor supply	σ	2.59	Consumption floor	$\underline{c}$	\$100
Number of years working	T	458	Grace period	t_0	6
Repayment period (FIX)	t^{FIX}	126	Repayment period (IBR)	t^{IBR}	306
IBR repayment rate	ϱ	15%	Poverty guideline	pov	\$870
Duration of default	π	0.083	Meeting technology	ω	0.72
Consumption loans	ς	0.185			

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. The estimated values are $\varkappa = 2.17$ and $\tau = 0.11$.

I take advantage of the existing findings to determine the values of γ and σ. I choose γ according to the literature that is most closely related to this paper. In particular, I set $\gamma = 3$ consistent with the precautionary savings literature (e.g., Hubbard, Skinner and Zeldes, 1995). The tax-modified Frisch elasticity of labor supply with respect to pre-tax wage rates is $(1 - \tau)/(\sigma + \tau)$. Thus I set $\sigma = 2.59$, which implies that the tax-modified Frisch elasticity is 0.33, broadly consistent with microeconomic evidence (Keane, 2011).

I set the monthly risk-free rate to be $r = (1 + 4.5\%)^{1/12} = 0.37\%$, corresponding to the average real interest rate in the U.S. between 1997-2008 (source: World Development Indicators). Following the standard practice, I set the monthly discount rate to be $\beta = 0.997$. Between 2002-2008, the average retirement age is around 60. I set $T = 458$, which corresponds to a real-life working age of 23 to 60.

I set the matching parameter and bargaining parameter to be $\omega = \xi = 0.72$ following Krusell, Mukoyama and Sahin (2010). In the U.S., UI benefits generally pay eligible workers between 40%-50% of their previous pay. The standard time-length of unemployment compensation is 6 months. In my model, unemployed agents receive UI benefits every month. Therefore, I choose a relatively lower value of UI benefits to account for this discrepancy. I set $\theta = \$650$, which means that yearly UI benefits roughly equal to 40% of the average 6-month income.

Means-tested benefits include Aid to Families with Dependent Children (AFDC), food stamps, and Women, Infants, Children (WIC). In my sample, the percent of youths who had ever received AFDC, food stamps, and WIC by 2009 are 1.3%, 8.4%, and 6.3%. About 11.5% of youths had ever received any means-test benefits during my sample period, with a median monthly benefit level of \$150. Because the take-up rate is far from universal, following Kaplan (2012), the monthly consumption floor is set to be $\underline{c} = \$100$. Kaplan and Violante (2014) estimate that the median ratio of credit limit to labor income is 18.5% for households aged 22 to 59. I thus set $\varsigma = 0.185$.

The parameters t_0, t^{FIX}, t^{IBR}, ϱ, pov, π, and r_s are chosen to capture a setting for federal student loan borrowers. I set $t_0 = 6$ as the non-repayment grace period is 6 months for most student loans. Under the standard fixed repayment plan, borrowers have to 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 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 for the 48 contiguous states (excluding Hawaii and Alaska) and the District of Columbia between 1997-2008 measured in 2009 dollars. Following Ionescu (2009), I set $\pi = 0.083$ so that borrowers on average spend 1 year in default status. I set the interest rate on student loans to be $r_s = 0.53\%$, which implies a risk premium consistent with the annualized mark-up over the Treasury bill rate, 2.1%, set by the government for subsidized loans issued before 2006.

3.2.3 Internally Estimated Parameters

I now turn to the identification discussion of internally estimated parameters.

Labor Market Moments The exogenous job separation rate κ is identified from the average duration of employment spells. In the NLSY97 sample, employment spells last for about 2.2 years on average, consistent with the calculations of Shimer (2005) using CPS data.

The search intensity during employment q^e is normalized to be 1. The search intensity during unemployment q^u and the parameter governing matching efficiency χ are identified from the average unemployment duration and the average duration of job tenure. In the data, the average unemployment duration is 27.2 weeks and jobs last for about 1.5 years on average. Because job separations could either result in a transition into unemployment or a transition into another job, the small difference between the average employment duration and the average job tenure implies that on-the-job search is much less efficient compared to searching during unemployment.[12]

[12] In the extreme case where the average employment duration is equal to the average job tenure, there are no job-to-job transitions, which implies the absence of on-the-job search. On the other hand, if the average job tenure is much shorter than the average employment duration, it means most of the job separations are due to job-to-job transitions instead of employment-to-unemployment transitions.

Table 2: Model fit for targeted moments.

Targeted Moments	Model	Data
Mean of employment duration (year)	2.2	2.2
Mean of unemployment duration (week)	27.2	27.2
Mean of job tenure (year)	1.5	1.5
Variance of log wage income	0.183	0.155
Skewness of log wage income	0.054	-0.174
Mean of log wage increase upon job-to-job transitions	0.135	0.150
Variance of log wage increase upon job-to-job transitions	0.022	0.042
Vacancy to unemployment ratio	0.409	0.409
Average hours worked per year	1,732	1,729
Life-cycle earnings profile	Figure 2, Panel C	
Fraction of agents with a bachelor's degree	41.9%	42.2%
Unexplained variance in college entry decisions $(1 - R^2)$	0.62	0.64
Correlation between talent and student debt	0.05	0.04
Two-year cohort default rate	9.55%	9.26%
Student debt distribution upon college graduation	Figure 2, Panel B	

As argued by Jarosch (2015), the second and third moments of the cross-sectional log wage income distribution are informative about the distribution of job productivity. However, in my model the productivity of matched worker job pair is given by $z\rho$. The symmetric roles played by worker productivity z and job productivity ρ suggest that it is impossible to separately identify the parameters f_1^a, f_2^a governing the marginal distribution of talent and the parameters f_1^ρ, f_2^ρ governing the marginal distribution of vacancy's productivity if we only use moments from the cross-sectional log wage income distribution. Note that upon job-to-job transitions, worker productivity remains the same but job productivity increases. Therefore, the mean and variance of log wage increase upon job-to-job transitions are informative about the value of parameters f_1^ρ, f_2^ρ. In the data, there are unmodeled sources of variation that affect the dispersion of the log wage income distribution, thus I adjust for these sources of variation when constructing the variance and skewness (see Appendix C.2). The cross-sectional log wage income residuals have variance 0.155 and skewness -0.174. The log hourly wage rate rises by about 15.0% upon job-to-job transitions on average with a variance of 0.042.

The flow cost of vacancy creation ν is identified from the vacancy to unemployment ratio. The Job Openings and Labor Turnover Survey (JOLTS) collected job openings information since December 2000 in the United States. I estimate the vacancy to unemployment ratio to be 0.409 using the data between 2001-2008. This estimate is smaller than the estimate of 0.539 provided by Hall (2005), who uses data between 2001-2002.

Parameter ϕ is a scale factor of labor supply, which is identified from the average number of hours worked in each year. In the data, people with full-time jobs work for roughly 1,729 hours per year on average.

Parameters $\mu_{n,0}$, $\mu_{n,1}$, $\mu_{n,2}$, and $\mu_{n,3}$ are identified to match the average wage income in each year between ages 23-60 for high school and college graduates, respectively. Because NLSY97 does not provide individual labor market histories at this length, I construct the life-cycle earnings profile using March CPS 1997-2008 data (see panel C of Figure 2). Following Rubinstein and Weiss (2006), I pool the CPS data from different years and cohorts and focus only on the stage in an individual's life cycle.[13]

College and Debt Moments The average psychic cost μ_e is identified to match the average fraction of students with a bachelor's degree. The parameter σ_e is identified to match the variation in college entry decision not explained by individual talent and wealth. Specifically, I regress the college entry dummy on talent and initial wealth using the actual data and the simulated data. The value of parameter σ_e is identified to match the unexplained variance (i.e., $1 - R^2$).

The parameter ϑ captures the correlation between talent and initial wealth. A greater ϑ suggests that talented agents are wealthier and as a result, demand fewer student loans. Therefore, the value of ϑ can be identified to match the correlation between individual AFQT score[14] and student debt upon college graduation. In the data, there is a slight positive correlation between AFQT and student debt, 0.04, after controlling for other characteristics.

The disutility of default η is identified from the equilibrium two-year cohort default rate on student loan debt. Using a random 1% sample of National Student Loan Data System (NSLDS), Yannelis (2015) computes that the average two-year cohort default rate for undergraduate borrowers is 9.26% between 1997-2011.

The two parameters (μ_k, σ_k) capturing the pecuniary costs of college study are identified to match the distribution of student loan debt upon college graduation. In the data, about 61.6% of college graduates have outstanding student loans with a mean of \$11,873. I use 40 equally spaced moments to capture the empirical histogram of student debt distribution (see panel B of Figure 2).[15]

[13] The pooled data analysis is valid only under stationary conditions. The condition would be violated if the wage structure had undergone major changes during this period or the cohort quality changes substantially over time.

[14] AFQT scores are computed using the Standard Scores from four ASVAB subtests: Arithmetic Reasoning (AR), Mathematics Knowledge (MK), Paragraph Comprehension (PC), and Word Knowledge (WK). It is used as a proxy of human capital skills in human capital literature.

[15] It is difficult to directly estimate these two parameters based on college tuition, because in principle students also receive parental transfers, scholarships, and incur living costs (consumption, housing, etc)

Estimation I estimate the set of internally-estimated parameters Ξ using MSM:

$$\hat{\Xi} = \underset{\Xi}{\operatorname{argmin}}\, L(\Xi) \tag{3.4}$$

Table 3: Parameters estimated jointly using MSM.

Labor Market Parameters	Symbol	Value	Std. Error
Exogenous job separation rate	κ	0.31	0.04
Search intensity during unemployment	q^u	4.81	0.55
Search intensity during employment	q^e	1	N/A
Matching efficiency	χ	0.69	0.13
Talent distribution	f_1^a	1.48	0.36
Talent distribution	f_2^a	0.42	0.13
Vacancy productivity distribution	f_1^ρ	1.43	0.29
Vacancy productivity distribution	f_2^ρ	0.50	0.10
Flow cost of vacancy creation	ν	47,435	4,184
Labor supply scaling factor	ϕ	6.2×10^{-8}	0.4×10^{-8}
Constant term in worker's ability	$\mu_{0,0}, \mu_{1,0}$	0.578, 0.873	0.027, 0.019
Linear term in worker's ability	$\mu_{0,1}, \mu_{1,1}$	0.080, 0.091	0.005, 0.004
Square term in worker's ability	$\mu_{0,2}, \mu_{1,2}$	$-3.8, -4.0(\times 10^{-3})$	$0.5, 0.4(\times 10^{-3})$
Cubic term in worker's ability	$\mu_{0,3}, \mu_{1,3}$	$5.3, 5.6(\times 10^{-5})$	$0.7, 0.5(\times 10^{-5})$
College and Debt Parameters	**Symbol**	**Value**	**Std. Error**
Mean of psychic cost	μ_e	3.1×10^{-9}	0.8×10^{-9}
Stdev. of psychic cost	σ_e	5.4×10^{-8}	1.1×10^{-8}
Talent and initial wealth correlation	ϑ	0.45	0.16
Default cost	2.9×10^{-8}	η	0.5×10^{-8}
Mean of pecuniary cost ($)	μ_k	12,673	1,325
Stdev. of pecuniary cost ($)	σ_k	16,788	2,730

The objective function is given by

$$L(\Xi_2) = [\hat{m}_N - \hat{m}_S(\Xi)]^T \hat{\Theta}^{-1} [\hat{m}_N - \hat{m}_S(\Xi)]. \tag{3.5}$$

where $\hat{m}_N = \frac{1}{N}\sum_{i=1}^{N} m_i$ is the vector of moments computed in the data. $\hat{m}_S(\Xi)$ is the vector of moments generated by the model simulation in the stationary equilibrium. $\hat{\Theta}$ is a weighting matrix, constructed from the diagonal of the estimated variance-covariance matrix of $\hat{m}_N$

during college study. My indirect inference suggests that the average total college cost is about $12,673. Data from IPEDS documents that during 2001-2004, the annual college tuition for a four-year college is between $989-$2,520 depending on state category, and the national average cost of room and board is $6,532 (Johnson, 2013). This implies a total college cost of $10,488-$16,612.

using bootstrapping. Estimates are not sensitive to alternative choices of weighting matrices because most moments are matched well (see Table 2). I detail the estimation procedure and numerical algorithm in Appendix D.

The asymptotic variance-covariance matrix for MSM estimators $\hat{\Xi}$ is given by:

$$Q(\hat{\Theta}) = (\nabla^T \hat{\Theta} \nabla)^{-1} \nabla^T \hat{\Theta} \widehat{\text{COV}} \hat{\Theta}^T \nabla (\nabla^T \hat{\Theta}^T \nabla)^{-1}, \tag{3.6}$$

where $\widehat{\text{COV}}$ is the variance-covariance matrix of $\hat{m}_N$ and $\nabla = \frac{\partial \hat{m}_S(\Xi)}{\partial \Xi}|_{\Xi=\hat{\Xi}}$ is the Jacobian matrix of the simulated moments evaluated at the estimated parameters.[16] The first derivatives are calculated numerically by varying each parameter's value by 1%. The standard errors of $\hat{\Xi}$ are given by the square root of the diagonal elements of $Q(\hat{\Theta})$. Table 3 presents the internally estimated parameters. Given the estimated parameters, the implied equilibrium government spending is determined by equation (2.31), $G = 60,000$, as FGV $= 0$ under the fixed repayment plan. Through my quantitative analyses conducted in Section 4, the value of G is fixed and the parameter $\Delta\kappa$ is adjusted to balance the government's budget in different counterfactual experiments.

3.3 External Validation

To provide a type of out-of-sample validation, I check whether the model can produce structural estimates of several elasticity measures that are consistent with the micro estimates from quasi-experiment variations. The key mechanism through which student debt affects borrowers' job search decisions is related to the mechanism through which UI benefits and access to credit affects unemployed workers' job search decisions. The model's prediction on the effect of student debt would be more reliable if the model can match the sensitivity of unemployed workers' job search outcomes to UI benefits and credit.

I thus conduct a series of partial-equilibrium counterfactual simulations in which the job contact rates and fiscal parameters are fixed, so that the elasticities are estimated in a context consistent with the setting in which the micro estimates are obtained. Table 4 presents the results. My model's structural estimates of the elasticity of UI is 0.49, which lies in the range of the estimates of Card et al. (2015), 0.35-0.9. My model implies that reservation wages increase by about 4% following a 10% increase in the UI replacement ratio, a bit higher compared to the estimate of Feldstein and Poterba (1984), 4%. Regarding

[16] In general, the formula should also incorporate simulation errors, thus the variance-covariance matrix for MSM estimators also depends on the number of simulated agents (Gourieroux and Monfort, 1997). The formula I use does not consider this type of simulation errors because instead of simulating a number of agents, I adopt the histogram method by simulating the distribution of characteristics. Therefore, the simulated values of aggregate moments are not dependent on randomly drawn shocks.

Table 4: Comparison to micro estimates.

Elasticities	Model	Micro estimates
UI on unemployment duration	0.49	0.35-0.9
UI on reservation wage	5.4%	4%
Credit on unemployment duration	0.8 week	0.15-3 weeks
Credit on reemployment wage	1.5%	0.8%-1.7%
Tuition elasticity	0.7	0.52-0.83

the implication of credit, my model implies that unemployment duration increases by 0.8 week and reemployment wage increases by 1.5% if credit increases by 10% of income. These estimates are within the range of the estimates of Herkenhoff, Phillips and Cohen-Cole (2016).

Finally, I check whether the college entry decision is reasonably captured by the model. I calculate the elasticity of college attendance rate with respect to college tuition, and my model gives an estimate of 0.7, which is also within the range of micro estimates summarized by Kane (2006).

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 and illustrate the distributional implications of IBR. I then conduct counterfactual analyses in general equilibrium to shed light on the welfare implications of student debt, provided under the fixed repayment plan and IBR. I also evaluate the importance of allowing borrowers to endogenously choose their job search strategies. Finally, I use the model to separately quantify the effect of IBR through three channels: labor market insurance, job creation, and higher college attendance.

4.1 The Effect of Student Debt on Labor Market Outcomes

Fixed Repayment Plan I begin by investigating the effect of student debt on labor market outcomes when borrowers repay under the standard fixed repayment plan. Panel A of Figure 3 shows that borrowers tend to be less picky in job search. At age 23, borrowers under the fixed repayment plan accept jobs with productivity above 0.488 (blue solid line), as compared to non-borrowers whose reservation productivity is about 0.515 (red dash-dotted line). Due to the lower reservation productivity, borrowers on average spend 2.7 weeks fewer when searching for their first jobs compared to non-borrowers (Panel B) and earn about $3,400 less at age 23 (blue solid line in Panel C).

The differences are persistent over 15 years even after debt has been paid off. This is because between ages 22-32, borrowers accumulate significantly less wealth compared to non-borrowers due to lower wage income and debt repayment. At age 32, the average wealth among borrowers is about $9,000 lower compared to that of non-borrowers (see Appendix Figure OA.4), consistent with the evidence from Elliott, Grinstein-Weiss and Nam (2013). Although there no longer exists any pressure from debt repayment after age 33, the lower wealth would continue affecting borrowers' job search decisions through a mechanism similar to that of debt repayment.

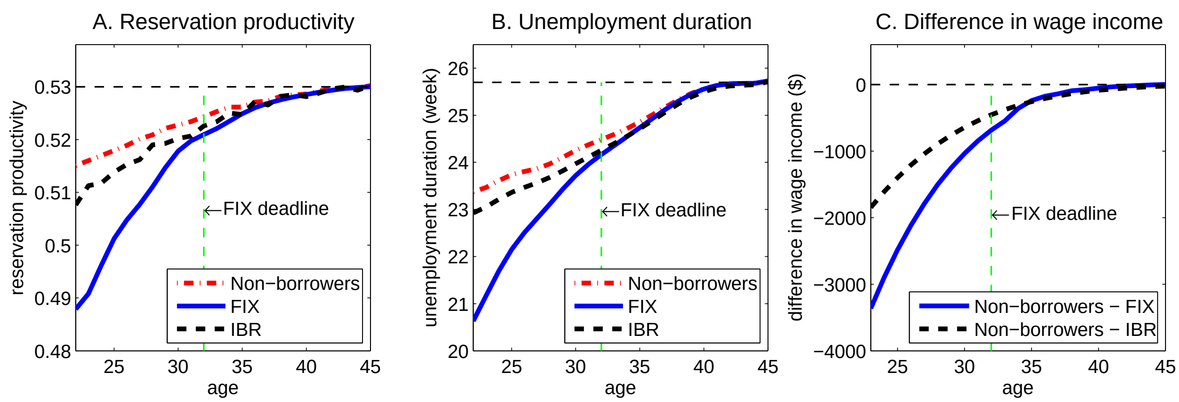


Figure 3: Simulated reservation productivity, unemployment duration, and wage income over the life cycle.

Borrowers are less picky in job search because search risks are not perfectly insured. Intuitively, marginally raising the reservation productivity increases both expected wage income and search risks, generating a tradeoff between risks and returns. When debt is higher, agents become more risk averse due to lower consumption, which pushes them to avoid search risks by setting a lower reservation wage. In a perfect credit market, the quantitative effect on reservation productivity is small because debt only represents just over one percent of lifetime earnings. However, as agents have limited credit access in my model, the low income during unemployment implies that borrowers have strong incentive to accept a job quicker, implicitly transferring future wealth to 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. An alternative way to think of this mechanism is to consider continuing job search as an investment decision that pays off in the future. Agents, like firms, cut investment in physical (e.g., Bolton, Chen and Wang, 2011) and customer capital (e.g., Gilchrist et al., 2017, 2018) when they are financially constrained.

I now check whether the effects of comparable magnitude are also observed in the data. I explore my NLSY97 sample to provide some suggestive evidence. Due to limited sample size,

Table 5: Comparing reduced-form regression estimates in model and data.

	Uemp. duration	Wage income		
		Year 1	Year 2	Year 3
Data				
Impact coefficient	-2.08***	-2,067**	-2,152**	-2,619**
Standard error	(0.68)	(890)	(865)	(1,309)
Model				
Impact coefficient	-1.92**	-2,204**	-1,985*	-1,725*
Standard error	(0.69)	(905)	(1,139)	(1,078)
Chow test p-value	0.81	0.83	0.85	0.83

Note: The last row reports the p-value of the Chow test, where the null is no structural break between the actual and simulated data. The Chow test shows formally that the regression estimates from the model are statistically similar to those in the data at a 5% significance level. ***, **, indicate significance at the 1 and 5 percent level. Full regression tables of actual data are in Appendix C.3.

I focus on the duration of the first unemployment spell and the wage income in the first three years after college graduation.[17] I regress these variables on student debt (in $10,000) and control variables X_i including parental wealth, parental education, gender, race, AFQT score, marital status, the cubic age polynomials, and the county of residence in the graduation year:

$$\text{duration}_i = \alpha + \beta_1 \text{student debt}_i + \beta_2 X_i + \varepsilon_i. \tag{4.1}$$

$$\text{wage}_{i,t} = \alpha_t + \beta_{1,t} \text{student debt}_i + \beta_{2,t} X_{i,t} + \varepsilon_{i,t}, \quad \text{for } t = 1, 2, 3. \tag{4.2}$$

Turning to the model, I simulate the same number of college graduates over their life cycles. I do this 500 times to create 500 simulated datasets. I run similar regressions for each simulated dataset to construct the mean and standard errors of the estimates. Table 5 shows that the model-implied estimates are quite consistent with the data. Specifically, a $10,000 increase in the amount of student debt reduces the duration of first unemployment spells by about 2 weeks and reduces the annual wage income by about $2,000 in the first three years after college graduation.

Income-Based Repayment Plan The significant difference in labor market outcomes between non-borrowers and borrowers has two major implications. First, borrowers' endogenous adjustment on reservation productivity offers an important self-insurance channel to alleviate the burden of debt repayment, which has been neglected in existing literature (see, e.g., Ionescu, 2009; Abbott et al., 2016). Second, the large difference in reservation productivity reflects the extent to which the burden of debt repayment reduces welfare. Therefore, we

[17] As youths were born between 1980 and 1984, the sample size shrinks significantly with longer labor market experience.

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 on labor market outcomes if student loan borrowers were unexpectedly enrolled in IBR immediately after college graduation. The black dashed lines in Figure 3 plot the counterfactual simulation results. My model suggests that at age 23, borrowers under IBR on average spend 2 weeks more relative to borrowers under the fixed repayment plan and their average wage income is about $1,500 higher. Although borrowers under IBR still receive less wage income compared to non-borrowers, my results indicate that IBR significantly alleviates the debt burden relative to the fixed repayment plan.

Intuitively, agents who just graduated from college are either unemployed or starting their jobs with lower earnings, as captured by the hump-shaped life-cycle earnings profile. Under the standard fixed repayment plan, student loans are due when borrowers have the least capacity to pay. This mismatch in the timing of a well-paying job and loan repayment calls borrowers to significantly lower their reservation productivity, more likely to end up with lower-paid jobs. IBR offers insurance to job search outcomes, allowing borrowers to better smooth consumption and conduct more adequate job search. This result is related to Golosov, Maziero and Menzio (2013)'s insight that insuring search risks would allow agents to search for higher-paid jobs.

I continue to study the cross-sectional implications of IBR. Specifically, I sort borrowers into five quintiles based on their student debt balance at age 22. Table 6 presents the statistics for each group of borrowers averaged over ages 23-32. The average amount of debt is about $20,175 for the most indebted group (Q5). Borrowers' unemployment duration and wage income are 20.4 weeks and $44,300 under the fixed repayment plan, while those of non-borrowers are significantly higher, 23.7 weeks and $47,654, respectively. The lower wage income results in lower consumption; the most indebted borrowers' average annual consumption is about $2,771 (28,928-26,157) lower compared to non-borrowers. Under IBR, the average unemployment duration of the most indebted borrowers is only about 0.4 week (23.7-23.3) lower compared to that of non-borrowers. Their wage income and consumption are about $1,524 (45,824-44,300) and $1,241 (27,398-26,157) higher relative to what they have under the fixed repayment plan.

By contrast, my model suggests that providing IBR to the least indebted group of borrowers (Q1 and Q2) would have almost no effect on their consumption and labor market outcomes. This is because the payment calculated based on income is usually higher than the payment required by the fixed repayment plan due to low debt balance. Overall, the model suggests that IBR generates distributional effects toward benefiting more indebted borrowers. This coincides with the characteristics of borrowers enrolled in IBR in reality. The Executive

Table 6: The distributional effects of IBR on labor market outcomes.

		Borrowers					Non-
		Q1	Q2	Q3	Q4	Q5	borrowers
Average debt ($)		2,833	6,175	9,450	13,294	20,175	0
Uemp. dur. (week)	FIX	23.7	23.6	22.6	22.0	20.4	23.7
	IBR	23.7	23.6	23.5	23.4	23.3	
Wage income ($)	FIX	47,625	47,574	46,110	45,450	44,300	47,654
	IBR	47,630	47,598	46,520	46,588	45,824	
Job productivity	FIX	0.834	0.833	0.820	0.814	0.795	0.834
	IBR	0.834	0.833	0.833	0.831	0.830	
Consumption ($)	FIX	28,895	28,830	27,750	27,155	26,157	28,928
	IBR	28,900	28,846	28,125	27,814	27,398	

Office of the President of the United States (2016) documents that undergraduate-only borrowers in IBR have a median outstanding debt much higher than those in the fixed repayment plan in 2015.

4.2 General Equilibrium Implications of IBR

My above analyses assume that all borrowers are unexpectedly enrolled in IBR after college graduation. While this assumption allows the model to separately quantify the effect of IBR on labor market outcomes, it does not provide a full welfare evaluation in general equilibrium. In this subsection, I evaluate the effect of IBR by assuming that borrowers know the available repayment plans before making college entry decisions.

Specifically, I conduct a counterfactual experiment and compare its results with the benchmark economy in which only the fixed repayment plan is provided. In my experiment, borrowers are allowed to choose between the fixed repayment plan and IBR every 12 months. Enrolling in IBR requires borrowers to pay a fixed upfront cost, capturing bureaucratic hurdles and detailed paper work (Dynarski and Kreisman, 2013). I focus on the stationary equilibrium, taking into account the three general equilibrium effects after a policy change, including: (1) the change in college entry and borrowing decisions; (2) the change in firms' job posting decisions; and (3) the change in overall tax level $\Delta\varkappa$ to balance the government's budget constraint (2.31).

Table 7 presents the simulation results. In column IBR-(i), I adjust the fixed cost to target the 20% IBR enrollment rate in 2016. It is shown that offering IBR increases the college entry rate from 41.9% to 46.1%. The increased college attendance is due to more agents borrowing student debt to finance their education, as reflected by the increase in the fraction of borrowers from 61.8% to 66.3%. Among borrowers, the average amount of

Table 7: General Equilibrium Implications of Student Debt.

	FIX	IBR		No debt	FIX
		(i)	(ii)		no search
Fraction of college graduates	41.9%	46.1%	47.8%	21.2%	37.7%
Fraction of borrowers	61.8%	66.3%	67.7%	0%	57.9%
IBR enrollment rate	N/A	20%	31.2%	N/A	N/A
Avg debt of borrowers ($)	10,358	16,260	17,015	N/A	8,769
Job contact rate	0.82	0.86	0.88	0.67	0.79
Wage income ($)	37,360	38,047	38,489	34,135	37,012
Output ($)	45,755	46,221	46,535	42,877	45,490
Labor supply (hours)	1,635	1,644	1,650	1,610	1,630
Default rate	9.55%	2.10%	0.80%	N/A	12.28%
Debt forgiveness ($)	0	615	670	N/A	0
Average tax rate	31.8%	32.2%	32.4%	35.3%	32.0%
Welfare	N/A	0.42%	0.61%	-5.45%	-0.30%

debt increases from $10,358 to $16,260. Note that borrowers are in general more talented compared to non-borrowers, who are more talented than high-school graduates (see Appendix A.2). The increase of college entry rate after adopting IBR implies that the average talent of college graduates decreases.

The adoption of IBR increases the average annual wage income and output by $687 (38,047-37,360) and $466 (46,221-45,755) between ages 23-32. The equilibrium job contact rate is also higher under IBR. This is because college graduates are more productive compared to high school graduates at any jobs. Thus the increase in college entry rate increases firms' profits, motivating firms to post more vacancies.[18]

IBR largely reduces the two-year cohort default rate from 9.55% to 2.10% by allowing enrolled borrowers to postpone debt repayment when income is low. However, interest accrues and some borrowers may not be able to repay their outstanding balance within the 25-year repayment period. On average, the debt forgiveness from IBR is about $615 per borrower. The average tax rate only increases by 0.4% (32.2%-31.8%) to maintain a balanced budget.

Following Abbott et al. (2016), I measure the change in welfare by considering the percentage change of lifetime consumption for a newborn economic agent (at age $t = 0$) before drawing her initial conditions (k, e, a, b_0). The last row of Table 7 indicates that providing IBR increases the average welfare by about 0.42%.

In column IBR-(ii), I further reduce the fixed cost to zero, which basically allows every

[18] There is also a countervailing effect from IBR. When borrowers become pickier under IBR, they set higher reservation productivity and decline more wage offers. This reduces firms' profits and dampen their incentive to post vacancies. This effect, however, is dominated by the main effect from a higher college entry rate.

borrower to freely enroll in IBR. The IBR enrollment rate increases to 31.2%. Many borrowers choose not to enroll because their current debt repayment under the fixed repayment plan might be the same (i.e. $y_t^{\text{IBR}} = y_t^{\text{FIX}}$ according to equation (2.14)). The increased enrollment rate further pushes the outcome variables toward the same directions discussed above.

Table 8: Quantifying the effects of IBR through three channels.

	IBR-(i)			IBR-(ii)		
	(1)	(2)	(3)	(1)	(2)	(3)
Fraction of college graduates	46.1%	46.1%	41.9%	47.8%	47.9%	41.9%
Fraction of borrowers	66.3%	66.4%	61.8%	67.7%	67.9%	61.8%
Avg debt of borrowers ($)	16,260	16,305	10,358	17,015	17,150	10,358
Job contact rate	0.86	0.82	0.82	0.88	0.82	0.82
Wage income ($)	38,047	37,810	37,527	38,489	38,155	37,603
Output ($)	46,221	46,098	45,844	46,535	46,376	45,930
Labor supply (hours)	1,644	1,640	1,625	1,650	1,647	1,619
Default rate	2.10%	2.37%	2.24%	1.80%	1.89%	1.85%
Debt forgiveness	615	664	243	670	707	280
Average tax rate	32.3%	32.6%	32.2%	32.4%	32.3%	32.2%
Welfare	0.42%	0.31%	0.13%	0.61%	0.48%	0.22%

Evidently, my simulation indicates that IBR increases social welfare through three channels. First, borrowers conduct more adequate job search because of better insurance in the labor market. Second, college attendance and borrowing increase as agents anticipate a lower burden from debt repayment. Third, better education outcomes increase match-specific productivity and profits, motivating firms to post more jobs. I now run two additional counterfactual experiments to quantify the importance of these channels.

In Table 8, columns IBR-(i) and IBR-(iii) present the outcome variables when IBR enrollment rate is 20% and 31.2%. Taking IBR-(i) as an example, column (1) presents the full effect of IBR as in Table 7. Column (2) tabulates the outcome variables under IBR when the equilibrium job contact rate is set equal to that under the fixed repayment plan. The difference between columns (1) and (2) is thus informative about the importance of more job postings. My simulation suggests that reducing the job contact rate from 0.86 to 0.82 for unemployed agents would reduce the wage income and output by about $237 (38,047-37,810) and $123 (46,221-46,098). In terms of welfare, IBR increases lifetime consumption by an additional 0.11% (0.42-0.31) by incentivizing firms to post more jobs.

Column (3) reports the outcome variables under IBR when both the equilibrium job contact rate and the college entry/borrowing decisions are set identical to those under the fixed repayment plan. Thus column (3) quantifies the importance of better job search and insurance in the labor market, and the difference between columns (2) and (3) is informative about the contribution of more college entry and borrowing. My simulation implies that insurance in the labor market increases wage income, output, and welfare by about \$167 (37,527-37,360), \$89 (45,844-45,755), and 0.13%, while more college entry and borrowing increases these statistics by about \$283 (37,810-37,527), \$254 (46,098-45,844), and 0.18% (0.31-0.13).

Column (3) also indicates that, if the only benefit of IBR comes from better insurance in the labor market, annual labor supply will on average reduce by about 10 hours (1,635-1,625) compared to that under the fixed repayment plan. This is because IBR imposes an income-taxish distortion that reduces workers' incentive to work. Overall, my model suggests that the insurance provided by IBR seems to dominate this adverse incentive effect, bringing an increase in social welfare.

4.3 The Student Loan Program and Endogenous Job Search

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

I first conduct a counterfactual experiment in which agents cannot borrow student loans to enter college. The column "No debt" of Table 7 tabulates the results. College attendance rate reduces almost by half, from 41.9% to 21.2%. The average job contact rate, wage income, output, and labor supply all decrease because workers are less productive in general. The drop in tax revenue implies that the government has to increase the average tax rate from 31.8% to 35.3% to balance the budget constraint. The expected welfare of a newborn agent is reduced by 5.45%. This indicates that the student loan program offered under the fixed repayment plan roughly increases a newborn agent's lifetime consumption by about 5%.

To evaluate the welfare implication of endogenous job search. I conduct counterfactual experiment in which I restrict borrowers to choose the same reservation productivity (i.e., face the same income process) as non-borrowers of identical characteristics. The last column of Table 7 presents the results. Compared to the benchmark economy with fixed repayment plan, the college attendance rate drops by about 4.2% (37.7-41.9), as the burden of debt repayment increases when borrowers cannot adjust their job search strategies. As a consequence, the default rate increases by 2.73% (12.28-9.55) and the expected welfare of a newborn agent declines by about 0.30%.

Overall, my counterfactuals imply that the student loan program significantly increases welfare even under the fixed repayment plan. Although borrowers are less picky and more likely to work in lower-paid jobs, the change in job search strategies itself is an optimal response to the burden of debt repayment. Thus forcing borrowers to search for the same jobs as non-borrowers would reduce borrowers' 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.[19] Allowing borrowers to change their job search strategies essentially makes income risk endogenous, which creates an important self-insurance channel to the correction of the credit and insurance market failures for indebted youth. Indeed, my simulation results indicate that the endogenous adjustment of job search strategies plays a quantitatively important role in assessing the welfare implication of the student loan program.

5 Robustness Checks

I conduct robustness checks for the main quantitative results reported in Table 7. For each robustness check, I reestimate the parameters in Table 3 to match the moments in Table 2.

Risk Aversion One important parameter that determines the effect of debt on job search is risk aversion γ. In my baseline specification, γ is set to be 3. I now reduce its value to 1.5, commonly used for heterogeneous-agent models with financial frictions (e.g., Buera and Shin, 2013; Moll, Townsend and Zhorin, 2016). Appendix Table OA.5 indicates that when agents are less risk averse, providing IBR would have a smaller effect. The welfare of a newborn agent increases by 0.22% as opposed to 0.42% in the baseline specification; the increase in college attendance rate, job contact rate, and wage income all become smaller.

Elasticity of Labor Supply The elasticity of labor supply determines the incentive distortion of IBR on labor supply. In my baseline specification, σ is set to be 2.59 so that the tax-modified Frisch elasticity is 0.33. The micro estimates of intensive margin Hicksian labor supply elasticities range from 0 to 1. I check the model's implication by setting $\sigma = 0.78$ and $\sigma = 88.89$, corresponding to 1 and 0.01 tax-modified elasticities of labor supply. As shown in Appendix Table OA.6, when elasticity is 1, IBR barely increases welfare due to the large

[19] A related insight is drawn in the optimal UI literature. Shimer and Werning (2007) show that a worker's after-tax reservation wage is a sufficient statistic about her welfare.

distortion on labor supply. The average annual labor supply under IBR is about 26 hours (1578-1552) lower compared to that under the fixed repayment plan. When elasticity is 0.01, Appendix Table OA.7 shows that there is almost no response in labor supply when borrowers switch to IBR. As a result, IBR becomes very effective in alleviating the burden from debt repayment. The welfare of a newborn agent increases by 0.56% as opposed to 0.42% in the baseline specification.

Credit Access Credit access alleviates the effect of debt repayment on job search. In the baseline specification, agents can borrow up to $\varsigma = 18.5\%$ of their income. I now evaluate the model when agents cannot borrow. Appendix Table OA.8 indicates that excluding credit access would imply a slightly larger effect from IBR. The welfare of a newborn agent increases by 0.45% on average after introducing IBR as opposed to 0.42% in the baseline specification. Overall, the effect of having credit access is not very significant because agents cannot borrow much due to the low income during unemployment.

6 Conclusion

In this paper, I develop a structural model with college entry, borrowing, and job search to evaluate the implication of student debt on labor market outcomes. My estimated model implies that student loans have significant effects on borrowers' unemployment duration and wage income under the fixed repayment plan. The key reason is that, in the absence of perfect credit and insurance markets, the labor market offers its own version of insurance and credit provision. Thus ruling out the adjustment on job search strategies would underestimate the welfare benefit of student debt.

The significant change in borrowers' job search strategies is also informative about the burden of debt repayment under the fixed repayment plan due to its inflexible repayment schedule. Counterfactual simulations suggest that IBR largely alleviates the debt burden and motivates more adequate job search. In addition to providing insurance against job search risks, IBR also increases social welfare by encouraging college attendance through borrowing and by motivating firms to post more job vacancies.

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=== *Not for Publication* ===

Yan Ji

Contents

A Supplementary information on Quantitative Analyses

A.1 Calculating The Model-Implied Elasticities

In this appendix, I present the details on estimating the model-implied elasticities mentioned in Section 3.3.

To estimate the elasticity of unemployment duration with respect to UI benefits, I simulate a counterfactual by increasing UI benefits θ by 5%, from \$650 to \$682.5. I find that the average unemployment duration increases by about 3.3 weeks, implying that the elasticity of unemployment duration with respect to UI benefits is about 0.46. This elasticity is roughly in line with the estimate of Card et al. (2015), who find that the elasticity is around 0.35 during the pre-recession period (2003-2007) and between 0.65 and 0.9 during the recession and its aftermath.

The estimate of Feldstein and Poterba (1984) indicates that a 10% increase in the UI replacement ratio raises the reservation wage by 4% for job losers who are not on layoff. My model generates a larger response in the reservation wage, 5.4%. The empirical evidence on the effect of UI benefits on reemployment wages is mixed. My model's simulation results indicate that reemployment wages increase by about 3.9% following a 10% increase in the UI replacement rate.

Using administrative data from TransUnion and Longitudinal Employment and Household Dynamics (LEHD), Herkenhoff, Phillips and Cohen-Cole (2016) find that increasing credit limits by 10% of prior annual earnings would lead displaced workers to take 0.15 to 3 weeks longer to find a job. Among job finders, the replacement earnings increase by 0.8% to 1.7%.

To evaluate the impact of access to credit on job search and wage income, I isolate agents who are newly laid off due to exogenous job separations in the model. Denote their prior wage income as $\text{Inc}_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})$ and the set of agents as I_κ. I then simulate these agents' over time until they find the next job and obtain unemployment duration, $\text{Dur}(\Omega)$, and wage income, $\text{Inc}(\Omega, \rho, \rho')$. Finally, I run a counterfactual experiment in partial equilibrium to obtain the unemployment duration, $\text{Dur}^\Delta(\Omega)$, and wage income, $\text{Inc}^\Delta(\Omega, \rho, \rho')$, if these agents were provided with 10% unused credit during unemployment, i.e., the borrowing constraint is relaxed from $b \geq -\varsigma\theta$ to $b \geq -\varsigma\theta - 0.1\text{Inc}_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})$. Following Herkenhoff, Phillips and Cohen-Cole (2016), I estimate the duration and earnings elasticity using the following formulas:

$$\epsilon_{\text{dur}} = \sum_{I_\kappa} \text{Dur}^\Delta(\Omega) - \text{Dur}(\Omega)/10\%, \tag{A.1}$$

$$\epsilon_{\text{inc}} = \sum_{I_\kappa} [\text{Inc}^\Delta(\Omega, \rho, \rho') - \text{Inc}(\Omega, \rho, \rho')]/\text{Inc}_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})/10\%. \tag{A.2}$$

The structural estimates of ϵ_{dur} and ϵ_{inc} are 0.14 year and 0.15. Therefore, the model predicts that in response to a 10% increase in unused credit, unemployed workers will take 0.8 week longer to find a job that on average pays 1.5% more wage income, roughly in line with the micro estimates of Herkenhoff, Phillips and Cohen-Cole (2016).

The existing micro estimates of the tuition elasticity of college attendance are between 0.52 and 0.83, based on the summary surveys of Leslie and Brinkman (1987) and Kane (2006). To structurally estimate this elasticity, I increase the monetary college cost μ_k by 5%, from \$12,673 to \$13,307. The model implies that the college enrollment rate increases from 41.9% to 45.4%, indicating that the implied-elasticity is 0.7.

A.2 College Entry and Borrowing

The model implies that more talented agents are more likely to attend college because of the higher college premium captured by equation (2.2). Among college graduates, the model is able to capture the small positive correlation between talent and student loan debt, consistent with the data. In terms of talent distribution, Figure OA.1 shows that the distribution of talent among college borrowers, college non-borrowers, and high school graduates can be ranked by first-order stochastic dominance, with the average group talent being 0.851, 0.843, and 0.823, respectively.

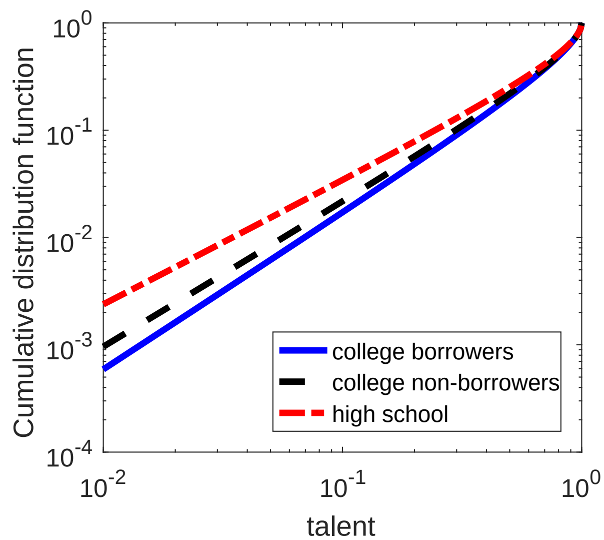


Figure OA.1: Model-implied talent distribution for high school and college graduates.

A.3 Illustration of Value Functions

In this appendix, I illustrate the underlying mechanism of IBR by plotting the value functions. In panel A of Figure OA.2, I plot the value function under the fixed repayment plan for an unemployed agent and the value function that could be achieved if the agent accepts a job with productivity $\rho = 0.35$ and negotiation benchmark $\rho' = 0.35$. Panel A illustrates the key mechanism of student debt by showing that the value function of being unemployed decreases faster with debt compared to the value function of being employed. As a result, there is an intersection between the two curves. In this example, when the level of student debt is below \$18,000, the agent rejects the job offer and stays unemployed. When the level of debt is above \$18,000, the agent takes the job.

Panel B plots the value functions under IBR. It shows that under IBR, a higher level of debt reduces the value only slightly for both unemployed agents and employed agents. This is because there is much

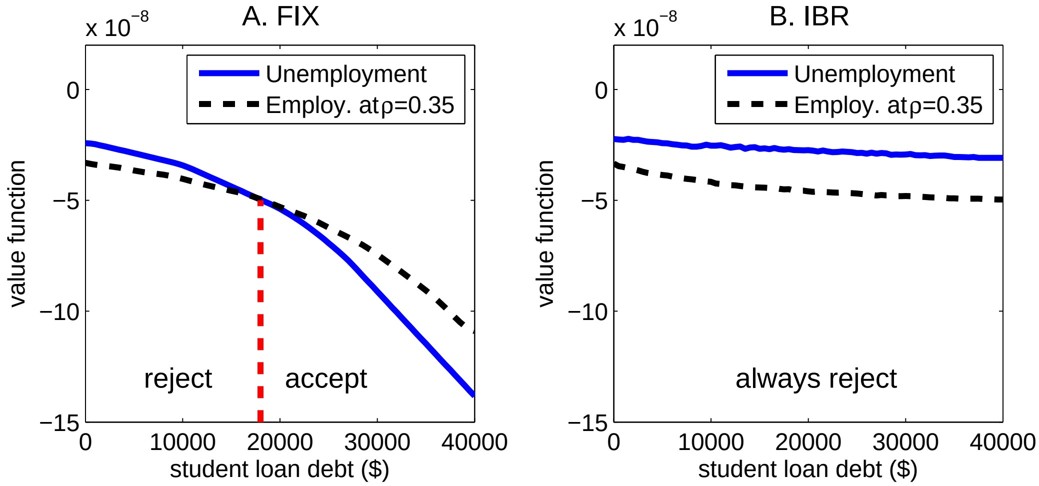


Figure OA.2: An illustration of the value functions under the fixed repayment plan and IBR.

better insurance provided by IBR. First, IBR allows agents to repay less when income is low, especially during unemployment. Second, there is debt forgiveness after 25 years, which convexifies the value functions. This example provides a sharp comparison as the unemployed agent always rejects the job offer with productivity ($\rho = 0.35$) and continues job search.

A.4 Wage Function

The wage rate is renegotiated in every period, reflecting the change in Ω. The assumption of Nash bargaining links workers' wage rates to their characteristics, implying that wealth, student debt, and labor productivity can influence income. The variation in student debt will affect workers' outside option's value, which in turn affect their wage rates. In this appendix, I show that this channel is much less significant compared to the main channel I hope to quantify, which is how student debt affects wage income by affecting borrowers' job search decisions.

In Figure OA.3, I consider the agent having average wealth ($4,500) and being employed at a job with average productivity (0.75) and with the negotiation benchmark's productivity being set at the reservation productivity (0.5). It shows that increasing the amount of student loan debt from $0 to the average amount ($10,000) reduces the wage rate by about 0.3% (from $18.06 to $18 per hour). For agents with other job productivity and negotiation benchmark, the sensitivity of wage rates with respect to student debt is similar. This suggests that the bargaining channel confounds the mechanism, but quantitatively it is much less important. Specifically, as shown in Table 6 column Q3, borrowers' wage income is 3.2% (46,110/47,654-1) lower compared to that of non-borrowers, suggesting that more than 90% of the reduction in wage income is caused by the mechanism that reduces the reservation wage, and less than 10% is caused by the Nash bargaining channel, which reflects the change in outside options.

Figure OA.3 also indicates that the wage rate is more sensitive to student debt when the amount of debt is very high. When student debt increases from $0 to $40,000, the reduction in wage rates caused by the Nash bargaining channel alone is as large as 13.1%. However, these rare cases are not driving the

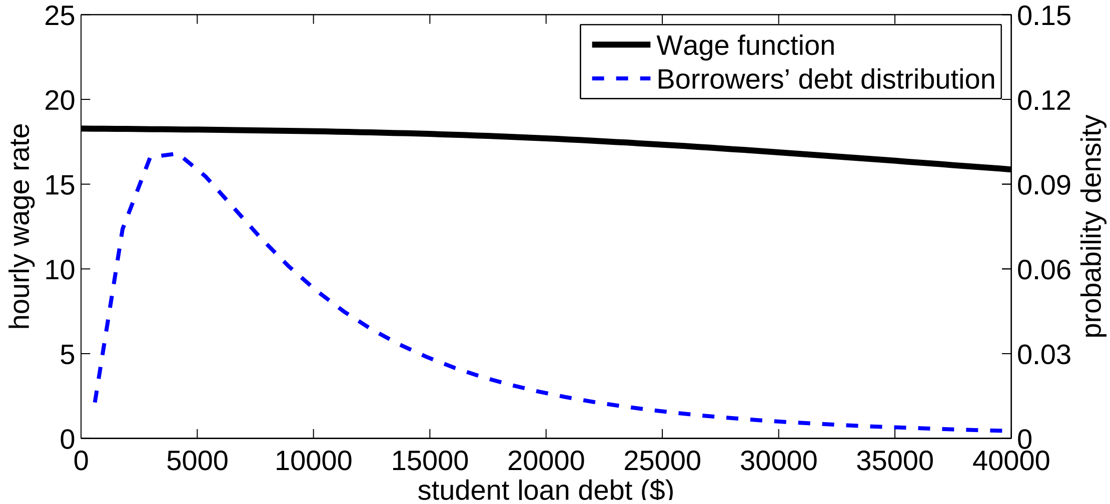


Figure OA.3: An illustration of the wage function under the fixed repayment plan.

quantitative results of my model, because most students have loan amounts below $20,000 according to the estimated distribution.

In fact, the strength of the bargaining channel in determining the wage rate also depends on the worker's bargaining parameter ξ. Loosely speaking, the wage rate becomes less sensitive with respect to student debt when ξ increases. In the extreme case with $\xi = 1$, the worker's wage rate is always equal to the marginal product of labor $z\rho$, and is therefore not varying with student debt at all. When $\xi = 0$, the worker's wage rate is set such that the employment value is equal to the unemployment value. In this case, the sensitivity of wage rate with respect to student debt closely depends on the sensitivity of the worker's unemployment value with respect to student debt. As a result, the strength of the bargaining channel is comparable to the strength of the mechanism through which debt affects job search decisions.

A.5 Value Functions of Employed Workers

In this appendix, I present the value functions for employed workers with $d_t = 0^-$ and $d_t = 1$.

With $d_t = 0^-$, the agent has the option to default by incurring disutility η:

$$
\begin{aligned}
W(\hat{\Omega}_t, 0^-, \rho, \rho') = \max_{c_t, l_t, d_{t+1}} \quad & u(c_t, l_t) + \beta \mathbb{1}_{d_{t+1}=0^-} \Bigg[(1-\kappa) \Bigg[[1 - \lambda^e + \lambda^e V(\rho')] W(\hat{\Omega}_{t+1}, 0^-, \rho, \rho') \\
&+ \lambda^e \Bigg(\int_{x \geq \rho} W(\hat{\Omega}_{t+1}, 0^-, x, \rho) \mathrm{d}V(x) + \int_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 0^-, \rho, x) \mathrm{d}V(x) \Bigg) \Bigg] + \kappa U(\hat{\Omega}_{t+1}, 0^-) \Bigg] \\
&+ \beta \mathbb{1}_{d_{t+1}=1} \Bigg[-\eta + (1-\kappa) \Bigg[[1 - \lambda^e + \lambda^e V(\rho')] W(\hat{\Omega}_{t+1}, 1, \rho, \rho') \\
&+ \lambda^e \Bigg(\int_{x \geq \rho} W(\hat{\Omega}_{t+1}, 1, x, \rho) \mathrm{d}V(x) + \int_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 1, \rho, x) \mathrm{d}V(x) \Bigg) \Bigg] + \kappa U(\hat{\Omega}_{t+1}, 1) \Bigg], \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)(w^e(\Omega_t, \rho, \rho') l_t)^{1-\tau} - y_t] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma w^e(\Omega_t, \rho, \rho') l_t,
\end{aligned}
\tag{A.3}
$$

With $d_t = 1$, the agent is in default at t and moves to $d = 0^+$ with probability π at $t+1$:

$$
\begin{aligned}
W(\hat{\Omega}_t, 1, \rho, \rho') = \max_{c_t, l_t} \quad & u(c_t, l_t) + \beta \pi \Bigg[(1-\kappa) \Bigg[[1 - \lambda^e + \lambda^e V(\rho')] W(\hat{\Omega}_{t+1}, 0^+, \rho, \rho') \\
&+ \lambda^e \Bigg(\int_{x \geq \rho} W(\hat{\Omega}_{t+1}, 0^+, x, \rho) \mathrm{d}V(x) + \int_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 0^+, \rho, x) \mathrm{d}V(x) \Bigg) \Bigg] + \kappa U(\hat{\Omega}_{t+1}, 0^+) \Bigg] \\
&+ \beta(1-\pi) \Bigg[(1-\kappa) \Bigg[[1 - \lambda^e + \lambda^e V(\rho')] W(\hat{\Omega}_{t+1}, 1, \rho, \rho') \\
&+ \lambda^e \Bigg(\int_{x \geq \rho} W(\hat{\Omega}_{t+1}, 1, x, \rho) \mathrm{d}V(x) + \int_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 1, \rho, x) \mathrm{d}V(x) \Bigg) \Bigg] + \kappa U(\hat{\Omega}_{t+1}, 1) \Bigg], \\
\text{subject to} \quad & b_{t+1} = (1+r)[b_t + (\varkappa - \Delta\varkappa)(w^e(\Omega_t, \rho, \rho') l_t)^{1-\tau}] - c_t + \varpi_t, \\
& s_{t+1} = (1+r^s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma w^e(\Omega_t, \rho, \rho') l_t,
\end{aligned}
\tag{A.4}
$$

B Mechanism and Channels

In this appendix, I illustrate the effect of student debt repayment plans on labor market outcomes through the lens of a simple partial equilibrium model based on McCall (1970). I analytically prove that agents take lower-paid jobs because they are more risk averse and liquidity constrained under the burden of debt repayment. The core assumption is that agents are risk averse and job search risks are not perfectly insured. The quantitative model developed in Section 2 is an extension of this simple partial equilibrium model with more realistic features, which is used to quantify the implication of this mechanism.

B.1 Environment

Consider an agent who is born at $t = 0$ and sequentially searches for a job. Time is discrete and there is no aggregate uncertainty. The agent maximizes lifetime utility from consumption, $E \sum_{t=1}^{\infty} \beta^t u(c(t))$ with subjective rate of time preference β. The per-period utility function, $u(x)$, is bounded from above, strictly increasing, concave, and twice continuously differentiable, i.e., $\lim_{x \to \infty} u(x) = M, u'(x) > 0, u''(x) < 0$.

The agent can either be unemployed or employed. For now, suppose that the agent supplies one unit of labor inelasticly when being employed. Starting from $t = 1$, if the agent is unemployed, the agent receives UI benefits $\theta > 0$, and wage offers w from an exogenous cumulative distribution function $F(w)$ in each period, which is differentiable on the support $[\theta, \overline{w}]$.

The agent needs to decide immediately whether to accept the wage offer upon receiving it. There is no recall of past wage offers. Consumption is chosen after the realization of wage offers. If the agent rejects the offer, she continues to search. Otherwise, she gets employed at wage w forever.

The credit market is imperfect in the sense that savings are constrained to be non-negative, $s_t \geq 0$, for all t. The interest rate on savings is r. For simplicity, I assume $\beta(1 + r) = 1$ so that the agent has no incentive to transfer wealth across periods.[1]

The agent is born with outstanding debt S whose repayment schedule is specified in the contract. The interest rate on debt is equal to the interest rate on savings. In the following, I analyze the implication of the debt burden on job search decisions for two stylized repayment contracts.

B.2 Fixed Repayment Contract

In this subsection, I analyze job search decisions under the fixed repayment contract. To obtain a stationary result, I consider indefinite fixed payment flows such that the present value of this perpetuity covers the initial outstanding debt S.

Definition 1. *The fixed repayment contract requires the agent to repay $s = rS$ in each period.*

For tractability, I assume that the agent cannot be delinquent on making payments. Therefore, to avoid the pathological case, I consider $S < \frac{\theta}{r}$ so that the agent can repay the loan, while at the same time maintaining positive consumption, even if she is permanently unemployed.[2]

Denote U as the value function of an unemployed agent, and $W(w)$ as the value function of an employed agent with wage w. Thus,

$$W(w) = \frac{u(w - s)}{1 - \beta}. \tag{B.1}$$

When the agent rejects the wage offer, the income in the current period is θ and the value function U

[1] When the agent is unemployed, the agent does not save because she expects future income to be higher. When the agent is employed, the agent is indifferent about savings because wage income is flat and $\beta(1 + r) = 1$.

[2] If $S > \frac{\theta}{r}$, the agent is involuntarily forced into delinquency either when she is unemployed or when she is employed at wage $w < rS$. Suppose the remaining income is garnished upon delinquency. Then we can show how the reservation wage varies with debt depends on whether there is an Inada condition on $u(\cdot)$. If utility is bounded from below when consumption approaches zero, we can show that the reservation wage increases with debt. This is because limited liability in debt repayment generates a risk shifting effect as in Donaldson, Piacentino and Thakor (2016).

can be written as

$$U = u(\theta - s) + \beta \int_{\theta}^{\overline{w}} \max\{W(w), U\} dF(w). \tag{B.2}$$

Equation (B.2) states that the agent accepts the wage offer if it provides a higher value than unemployment. Because $W(w)$ is increasing in w, the optimal job search decision follows a cutoff strategy, and the wage offer is accepted if $w > w^*_{FIX}$, where w^*_{FIX} is the reservation wage under the fixed repayment contract. The agent sets w^*_{FIX} to maximize her welfare, which happens when the value of staying unemployed is equal to the value of being employed at the reservation wage, i.e., $U = W(w^*_{FIX})$:

$$u(w^*_{FIX} - s) = u(\theta - s) + \frac{\beta}{1-\beta} \int_{w^*_{FIX}}^{\overline{w}} [u(w - s) - u(w^*_{FIX} - s)] dF(w). \tag{B.3}$$

The RHS of equation (B.3) captures the per-period utility of rejecting the wage offer. It states that rejecting the wage offer results in a lower current utility $u(\theta - s)$ but preserves the possibility of receiving a higher wage offer in the future. Setting a higher reservation wage implies a smaller chance of being employed but also generates a higher expected employment value. The optimal reservation wage is set to balance these two effects.

B.2.1 The Risk and Liquidity Channel of the Debt Burden

Job search is a risky investment that pays off in the future. The agent controls the reservation wage to manage risks, as setting a lower reservation wage allows the agent to accept a constant wage offer sooner and take fewer search risks. Therefore, we can think of the reservation wage characterized by equation (B.3) as the certainty equivalent payoff of continued job search. More risk-averse agents have a lower certainty equivalent valuation of any risky lotteries, thus they set a lower reservation wage in job search, which is formalized in Proposition B.1.

Proposition B.1. *Under the fixed repayment contract, the effect of debt depends on how risk aversion varies with consumption. With decreasing absolute risk aversion, w^*_{FIX} is decreasing in debt; with increasing absolute risk aversion, w^*_{FIX} is increasing in debt; with constant absolute risk aversion, w^*_{FIX} is unaffected by debt.*

Because decreasing absolute risk aversion is empirically plausible (Friend and Blume, 1975), Proposition B.1 suggests that an indebted agent would set a lower reservation wage to avoid search risks. I discuss in the proof that this proposition holds even if the credit market is perfect. However, the quantitative effect would be much smaller because what would matter is the relative value of outstanding debt to total income instead of income in the current period. This implies that Proposition B.1 incorporates both a risk effect and a liquidity effect.

It is worth noting that the risk effect and the liquidity effect result from two different tradeoffs in job search. First, job search is risky. Therefore, an agent who becomes more risk averse due to a higher level of debt would trade off risks and returns by adjusting the reservation wage. This is the risk effect. Second, job search encodes an option value that only pays off in the future, at the time of accepting the wage offer. Therefore, the reservation wage implicitly determines the wealth transfer across periods. When the credit market is imperfect, the agent faces an intertemporal tradeoff in job search because a lower reservation wage increases the chance of accepting a wage offer, and thus more wealth is transferred from future periods to the current period. This is the liquidity effect.

A lower reservation wage implies that the agent is taking fewer search risks in the labor market. Because uninsured search risks are compensated with a risk premium, this implies that indebted agents would have less expected income compared to non-borrowers. To see this, let $I(w^*_{FIX})$ denote the present value of expected income as a function of the reservation wage w^*_{FIX}, and then it can be solved recursively:

$$I(w^*_{FIX}) = F(w^*_{FIX})[\theta + \beta I(w^*_{FIX})] + \int_{w^*_{FIX}}^{\overline{w}} \frac{w}{1-\beta} dF(w). \tag{B.4}$$

Equation (B.4) states that when the agent draws an offer below w^*_{FIX} with probability $F(w^*_{FIX})$, she rejects it and receives UI benefits θ in the current period and the same present value of expected income $I(w^*_{FIX})$ in the next period. When the wage offer is above w^*, she accepts it and gets paid perpetually. The compensation for search risks implies a monotonic relationship between w^*_{FIX} and $I(w^*_{FIX})$:

Proposition B.2. *There exists a unique income-maximizing reservation wage $\hat{w}$, determined by*

$$\hat{w} - \frac{\beta}{1-\beta} \int_{\hat{w}}^{\overline{w}} (w - \hat{w}) dF(w) = \theta. \tag{B.5}$$

The present value of expected income is strictly increasing in w^*_{FIX} when $w^*_{FIX} < \hat{w}$, and strictly decreasing in w^*_{FIX} when $w^*_{FIX} > \hat{w}$. Moreover, the optimal reservation wage for any risk-averse agent satisfies $w^*_{FIX} < \hat{w}$.

In fact, the income-maximizing reservation wage $\hat{w}$ is the reservation wage set by risk-neutral agents. In an incomplete market, the existence of uninsured search risks incentivizes risk-averse agents to set a strictly lower reservation wage in order to smooth consumption.

B.3 Income-Based Repayment Contract

The main feature of IBR is that borrowers make payments contingent on their income instead of the balance of outstanding debt. Although a realistic IBR also incorporates other auxiliary features like debt forgiveness and repayment caps, my theoretical analysis for now does not explicitly consider them. Instead, I consider IBR that allows the lender to recover all the outstanding debt in expectation conditional on the agent's endogenous job search decisions. Similar to the fixed repayment contract, I assume that the repayment period is indefinite.

Definition 2. *IBR requires the agent to repay a fraction α of her income. The repayment ratio α is set by the lender such that the expected present value of payment flows is just enough to cover the outstanding debt S:*

$$\alpha I(w^*_{IBR}) = \frac{S}{\beta}, \tag{B.6}$$

where w^*_{IBR} is the agent's optimal reservation wage under IBR:

$$u((1-\alpha)w^*_{IBR}) = u((1-\alpha)\theta) + \frac{\beta}{1-\beta} \int_{w^*_{IBR}}^{\overline{w}} \left[u((1-\alpha)w) - u((1-\alpha)w^*_{IBR})\right] dF(w). \tag{B.7}$$

I call equation (B.6) the lender's recoverability constraint. Expected repayment not only depends on the repayment ratio α but also on the agent's reservation wage w^*_{IBR}. Because the reservation wage is unobservable, IBR only specifies the repayment ratio α. The agent optimally chooses her reservation wage according to the indifference equation (B.7), which can be thought of as the incentive compatibility constraint.

IBR provides insurance and risk sharing for job search, because the agent repays less when income is low. In fact, we can view the fixed repayment contract as a pure debt contract and IBR as an equity contract. Intuitively, the agent should set a relatively higher reservation wage if debt is repaid under IBR, because equity contracts encourage activities with high returns and high risks. This result is summarized in the following proposition.

Proposition B.3. *With CRRA utility, the reservation wage under IBR is strictly higher, i.e.,* $w^*_{IBR} > w^*_{FIX}$.

Since CRRA utility has decreasing absolute risk aversion, Propositions B.1 and B.3 jointly imply that with CRRA utility, the fixed repayment of debt reduces the reservation wage and IBR alleviates this effect.

B.4 Proofs

B.4.1 Proof of Proposition B.1

Proof. Rearranging equation (B.3), the reservation wage is implicitly determined by

$$1 = \frac{\beta}{1-\beta}\int_{w^*_{FIX}}^{\overline{w}} \frac{u(w-s) - u(w^*_{FIX}-s)}{u(w^*_{FIX}-s) - u(\theta-s)} dF(w). \tag{B.8}$$

Consider increasing debt by Δs, and denote the reservation wage corresponding to $s+\Delta s$ as $\hat{w}^*_{FIX}$, thus according to (B.8),

$$1 = \frac{\beta}{1-\beta}\int_{\hat{w}^*_{FIX}}^{\overline{w}} \frac{u(w-s-\Delta s) - u(\hat{w}^*_{FIX}-s-\Delta s)}{u(\hat{w}^*_{FIX}-s-\Delta s) - u(\theta-s-\Delta s)} dF(w). \tag{B.9}$$

Define $u_2(x) = u(x-\Delta s)$, we can rewrite (B.9) as

$$1 = \frac{\beta}{1-\beta}\int_{\hat{w}^*_{FIX}}^{\overline{w}} \frac{u_2(w-s) - u_2(\hat{w}^*_{FIX}-s)}{u_2(\hat{w}^*_{FIX}-s) - u_2(\theta-s)} dF(w). \tag{B.10}$$

Let $r(x)$ and $r_2(x)$ be the local absolute risk aversion for $u(x)$ and $u_2(x)$. Thus

$$\begin{aligned} r(x) &> r_2(x) \quad \text{If } u(\cdot) \text{ has IARA;} \\ r(x) &= r_2(x) \quad \text{If } u(\cdot) \text{ has CARA;} \\ r(x) &< r_2(x) \quad \text{If } u(\cdot) \text{ has DARA.} \end{aligned} \tag{B.11}$$

Taking DARA as an example, note that $\theta - s < w^*_{FIX} - s < w - s$ for all $w \in (w^*_{FIX}, \overline{w}]$, thus according to Pratt (1964, Theorem 1),

$$\begin{aligned} 1 &= \frac{\beta}{1-\beta}\int_{w^*_{FIX}}^{\overline{w}} \frac{u(w-s)-u(w^*_{FIX}-s)}{u(w^*_{FIX}-s)-u(\theta-s)}dF(w) \\ &> \frac{\beta}{1-\beta}\int_{w^*_{FIX}}^{\overline{w}} \frac{u_2(w-s)-u_2(w^*_{FIX}-s)}{u_2(w^*_{FIX}-s)-u_2(\theta-s)}dF(w). \end{aligned} \tag{B.12}$$

Then (B.10) and (B.12) imply

$$\int_{\hat{w}^*_{FIX}}^{\overline{w}} \frac{u_2(w-s)-u_2(\hat{w}^*_{FIX}-s)}{u_2(\hat{w}^*_{FIX}-s)-u_2(\theta-s)}dF(w) > \int_{w^*_{FIX}}^{\overline{w}} \frac{u_2(w-s)-u_2(w^*_{FIX}-s)}{u_2(w^*_{FIX}-s)-u_2(\theta-s)}dF(w). \tag{B.13}$$

Because $\int_{w^*_{FIX}}^{\overline{w}} \frac{u_2(w-s)-u_2(w^*_{FIX}-s)}{u_2(w^*_{FIX}-s)-u_2(\theta-s)}dF(w)$ is decreasing in w^*_{FIX}, this implies $\hat{w}^*_{FIX} < w^*_{FIX}$.

Note that Danforth (1974) extends the result of Pratt (1964) to multi-dimensional lotteries. By applying Danforth (1974, Theorem 2), we can obtain a more general result, which indicates that higher debt reduces the agent's reservation wage even in a perfect credit market.

As an extension, if we assume that borrowers are protected from limited liability, i.e., they do not need to make repayment during unemployment, then equation (B.8) can be written as

$$\begin{aligned} 1 &= \frac{\beta}{1-\beta}\int_{w^*}^{\overline{w}} \frac{u(w-s)-u(w^*-s)}{u(w^*-s)-u(\theta)}dF(w) \\ &= \frac{\beta}{1-\beta}\int_{w^*}^{\overline{w}} \left[\frac{u(w-s)-u(\theta)}{u(w^*-s)-u(\theta)} - 1\right] dF(w). \end{aligned} \tag{B.14}$$

Equation (B.14) implies that an increase in s increases the reservation wage w^*. This is the risk-shifting effect of debt proposed by Donaldson, Piacentino and Thakor (2016) (a related discussion is in footnote 2).

□

B.4.2 Proof of Proposition B.2

Proof. Rearranging equation (B.4),

$$I(w^*_{FIX}) = \frac{\theta F(w^*_{FIX}) + \frac{1}{1-\beta}\int_{w^*_{FIX}}^{\overline{w}} w dF(w)}{1-\beta F(w^*_{FIX})}. \tag{B.15}$$

Take the first derivative,

$$I'(w^*_{FIX}) = \frac{f(w^*_{FIX})}{[1-\beta F(w^*_{FIX})]^2}\left[\theta - w^*_{FIX} + \frac{\beta}{1-\beta}\int_{w^*_{FIX}}^{\overline{w}} (w-w^*_{FIX})dF(w)\right]. \tag{B.16}$$

Denote

$$h(x) = \theta - x + \frac{\beta}{1-\beta}\int_x^{\overline{w}} (w-x)dF(w). \tag{B.17}$$

It is straightforward to show that $h(\theta) > 0$, $h(\overline{w}) < 0$, and $h(x)' < 0$. Thus there exists a unique

$w^*_{FIX} \in (\theta, \overline{w})$, denoted as $\hat{w}$, such that $I'(\hat{w}) = 0$. When $w^* < \hat{w}$, $I'(w^*_{FIX}) > 0$ and expected income is strictly increasing in w^*_{FIX}; when $w^*_{FIX} > \hat{w}$, $I'(w^*_{FIX}) < 0$ and expected income is strictly decreasing in w^*_{FIX}. Therefore, $\hat{w}$ maximizes expected income and is determined by

$$\hat{w} - \frac{\beta}{1-\beta} \int_{\hat{w}}^{\overline{w}} (w - \hat{w}) dF(w) = \theta. \tag{B.18}$$

Now, I prove that a risk-neutral agent sets her reservation wage to be $\hat{w}$. Because the interest rate is assumed to satisfy $\beta(1+r) = 1$, the risk-neutral agent is indifferent about savings. Without loss of generality, I assume that the risk-neutral agent also behaves hand-to-mouth, like a risk-averse agent. Therefore, her reservation wage is determined by equation (B.3).

The utility function of the risk-neutral agent has a linear form, i.e., $u(x) = ax + b$. Substituting this into equation (B.3), I obtain

$$w^*_{FIX} - \frac{\beta}{1-\beta} \int_{w^*_{FIX}}^{\overline{w}} (w - w^*_{FIX}) dF(w) = \theta. \tag{B.19}$$

There is a unique solution to equation (B.19), thus $w^*_{FIX} = \hat{w}$ for the risk-neutral agent. □

B.4.3 Proof of Proposition B.3

Proof. The mileage that CRRA utility buys me is that it is a homogeneous utility function with multiplicative scaling behavior. With CRRA utility, $u(c) = \frac{c^{1-\gamma}}{1-\gamma}$, equation (B.7) becomes

$$(w^*_{IBR})^{1-\gamma} = \theta^{1-\gamma} + \frac{\beta}{1-\beta} \int_{w^*_{IBR}}^{\overline{w}} [w^{1-\gamma} - (w^*_{IBR})^{1-\gamma}] dF(w). \tag{B.20}$$

Clearly, w^*_{IBR} does not depend on α. Therefore, under the IBR, when the utility has CRRA, the agent's reservation wage is equal to the reservation wage of the agent who has no debt. This suggests that

$$w^*_{IBR} = w^*|_{s=0} > w^*_{FIX}, \tag{B.21}$$

where the last inequality is from Proposition B.1 because CRRA utility has decreasing absolute risk aversion. Note that another way to see that the reservation wage does not depend on α when utility has CRRA is to calculate the absolute risk aversion for utility $u((1-\alpha)x)$, which is γ/x, not a function of α. Then, according to the proof of Proposition B.1, the reservation wage stays the same because the local absolute risk aversion does not change for any x when α changes. □

C Data

The details of the data construction are listed below.

C.1 Construction of Main Empirical Variables

Highest degree In each year, NLSY97 collects the highest degree received to the start of the interview year. The cumulative variable CVC_HIGHEST_DEGREE_EVER documents the highest degree received ever according to the most recent survey. I only keep the youths with a bachelor's degree (CVC_HIGHEST_DEGREE_EVER=4) or a high school degree (CVC_HIGHEST_DEGREE_EVER=2).

Military service I check two variables for military services. The variable YCPS_2400, available in years 1997, 2000, 2006, documents whether the youth is now in the active Armed Forces. I drop the the youths who answered yes in any of these surveys. The variable YEMP_59000, available in years 1998-2012, documents whether the youth is/was in the regular, the Reserves, or the National Guard. I drop youths who ever had these statuses.

Enrollment in grad schools Some youths choose to continue a graduate program after college graduation. I drop these students because their labor market experience is likely to be different. The variable CV_ENROLLSTAT, available in each year since 1997, documents the enrollment status as of the survey year. I drop youths who ever enrolled in a graduate program (CV_ENROLLSTAT=11).

Degree receiving date The variable CVC_BA_DEGREE documents the date on which the youth received a bachelor' s degree in a continuous month scheme. I drop youths who received the bachelor's degree before 1997 due to the lack of labor market information upon college graduation.

Student loan debt I construct the student loan debt variable following Addo (2014). The variable YSCH_25600 documents the amount of loans borrowed in government-subsidized loans or other types of loans while the youth attended schools/institutions in each term and each college. Together with the records on enrollment information, I construct the amount of student loans taken out in each year and the total amount of student loans borrowed before college graduation. Unfortunately, there is no information on repayment in the data. Because students rarely repay student loan debt during college, I consider the total amount of student loans borrowed as the amount of outstanding student loan debt upon college graduation. To prevent the skewness of the debt distribution having a large effect on the estimated means, the total amount of student loan debt is top coded at 99 percentile ($49,280).

Last date enrolled I construct a "last-enrolled" variable to record the last date on which the youth is in school. I consider the youth as in the labor market after this date is passed. For college graduates, the variable SCH_COLLEGE_STATUS documents the youth's college enrollment status in each month since 1997. Based on this information, I set the value of "last-enrolled" to be the latest month that the youth was enrolled in college (SCH_COLLEGE_STATUS=3). Then, I check whether the value of "last-enrolled" variable is consistent with the date that the youth receives her bachelor's degree, documented by the variable CVC_BA_DEGREE. Among the 1261 college graduates in my sample, 83 youths have the last date enrolled being inconsistent with the degree date for at least 1 year. These youths are not considered when constructing the labor market moments below. For high school graduates, I use the high school degree receiving date as the last date in school.

Duration of unemployment spells I construct the duration of unemployment spells by tracking the period until an unemployed (or out of the labor force) youth finds a job. In my sample, there are 7,969 unemployment spells with an average duration of 27.2 weeks and a standard deviation of 59.4 weeks.

Wage income The variable YINC_1700 documents income that the youth received from wages, salary, commissions, or tips from all jobs in past year, before deductions for taxes or anything else. This is the variable I use to construct annual wage income. An alternative method to construct annual wage income is to use the information on hours and hourly wage rate. The two methods usually provide different numbers due to measurement errors. I prefer to use the variable YINC_1700 to construct annual wage income because the value of this variable is directly obtained from the questionnaire but the second method uses data constructed by BLS staff based on several discretionary assumptions. To be consistent, I construct an average hourly wage rate by dividing deflated values of YINC_1700 by the total number of hours worked in that year. When constructing annual wage income for each youth, I follow Rubinstein and Weiss (2006) by excluding the youths whose hourly wage rates are below $4 or higher than $2,000 and who worked less than 35 weeks or less than 1,000 annual hours.

Hours The variable EMP_HOURS documents the total number of hours worked by a youth at any job in each week. Hours per week worked at each job are assumed constant except during a reported gap, when the hours for that job are assumed to be zero. Weekly hours are top coded at 140 hours.

Net liquid wealth I construct the net liquid wealth variable using financial assets. Loans received from family members and friends to help pay for college are not subtracted in the measure of net liquid wealth. This is because, as argued by Johnson (2013), it is not clear whether or when these youths would need to repay the loans from family members and friends for educational purposes. I do not include non-financial assets, e.g., housing and property values, farm operation, etc., because these assets are not as liquid, and accounting for their values downplays the marginal propensity to consume. As I show in section B, the repayment of student loans affects job search strategy through the liquidity channel, which depends on the marginal propensity to consume.

The variable CVC_ASSETS_FINANCIAL documents the value of financial assets when the youth reaches ages 18, 20, and 25. The financial assets include savings and checking accounts, money market funds, retirement accounts, stocks, bonds, and life insurance, etc. I use the value of financial assets at age 18 to proxy the net liquid wealth right before making the college entry decision. To prevent the skewness of the asset distribution having a large effect on the estimated means, the net liquid wealth values are top coded at 99 percentile ($69,695).

One concern is that money in retirement accounts is not as liquid. The adjustment is made using the variable YAST_4292, which documents the amount of savings in pension/retirement plans. Making this adjustment has almost no effect on the distribution of liquid wealth because only 50 youths reported to have positive balance in these plans with an average amount of $39.7.

Work status I construct the youth's work status using the variable EMP_STATUS, which documents the youth's weekly employment status since 1997. This variable documents whether the youth is employed, unemployed, or out of the labor force. Because my model does not distinguish between unemployed and out of the labor force, I consider the youths who are out of the labor force as unemployed. For employed youths, the associated employer number is also documented.

Duration of employment spells For each youth, I construct the duration of her employment spells by tracking the period between the date of moving from unemployment status to employment status and the date of moving from employment status to unemployment status. I drop employment spells whose duration is less than five weeks, because these are likely to be temporary or insecure jobs. In my sample, there are 8,130 employment spells with an average duration of 113.2 weeks and a standard deviation of 136.2 weeks.

Job tenure For each youth, I construct her tenure at each job (employer) by tracking the period between the date of moving to the job and the date of leaving the job. In my sample, there are 12,086 job spells with an average duration of 76.3 weeks and a standard deviation of 106.9 weeks.

Hourly wage rate The variable CV_HRLY_PAY documents the hourly rate of pay as of either the job's stop date or the interview date for on-going jobs. This variable is used to construct the wage increase upon job-to-job transitions (not wage income; see above).

Wage increase upon job-to-job transitions I construct the log wage increase upon job-to-job transitions by calculating the change in log hourly wage rate between consecutive job spells.

Government benefits The monthly take-up status and benefit amount of AFDC, food stamps, and WIC between 1997-2009 are documented in variables, AFDC_AMT, AFDC_STATUS, FDSTMPS_AMT, FDSTMPS_STATUS, WIC_AMT, WIC_STATUS.

Parental wealth and education The variable CV_HH_NET_WORTH_P documents household net worth from parent interview in 1997. I use this variable to proxy parental wealth. The variable, CV_HGC_BIO_DAD and CV_HGC_BIO_MOM, document the highest grade completed by each youth's biological father and mother. I use the mean of the two variables to proxy parental education.

Gender, race, age, and AFQT score can be found from variables, KEY!SEX, KEY!RACE_ETHNICITY, KEY!BDATE, ASVAB_MATH_VERBAL_SCORE_PCT.

County of residence is available from NLSY restricted geocode CD. The variable GEO01 documents the youth's residence in each survey year.

Job industry The variable YEMP_INDCODE_2002 documents the 4-digit business or industry code based 2002 Census Industry Codes for each youth between 1997-2013. Industry codes between 6870-6990 are classified as finance and banking jobs and those between 7270-7460 are classified as consulting jobs.

Length of college study The length of college study is constructed by taking the difference between the first date enrolled in college, available from variable SCH_COLLEGE_STATUS, and the BA degree receiving date, documented by variable CVC_BA_DEGREE.

Sector The variable YEMP_58500 documents whether the worker is employed by government, a private company, a nonprofit organization , or is working without pay in a family business or farm since 1997. I consider the respondent as working in the public sector if she is employed by government or by a nonprofit organization. There is only one respondent working without pay in a family business or farm. This data point is dropped when running regressions.

College major Respondents in rounds 1-13 (1997-2009) indicated their college majors from a pick list. The variable YSCH_21300 documents the youth's major field in each college each term since the date of last interview. Beginning in round 14 (2014), respondents' majors were collected in a verbatim format and then coded using the CIP (Classification of Instructional Programs) 2010 codes under the variable YSCH_21300_COD. In my sample, only 7 youths received the BA degree after 2010 (the most recent graduate received his degree in September 2011). For these youths, I use the majors recorded before round 14 to be consistent with the old coding system. Among the rest 1254 youths, 1234 youths' majors are documented in at least one of the survey between 1997-2009. For the 104 youths who changed majors during college study, I use the most recently reported major before the degree receiving date to represent the major associated with the BA degree. The old coding system has a very fine category with 45 different majors, which generates a collinearity problem (with the county fixed effect) in my wage regressions because of the small sample size. Therefore, I reclassify the recorded majors into four broader category, including physical science, social science, engineering, and others.

Others The remaining moments are constructed using other data sources. The vacancy to unemployment ratio is constructed using job openings information since December 2000 from JOLTS. The life-cycle earnings profile between ages 23-60 is constructed using March CPS 1997-2008 from Acemoglu and Autor (2011) (available on David Autor's website).

C.2 Adjusting the Higher-Order Moments for Unmodeled Variation

In the model, the exogenous sources of variation among agents come from differences in initial wealth, talent, student loan debt, and histories of shocks to job offers. By contrast, the data contain unmodeled variation due to heterogeneity in personal characteristics, family background, occupation, and industry fixed effects. Ignoring these sources of variation would not be problematic if the moments used in identification only include sample averages. However, because the talent and vacancies' productivity distribution are identified using the second (variation) and third (skewness) moments of the cross-sectional log wage income distribution and the variance of log wage increase upon job-to-job transitions, ignoring these sources of variation would bias the estimation result. Intuitively, failure to account for the unmodeled variation in the data would result in a more dispersed estimated productivity distribution, which will in turn exaggerate the option value of staying unemployment and overestimate the effect of the debt burden on job search decisions.

I adjust the data by purging the unmodeled sources of variation from the data following the approach of Gourinchas and Parker (2002) and Kaboski and Townsend (2011). In particular, I run linear regressions of log wage income. The estimated equation is:

$$\log Wage_{i,t} = \beta_w X_{i,t} + \epsilon_{w,i,t}, \tag{C.1}$$

where $X_{i,t}$ is a vector of controls including race, gender, parental net worth and education, occupation, and year fixed effects. I then construct the adjusted data for individuals with mean values of the explanatory variables ($\overline{X}$) using the estimated coefficients and residuals:

$$\widetilde{\log Wage}_{i,t} = \hat{\beta}_w \overline{X} + \hat{\epsilon}_{w,i,t}.$$

Finally, I construct the variance and skewness moments of the cross-sectional log wage income distribution using the adjusted log wage income $\widetilde{\log Wage}_{i,t}$.

C.3 Suggestive Evidence

In this subsection, I present the full regression table for Table 5 in the maintext.

Table OA.1: The duration of the first unemployment spell after college graduation.

	Duration of the first unemployment spell		
	(1)	(2)	(3)
Loan amount	-1.54**	-2.08***	-1.92***
(in $10,000)	(0.66)	(0.68)	(0.63)
Parental wealth	-0.02	-0.00	0.03
(in $10,000)	(0.06)	(0.07)	(0.08)
Parental education	0.36	0.68	0.57
	(0.41)	(0.53)	(0.53)
Female		3.37	1.91
		(2.23)	(2.27)
AFQT		-0.01	-0.03
		(0.06)	(0.06)
Race: Black		-0.23	-2.10
		(5.24)	(4.09)
Hispanic		2.62	2.92
		(9.49)	(9.18)
Mixed Race		1.56	3.51
		(4.00)	(3.60)
Married		1.00	-0.81
		(3.41)	(3.29)
age		-28	-148
		(271)	(227)
age^2		1.38	6.17
		(10.91)	(9.04)
age^3		-0.02	-0.08
		(0.15)	(0.12)
Major: Physical Science			6.55
			(4.31)
Social Science			4.35
			(2.70)
Others			5.71*
			(3.28)
Industry: finance, banking,			-6.78***
and consulting			(2.02)
Length of college study			0.42
			(0.58)
Observations	884	771	728
County fixed effect	√	√	√
R^2	0.0057	0.0183	0.0291

Note: This table examines the impact of student loan debt on the duration of the first unemployment spell after college graduation. A $10,000 increase in the amount of student loans reduces the duration of the first unemployment spell by about 2 weeks. Each observation is at the individual level. The dependent variable is the number of weeks elapsed from the college graduation date to the date of starting the first full-time job (i.e., work more than 35 hours per week for at least two consecutive weeks). The dependent variable is regressed on the total amount of student loan debt borrowed during college study, recorded in units of $10,000. All regressions control for parental wealth, parental education, and the county of residence in the graduation year. Column (2) adds additional controls for gender, race, AFQT score, marital status, and the cubic age polynomials. Column (3) adds additional controls for college major, job industry, and the length of college study. Standard errors are clustered at the county level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table OA.2: The impact of student loan debt on post-graduation wage income.

	First year			**Second year**			**Third year**		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Loan amount	-1,830**	-2,067**	-2274**	-1,812**	-2,152**	-2,232**	-2,009*	-2,619**	-2,821**
(in $10,000)	(770)	(890)	(920)	(789)	(865)	(882)	(1,117)	(1,309)	(1,372)
Parental wealth	100*	94*	77	91	106	95	53	33	56
(in $10,000)	(56)	(55)	(56)	(70)	(84)	(69)	(85)	(83)	(90)
Parental education	19	-376	-146	290	-364	-130	611	-29	320
	(305)	(380)	(405)	(389)	(523)	(516)	(538)	(623)	(565)
Female		-6,140***	-3,585*		-6,347***	-3,135		-8,154***	-4,738*
		(1,969)	(1,864)		(2,142)	(2,155)		(2,765)	(2,513)
AFQT		80.7	55.4		112.0	94		117	108
		52.6	(51.8)		(69.5)	(68)		(78)	(74)
Race: Black		1,491	52		-835	-142		992	1,613
		(3,679)	(3,741)		(4,986)	(4,825)		(5,340)	(5,931)
Hispanic		-730	-696		-8,496	-5,825		-12,583	-6,366
		(8,473)	(8,049)		(8,113)	(8,049)		(13,008)	(11,574)
Mixed Race		2,051	513		-1,323	-2,841		1,326	-446
		(2,850)	(2,820)		(3,515)	(3,335)		(4,102)	(4,129)
Married		-1,153	-2,415		-2,337	-2,081		-4,563	-4,860
		(2,457)	(2,469)		(3,349)	(3,166)		(3,616)	(3,871)
age		-9.3e4	1.5e4		2.4e5	-2.3e5		9.9e4	5.9e5
		(3.0e5)	(3.0e5)		(4.2e5)	(4.8e5)		1.1e6	1.6e6
age^2		3.4e3	-1.0e3		1.0e4	9.8e3		-3.3e3	-2.4e4
		(1.2e4)	(1.2e4)		(1.8e4)	(2.0e4)		(4.7e4)	6.6e4
age^3		-42	18		-145	-138		33	323
		(163)	(163)		(244)	(276)		(662)	929
Major: Physical Science			-20,189***			-19,244***			-20,969***
			(4,988)			(4,631)			(6,697)
Social Science			-20,370***			-21,147***			-23,233***
			(4,627)			(4,512)			(6,453)
Others			-24,729***			-26,608***			-28,201***
			(4,532)			(5,184)			(6,708)
Industry: finance, banking,			5,632***			5,498**			4,358
and consulting			(2,158)			(2,615)			(3,088)
Length of college study			495			-536			-164
			(563)			(647)			(863)
Observations	671	596	582	588	518	507	483	427	415
County fixed effect	√	√	√	√	√	√	√	√	√
R^2	0.0175	0.0651	0.1455	0.0221	0.0733	0.1361	0.0185	0.0713	0.1311

Note: This table examines the impact of student loan debt on wage income in the first three years after college graduation. A $10,000 increase in the amount of student loans reduces the annual wage income by about $2,000. The dependent variable is wage income in the t-th year ($t = 1, 2, 3$) after college graduation. The dependent variable is regressed on the total amount of student loan debt borrowed during college study, recorded in units of $10,000. All regressions control for parental wealth, parental education, and the county of residence in the graduation year. Column (2) adds additional controls for gender, race, AFQT score, marital status, and the cubic age polynomials. Column (3) adds additional controls for college major, job industry, and the length of college study. Standard errors are clustered at the county level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table OA.3: The impact of student loan debt on first jobs' industry, sector, and labor supply.

	High-paid industry			**Private sector**			**Labor supply**		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Loan amount	-0.005	-0.032	-0.033	0.026	0.037	0.031	13.0	24.9	20.2
(in \$10,000)	(0.047	(0.051)	(0.052)	(0.061)	(0.069)	(0.070)	(23.8)	(29.4)	(29.0)
Parental wealth	0.005*	0.005*	0.005	-0.002	-0.002	-0.002	1.55	1.00	1.25
(in \$10,000)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(1.69)	(1.76)	(1.79)
Parental education	-0.008	-0.041*	-0.042*	0.067**	0.041	0.041	-9.4	-30.1**	-29.5**
	(0.019)	(0.022)	(0.022)	(0.029)	(0.034)	(0.034)	(12.5)	(13.2)	(13.7)
Female		-0.28***	-0.24**		-0.38**	-0.35**		-235***	-219***
		(0.11)	(0.11)		(0.16)	(0.17)		(60)	(60)
AFQT		0.006**	0.006**		-0.001	-0.001		1.68	1.40
		(0.003)	(0.003)		(0.003)	(0.003)		(1.30)	(1.32)
Race: Black		0.015	-0.005		0.103	0.107		3.8	-16.0
		(0.231)	(0.231)		(0.319)	(0.322)		(159.2)	(154.5)
Hispanic		-0.270	-0.170		0.277	0.419		12.3	-3.8
		(0.579)	(0.578)		(0.711)	(0.702)		(184.0)	(193.2)
Mixed Race		0.011	-0.004		0.288	0.298		59.1	42.2
		(0.193)	(0.195)		(0.244)	(0.245)		(99.4)	(101.4)
Married		0.118	0.132		-0.372*	-0.374*		-130.5	-158.6*
		(0.152)	(0.153)		(0.224)	(0.227)		(91.4)	(82.4)
age		-32.9*	-33.9*		-44.0***	-44.0**		748	3,825
		(18.6)	(18.7)		(17.0)	(17.2)		(7,066)	(7,085)
age^2		1.37*	1.42*		1.76***	1.77**		-35.8	-162.1
		(0.76)	(0.77)		(0.68)	(0.69)		(286.3)	(287.3)
age^3		-0.019*	-0.020*		-0.023***	-0.024**		0.545	2.242
		(0.010)	(0.011)		(0.009)	(0.009)		(3.851)	(3.863)
Major: Physical Science			0.148			0.030			-222.3
			(0.246)			(0.415)			(147.1)
Social Science			-0.040			-0.019			-242.9*
			(0.209)			(0.354)			(131.7)
Others			-0.306			-0.278			-167.1
			(0.232)			(0.374)			(135.8)
Length of college study			-0.027			0.021			42.3
			(0.021)			(0.035)			(33.5)
Observations	884	775	773	365	319	317	812	705	705
County fixed effect							√	√	√
R^2	0.0037	0.0417	0.0506	0.0142	0.0638	0.0694	0.0029	0.0383	0.0521

Note: This table examines the impact of student loan debt on the industry and sector of first jobs and the number of working hours in the first year after college graduation. There is no significant finding on these margins. The first three columns estimate a Probit model using whether the respondent's first job is in finance, banking, and consulting industry as the dependent variable. The next three columns estimate a Probit model using whether the respondent's first job is in private sector as the dependent variable. The last three columns estimate an OLS regression using the number of workings hours in the first year after college graduation as the dependent variable. The treatment variable is the total amount of student loan debt borrowed during college study, recorded in units of \$10,000. All regressions control for parental wealth, parental education, and the county of residence in the graduation year. Column (2) adds additional controls for gender, race, AFQT score, marital status, and the cubic age polynomials. Column (3) adds additional controls for college major, job industry, and the length of college study. Standard errors in the last three columns are clustered at the county level. ***, **, and * indicate significance at the 1, 5, and 10 percent level.

D Estimation and Numerical Methods

In this appendix, I present the estimation and numerical method.

D.1 Estimating Standard Errors

To estimate standard errors, I estimate the variance-covariance matrix $\widehat{\text{COV}}$ for all moments. Because the vector of moments in the data can be computed without knowing parameter values, $\widehat{\text{COV}}$ can be computed by bootstrapping the data directly without doing iterated MSM. Specifically, I calculate the moments $N = 200$ times by bootstrapping, then use these N observations of moments to construct the variance-covariance matrix. There are two issues in estimating $\widehat{\text{COV}}$. First, moments are constructed using different data sources. The life-cycle moments are constructed using March CPS, the vacancy to unemployment ratio is constructed using JOLTS, the default rate is constructed using NSLDS, and the remaining moments are constructed using NLSY97. The covariance between moments constructed in different data sources is set to be zero. Second, the moments in NLSY97 are constructed using different number of observations due to missing values. The covariance between any pair of moments is constructed by bootstrapping non-missing-value observations for both moments.

In my estimation, I use a diagonal weighting matrix, $\hat{\Theta} = [\text{diag}(\widehat{\text{COV}})]^{-1}$, because covariance is not precisely estimated and may bias the estimated parameter values. The asymptotic variance-covariance matrix for MSM estimators $\hat{\Xi}$ is given by:

$$Q(\hat{\Theta}) = (\nabla^T \hat{\Theta} \nabla)^{-1} \nabla^T \hat{\Theta} \widehat{\text{COV}} \hat{\Theta}^T \nabla (\nabla^T \hat{\Theta}^T \nabla)^{-1}, \tag{D.1}$$

where $\nabla = \frac{\partial \hat{m}_S(\Xi)}{\partial \Xi}|_{\Xi=\hat{\Xi}}$ is the Jacobian matrix of the simulated moments evaluated at the estimated parameters.[3] The first derivatives are calculated numerically by varying each parameter's value by 1%. The standard errors of $\hat{\Xi}$ are given by the square root of the diagonal elements of $Q(\hat{\Theta})$.

D.2 Numerical Method

Algorithm Because I focus on the stationary equilibrium, the value functions and policy functions across different generations are identical. The model is solved by backward induction using the following algorithm:

(1). Guess the equilibrium job contact rates λ^u for unemployed workers, and $\lambda^e = \frac{q^e}{q^u}\lambda^u$ for employed workers.

(2). Solve the value functions $U(\Omega)$, $W(\Omega, \rho, \rho')$, and $J(\Omega, \rho, \rho')$ in the following steps:

(2.1). Guess wage functions $w(\Omega, \rho, \rho')$ for all Ω, ρ, and ρ'.

[3] In general, the formula should also incorporate simulation errors, thus the variance-covariance matrix for MSM estimators also depends on the number of simulated agents (Gourieroux and Monfort, 1997). The formula I use does not consider simulation errors because instead of simulating a number of agents, I adopt the histogram method by simulating the distribution of characteristics. Therefore, as long as I focus on the stationary equilibrium, the simulation outcomes are not dependent on randomly drawn shocks.

Table OA.4: Discretization of state space.

Parameters	Value	Description
n_b	400	Number of wealth grids
Δ_b	\$500	Length of wealth grids
$[\underline{b} \quad \overline{b}]$	[\$0 \$200,000]	Range of wealth
n_s	100	Number of student loan debt grids
Δ_s	\$500	Length of student debt grids
$[\underline{s} \quad \overline{s}]$	[\$0 \$50,000]	Range of student debt
n_ρ	20	Number of productivity grids
Δ_ρ	0.05	Length of productivity grids
$[\underline{\rho} \quad \overline{\rho}]$	[0 1]	Range of productivity

(2.2). Solve problems (2.19-2.23) by backward induction from $t = T$ to $t = 1$ to obtain $U(\Omega)$, $W(\Omega, \rho, \rho')$, $J(\Omega, \rho, \rho')$, and the corresponding policy functions.

(2.3). Solve the Nash bargaining problems (2.6) and (2.9-2.11) to obtain wage $w'(\Omega, \rho, \rho')$.

(2.4). If $w'(\Omega, \rho, \rho') \approx w(\Omega, \rho, \rho')$ for all Ω, ρ, and ρ', go to step (3); otherwise, go to step (2.1).

(3). Given initial distributions $\mho(a, b_0)$ and the computed value functions, solve the optimal college entry decisions. Then given the policy functions, forward simulate the model from $t = 1$ to $t = T$ to obtain distributions $\phi^u(\Omega)$ and $\phi^e(\Omega, \rho, \rho')$.

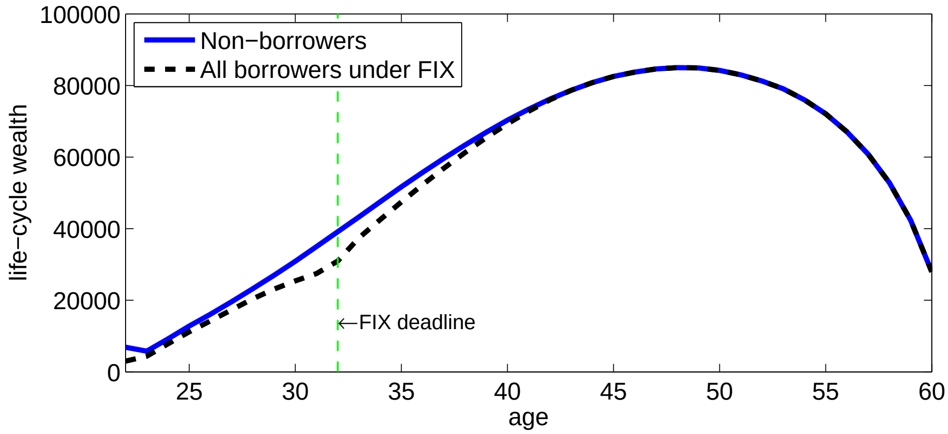
(4). Compute the equilibrium unemployment rate $\overline{u}$ using equation (2.29) and the aggregate level of search intensity Q using equation (2.24). Compute the probability of contacting a worker h using the free entry condition (2.28).

(5). Substituting Q and h into equations (2.25-2.27) to obtain the number of meetings M, the number of vacancies N, and the equilibrium job contact rates $\hat{\lambda}^u$.

(6). Check if $\hat{\lambda}^u \approx \lambda^u$. If not, go to step (1).

Implementation To ensure accuracy, I choose relatively fine grids (see Table OA.4), and the values between grids are approximated by linear interpolation. I use the golden section search method to find the optimal decision rules. The advantage of the golden section search method is that it is robust to the choice of initial values because convergence is guaranteed. However, convergence to the global optimum is not ensured if there are many local optima. Therefore, I further divide the whole decision space into multiple sub-space and select the largest local optimum. I do a robustness check after the estimation using a sequential grid search, and the results are identical. When solving the Nash bargaining problem, I need to invoke the calculation for utility from consumption and utility from the future multiple times. I save the computation time by calculating these values in advance and store them in memory.

The numerical algorithm is implemented using C++. The program is run on the server of MIT Economics Department, *supply.mit.edu*, which is built on Dell PowerEdge R910 running RedHat 6.7 (64-core processor, Intel(R) Xeon(R) CPU E7-4870, 2.4GHz). I use OpenMP for parallelization when iterating value functions and simulating the model. My baseline model requires 200GB of RAM to store the large number of decision rules and value functions.



Note: This figure plots the average wealth of borrowers and non-borrowers over their entire life-cycle. It shows that borrowers accumulate significantly less wealth compared to non-borrowers when they are young. This explains why even after debt has been paid off, borrowers still spend less time on job search and earn relatively less.

Figure OA.4: Average wealth of non-borrowers and borrowers under the fixed repayment plan.

Table OA.5: Low risk aversion, $\gamma = 1.5$: General Equilibrium Implications of Student Debt.

	FIX	IBR		No debt	FIX
		(i)	(ii)		no search
Fraction of college graduates	42.1%	44.9%	46.2%	20.9%	39.3
Fraction of borrowers	61.5%	64.5%	65.3%	0%	59.1
IBR enrollment rate	N/A	20%	29.8%	N/A	N/A
Avg debt of borrowers ($)	10,420	15,452	16,039	N/A	8,842
Job contact rate	0.81	0.85	0.87	0.66	0.78
Wage income ($)	37,421	37,821	38,136	34,189	37,165
Output ($)	45,698	46,035	46,238	42,845	45,512
Labor supply (hours)	1,627	1,638	1,641	1,611	1,621
Default rate	9.32%	1.80%	0.60%	N/A	11.70%
Debt forgiveness ($)	0	510	545	N/A	0
Average tax rate	31.5%	31.9%	32.1%	35.1%	31.7%
Welfare	N/A	0.22%	0.31%	-5.23%	-0.17%

Table OA.6: High elasticity of labor supply, $\sigma = 0.78$: General Equilibrium Implications of Student Debt.

	FIX	IBR		No debt	FIX
		(i)	(ii)		no search
Fraction of college graduates	42.0%	43.1%	43.7%	20.7%	36.7%
Fraction of borrowers	61.3%	62.2%	62.5%	0%	57.2%
IBR enrollment rate	N/A	20%	30.4%	N/A	N/A
Avg debt of borrowers ($)	10,542	12,361	13,219	N/A	7,655
Job contact rate	0.80	0.81	0.81	0.63	0.76
Wage income ($)	37,398	37,545	37,601	33,048	36,945
Output ($)	42,680	42,810	42,867	39,583	42,327
Labor supply (hours)	1,578	1,552	1,549	1,558	1,562
Default rate	9.41%	2.40%	0.95%	N/A	13.15%
Debt forgiveness ($)	0	1,243	1,357	N/A	0
Average tax rate	27.5%	31.4%	32.2%	30.1%	27.9%
Welfare	N/A	0.11%	0.13%	-6.37%	-0.41%

Table OA.7: Low elasticity of labor supply, $\sigma = 88.9$: General Equilibrium Implications of Student Debt.

	FIX	IBR		No debt	FIX
		(i)	(ii)		no search
Fraction of college graduates	41.8%	46.5%	48.2%	22.1%	38.7%
Fraction of borrowers	62.0%	66.7%	68.1%	0%	59.3%
IBR enrollment rate	N/A	20%	32.2%	N/A	N/A
Avg debt of borrowers ($)	10,244	17,145	17,785	N/A	9,240
Job contact rate	0.82	0.87	0.89	0.70	0.80
Wage income ($)	37,028	37,923	38,012	34,215	36,835
Output ($)	47,984	49,110	49,345	44,320	47,814
Labor supply (hours)	1,632	1,633	1,633	1,631	1,632
Default rate	9.48%	1.70%	0.40%	N/A	11.20%
Debt forgiveness ($)	0	495	532	N/A	0
Average tax rate	32.1%	31.5%	31.2%	34.7%	32.2%
Welfare	N/A	0.4%	0.67%	-4.62%	-0.23%

Table OA.8: No credit access, $\varsigma = 0$: General Equilibrium Implications of Student Debt.

	FIX	IBR		No debt	FIX
		(i)	(ii)		no search
Fraction of college graduates	41.7%	46.4%	48.1%	20.9%	37.4%
Fraction of borrowers	61.5%	66.5%	68.0%	0%	57.8%
IBR enrollment rate	N/A	20%	30.9%	N/A	N/A
Avg debt of borrowers ($)	10,276	16,997	17,015	N/A	8,520
Job contact rate	0.83	0.87	0.88	0.68	0.79
Wage income ($)	37,512	38,154	38,532	34,120	37,200
Output ($)	46,068	46,439	46,620	42,556	45,789
Labor supply (hours)	1,638	1,646	1,651	1,614	1,632
Default rate	9.20%	2.30%	0.90%	N/A	12.50%
Debt forgiveness ($)	0	630	675	N/A	0
Average tax rate	31.6%	32.3%	32.5%	35.1%	31.9%
Welfare	N/A	0.45%	0.62%	-5.00%	-0.33%

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