Job Search under Debt:
Aggregate Implications of Student Loans

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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 (IBR) plan largely alleviates the burden of debt repayment by insuring job search risks. In general equilibrium, IBR also increases social welfare by encouraging college attendance and job postings.

JEL codes: E2, E6, J3, J6.

Keywords: student loan debt, search friction, reservation wage, risk and liquidity, income-based repayment plan.

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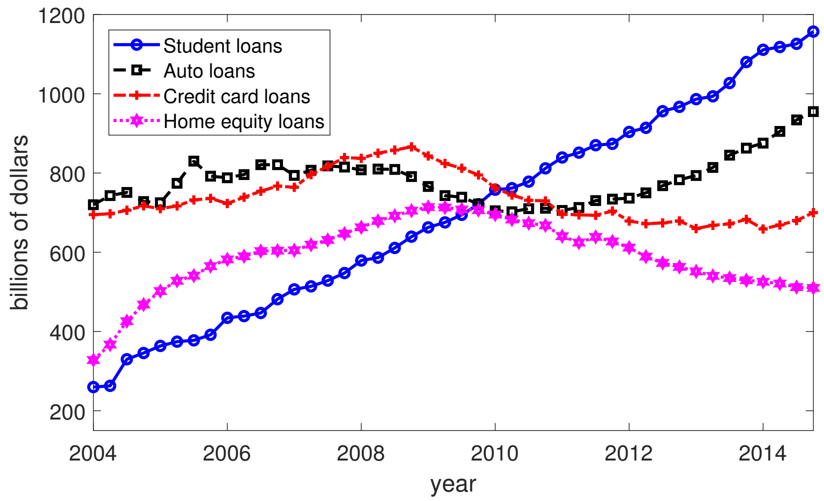
*Yan Ji, Hong Kong University of Science and Technology, Email: jiy@ust.hk. I am very grateful to my advisers Robert Townsend, Alp Simsek, and Abhijit Banerjee for invaluable guidance, support, and encouragement. I have particularly benefited from the detailed comments of Daron Acemoglu, Dean Corbae,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

1 Introduction

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



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 (New York Fed, 2015).

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

The escalation of student debt has brought widespread concerns about the aggregate implications of student loans. However, measuring the aggregate effects of student loans on employment outcomes and social welfare presents a challenge. Both borrowing and job search decisions are endogenous, and depend on the job vacancies created by firms. Although we can measure the local effects of student loans using reduced-form empirical techniques, evaluating their aggregate 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 decisions on consumption, loan repayment, and job search after college.

The key mechanism I propose is that risk-averse agents with debt tend to spend less time searching for a job and end up with lower-paid jobs. My main contribution is to present a rich quantitative framework to evaluate the strength of this mechanism and the welfare implications 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 modeling borrowers' endogenous job search decisions plays a quantitatively important role in assessing the welfare effects of student loans. The intuition is as follows. Students with debt are more risk averse and liquidity constrained. When access to credit is tightened, the labor market offers its own version of insurance and liquidity provision by allowing borrowers to change their job search decisions. Thus neglecting this option underestimates the welfare effect of student loans as all borrowers 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 giving displaced workers access to credit significantly increases their unemployment duration and wage income. An extensive body of literature investigates how unemployment benefits (e.g. Hansen and Imrohoroglu, 1992; Ljungqvist and Sargent, 1998; Acemoglu and Shimer, 1999; Chetty, 2008) and private savings affect employment incentives (e.g. Danforth, 1979; Lentz and Tranas, 2005; Rendon, 2006; Lentz, 2009; Bils, Chang and Kim, 2011; Lise, 2013).

My main quantitative exercise suggests that, under the standard fixed repayment plan, student debt repayment significantly reduces borrowers' average unemployment duration and wage income. Such a significant change in borrowers' job search outcomes is informative about the burden of debt repayment. Counterfactual simulations suggest that the income-based repayment (IBR) plan largely alleviates the debt burden, motivating a 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 encouraging college attendance and job postings. Quantitatively, my model implies that welfare would drop by 4% in the absence of the student loan program. Passed by Congress in 2009, IBR increases the welfare by about 0.45% on average.

My quantitative model is an equilibrium search model (e.g. Krusell, Mukoyama and Sahin, 2010; Herkenhoff, 2015; Lise, Meghir and Robin, 2016) that incorporates college entry and borrowing decisions. I explicitly model the key institutional details of the U.S. federal student loan program. There are two major repayment plans, the standard fixed repayment plan which requires borrowers to repay the same amount every month; and IBR, which allows borrowers to repay based on a fraction of their income. In the model, risk-averse agents decide whether or not to enter college and finance college expenses by borrowing student loans. After graduation, agents search for jobs in the labor market and receive wage offers from firms of different productivity levels. Agents decide whether to accept a wage offer or continue their search for a potentially higher-paid job.

The model implies that a higher level of debt induces agents to take 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 a longer search increases both expected wage income and search risks. When debt is higher, agents become more liquidity constrained and thus consume less, leading to higher risk aversion. This pushes them to avoid search risks and alleviate the contemporaneous liquidity constraint by accepting a job more hastily.

To evaluate the quantitative importance of this mechanism, I estimate the model based on panel data from the 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, the endogenous student debt distribution, and various labor market characteristics observed in the data.

My first key result is 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 than non-borrowers. On average, borrowers spend 1.8 weeks less searching for their first jobs and earn about $1,500 less in the first year after college graduation than non-borrowers. These effects persist 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 is associated with a decrease in the duration of the first unemployment spell by about 1.41-1.53 weeks and a decrease in the annual wage income by about 2.7%-4.0% in the first three years after college graduation. These effects remain robust after controlling for demographic characteristics, ability, and family background, as well as county fixed effects. Since regressions based on model-simulated data yield comparable effects, the credibility of the model is enhanced.

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 the expected welfare of a newborn agent would drop by 4% in the absence of the student loan program due to the significant drop in college attendance.

The implications of the significant difference in employment outcomes between borrowers and non-borrowers are twofold. First, neglecting borrowers' endogenous job search strategies largely underestimates the welfare benefit of providing student debt. My counterfactual simulation suggests that if borrowers are restricted to the same income process as non-borrowers, the default rate would rise by 2.93% and the expected welfare of a newborn agent would decline by about 0.32%. Second, the standard fixed repayment plan places a large burden on borrowers, which explains their job search strategies.

My second key result shows that the government can further improve employment outcomes and increase the welfare gain from 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, though the initial take-up was minimal. My model suggests that IBR largely increases borrowers' average wage income by allowing them to optimally spend more time on their 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 0.45%.

College graduates enter the labor market with low earnings ability, and under the fixed repayment plan, student loans are due when borrowers are least able to repay. IBR offers insurance against job search risks, allowing borrowers to better smooth consumption and conduct a more adequate job search. This sort of insurance which comes with loan repayment plans is helpful precisely because indebted young borrowers have limited access to credit and insurance in the market.

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 loans. As the labor force becomes more educated, firms are able to make more profits and create more jobs. 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 a more comprehensive job search and better insurance, higher college attendance and greater borrowing, and more job postings are 0.13%, 0.15%, and 0.17%, 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 than 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; Rendon, 2006; Chetty, 2008; Lentz, 2009; Bils, Chang and Kim, 2011; 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), the 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 line of research by explicitly modeling and quantitatively evaluating the implications of student debt on job search behavior and the mechanism of consumption smoothing offered by different repayment plans.

This paper contributes to the large literature on student loans (see Lochner and Monge-Naranjo, 2016, for a recent survey). Much of this literature focuses on the impact of financial aid during college (e.g. Keane and Wolpin, 2001; Lochner and Monge-Naranjo, 2011; Abbott et al., 2018). However, much less is known about the impact of student loans on labor market outcomes after college. In this paper, I take a structural approach to highlight one plausible mechanism that could influence indebted students' job search decisions. Abbott et al. (2018) develop a rich general equilibrium model with heterogeneous agents to evaluate education policies. My model is different for having search frictions in the labor market. In addition, I use the model to evaluate IBR, which has been argued to offer risk-sharing benefits with minimal incentive costs (Stiglitz, Higgins and Chapman, 2014). Several studies have used 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. In addition to providing insurance benefits, my analyses elucidate two general equilibrium channels through which income contingency influences social welfare.

This paper is also related 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 their liability is limited (Donaldson, Piacentino and Thakor, 2016). Third, borrowers tend to work in high-paid industries (Rothstein and Rouse, 2011). My paper proposes that borrowers are less picky about jobs and more likely to earn less than non-borrowers.

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.

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 discount factor β and per-period utility,

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

where c and l are consumption and labor supply. Because I focus on the stationary equilibrium, 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 the data (e.g. Heckman, Lochner and Todd, 2006; Johnson, 2013).

To capture the high dropout rate in the U.S., I assume that agents who enter college graduate with probability ψ. Agents can finance college study by borrowing student loans. In particular, wealth-constrained agents (i.e. $b_0 < k$) borrow an amount of $k - b_0$ to pay the pecuniary cost. Thus, the agent who enters college has initial debt $s_1 = \max\{k - b_0, 0\}$. At $t = 1$, the agent enters the labor market looking for a job, and her labor productivity $z(a, n, t)$ depends on her talent a, education level ($n = 0, n = 1$), and age t. Specifically, the agent's labor productivity is determined by

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

where $g(n, t)$ is a deterministic trend that depends on education levels.[1] Following Bagger et al. (2014), I assume $g(n, t)$ to be cubic as follows,

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

Parameters $\mu_{n,0}$, $\mu_{n,1}$, $\mu_{n,2}$, and $\mu_{n,3}$ depend on education levels and are estimated to match the life-cycle earnings profile of high school and college graduates. The assumption that labor productivity depends on age instead of the amount of time in employment simplifies the problem as z_t is homogeneous within the same cohort conditional on talent and education levels.

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

2.2 Labor Market

Job vacancies are created by firms of heterogeneous productivity ρ. Following the practice in the search literature, each firm only creates one job vacancy, and thus I do not distinguish between firms and jobs. Job search is a random matching process. Unemployed agents come across with job vacancies at the endogenous rate λ_u. Job productivity is randomly drawn from an endogenous distribution $V(\rho)$. When a match occurs between an agent and a job, a flow of output is produced using the following production technology:

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

To simplify notation, I denote the agent's characterisitic by $\Omega = (b, s, a, n, d, t)$, where d indicates the default status as described below. Denote by $W(\Omega, w, \rho)$ the value of an employed agent Ω at the wage rate w in job ρ, by $U(\Omega)$ the value of an unemployed agent Ω, and by $J(\Omega, w, \rho)$ the value of a filled job ρ that pays the wage rate w. A vacancy has zero value due to the free entry condition. When an agent comes across a job, a match occurs provided there exists a wage rate w, and the agent is willing to accept the job and the firm is willing to hire the agent. Thus the participation constraints are

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

The agent's wage income is given by the wage rate w specified in the contract multiplied by the units of labor supply l. When a match occurs between an agent and a firm, the wage rate is determined through Nash bargaining:

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

where ξ represents the agent's bargaining power.[2] Note that agents quit their jobs at an exogenous rate κ. After quitting, agents become unemployed and jobs disappear. An unemployed agent receives Unemployment Insurance (UI) benefits θ in every period. Determining wages through Nash bargaining facilitates comparison with other search-matching models because Nash bargaining is the most common assumption under risk neutrality (see Krusell, Mukoyama and Sahin, 2010, for a related discussion).

Agents face progressive income taxes. Following Benabou (2002) and Heathcote, Storesletten

[2] I consider a contract in which contracts are written in terms of wage rates but not labor supply to follow the optimal income taxation literature (e.g. Mirrlees, 1971), as later I will analyze the income-taxish distortion of IBR on labor supply. Bils, Chang and Kim (2014) analyze a novel search model, in which wage and labor effort for risk-neutral workers are jointly determined through Nash bargaining.

and Violante (2014), I model the after-tax income $\tilde{E}$ as:

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

where wl is the pre-tax wage income, and θ is the UI benefits which are taxable in the U.S. The fiscal parameters $\varkappa$ 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 tax 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 $1 - \varkappa$. When $\tau > 0$, the tax system is progressive. When evaluating counterfactuals, $\varkappa$ is adjusted to reflect the change in the overall level of taxation to keep the government's budget balanced.

On-The-Job Search Employed agents 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, 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 constraints (2.5) imply that the highest wage rate that firm ρ can offer to agent Ω is her 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 agent Ω. I define this as the maximal employment value in firm ρ.

Definition 1. *The maximal employment value offered by firm ρ, denoted by $\overline{W}(\Omega, \rho)$, is the value to agent Ω at firm ρ when the wage rate is set 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. This implies that the maximal employment value that an agent can obtain, $\overline{W}(\Omega, \rho)$, increases with ρ. Because on-the-job search is modeled based on Bertrand competition, the agent will choose the job with higher productivity. Therefore, on-the-job search may trigger job-to-job transitions or wage renegotiations, depending on the relative productivity of the two jobs the agent is considering.

To elaborate, consider an agent Ω holding a job with productivity ρ' and wage w', who comes across a new job with productivity ρ. If the maximal employment value of the new job ρ is lower than that of the current job, i.e. $\overline{W}(\Omega, \rho) < W(\Omega, w', \rho')$, then the agent will simply stay with the current job with the old wage w'.

If the new job can offer a higher job value, then the agent may try to see if the current job can beat the offer. The job with a higher productivity will win over the agent. There are two cases. First, if $\rho > \rho'$, the agent who is currently holding job ρ' will transfer to job ρ and the old job ρ' will become the negotiation benchmark due to Bertrand competition. This grants the agent 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 agent's outside option is captured by the old job's productivity ρ'.

Second, if $\rho \leq \rho'$, the agent 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 agent an outside option value that is equal to the maximal employment value of ρ. The new wage rate will be set according to

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

Reservation Productivity Equation (2.9) nests equation (2.6), if we treat an unemployed agent Ω as being employed in a 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 becoming employed with job $\rho_u(\Omega)$ or staying unemployed makes no difference to the agent. On the other hand, firm $\rho_u(\Omega)$ is also indifferent about hiring because it is offering the agent the maximal employment value. I define this formally as follows:

Definition 2. *The reservation productivity for an unemployed agent Ω is a job with productivity $\rho_u(\Omega)$ such that accepting the job or staying unemployed would make no difference to the agent,*

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

An increase in student debt s reduces the reservation productivity by making the agent more risk averse and liquidity constrained, inducing the agent to accept a job more hastily.

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 give borrowers a grace period immediately after college graduation so that they can postpone repayment. Thus I assume that agents only start repaying their student debt in period $t_0 > 1$. Student loan borrowers can choose the fixed repayment plan or IBR.[3] 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 $y_{t,\text{FIX}}$ in each period until time t_{FIX}. The per-period payment is calculated such that the loan is just fully repaid during the repayment period:

$$y_{t,\text{FIX}} = \frac{r_s}{(1+r_s)\left[1 - \dfrac{1}{(1+r_s)^{t_{\text{FIX}}-(t-t_0)}}\right]} s_t, \quad \text{for } t_0 \leq t \leq t_{\text{FIX}}. \tag{2.13}$$

A realistic IBR requires borrowers to repay the required amount under the fixed repayment plan or a fraction ϱ of their discretionary income, whichever is smaller. Discretionary income is defined as the difference between pre-tax income and 150% of the relevant 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.[4] To reflect these features, I model the per-period payment under IBR by:

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

In the U.S., borrowers are enrolled in the fixed repayment plan by default. After the introduction of IBR in 2009, qualified borrowers can apply to be enrolled in IBR. The application information has to be updated every year. In my model, borrowers are automatically enrolled in the fixed repayment plan and are allowed to switch to IBR every 12 months. Enrolling in IBR incurs an upfront disutility $\delta \geq 0$, capturing bureaucratic hurdles and tedious paper work (Dynarski and Kreisman, 2013).

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

[3] In the U.S., student loan borrowers can also choose the graduated repayment plan or the extended repayment plan. These plans are simply variations of the standard fixed repayment plan. Under certain circumstances, borrowers can receive a deferment or forbearance that allows them to temporarily postpone or reduce their federal student loan payments. However, because applying for deferment and forbearance involves bureaucratic hurdles and detailed paper work, many borrowers do not use these options (Cunningham, Alisa F. and Gregory S. Kienzl, 2011).

[4] 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 the TPO as participants are required to make payments until the debt of an entire "cohort" is repaid.

may occur 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 liquid wealth $b_t + \tilde{E}_t$ (wealth plus after-tax income) is higher than the required repayment, i.e. $b_t + \tilde{E}_t \geq y_{t,\text{FIX}}(\text{or } y_{t,\text{IBR}})$. An involuntary default occurs when the agent does not have enough liquid wealth to make the payment.

During the period of default ($d = 1$), borrowers are not required to make any payments. In reality, borrowers can rehabilitate their defaulted loans after 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 $y_{t,\text{FIX}}$ under the fixed repayment plan.[5] Note that because interest accrues, default delays the repayment but payments after the default period will increase, reflecting the reality.

I do not allow repeated voluntary defaults given the complexity of the current setup.[6] Thus I assume that borrowers do not have the option to default if $d = 0^+$ and $b_t + \tilde{E}_t \geq y_{t,\text{FIX}}(\text{or } y_{t,\text{IBR}})$. However, borrowers may still default involuntarily when their income falls short, in which case they repay all of their liquid wealth. Summarizing the different cases above, the repayment at 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 liquid wealth 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 an extremely large marginal value of consumption after involuntary defaults.

2.4 Value Functions

Denote by $U(\Omega)$ the value of an unemployed agent Ω in the labor market. After the pecuniary cost k and the psychic cost e are determined at $t = 0$, the agent decides whether to enter college.

[5] To obtain loan rehabilitation, borrowers must agree with the U.S. Department of Education on a reasonable and affordable repayment plan. The repayment plan after default is decided case by case. Generally, a monthly payment is considered to be reasonable but still affordable if it is at least 1.0% of the current loan balance, 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 default first occurred.

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

The agent enters college if $U_{\text{C}} > U_{\text{HS}}$, where U_{C} is the value (at $t = 1$) of entering college:

$$\begin{aligned} U_{\text{C}} =& \psi U(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}, a, 1, 0^-, 1) \\ &+ (1-\psi)U(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}, a, 0, 0^-, 1) - e, \end{aligned} \tag{2.17}$$

and U_{HS} is the value (at $t = 1$) of not entering college:[7]

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

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

An unemployed agent with $d_t = 0^+$ has defaulted before and does not have the option to default again. Such an agent optimally chooses consumption c and reservation productivity ρ_u. With probability λ_u, the agent comes across a job and accepts it 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:

$$\begin{aligned} U(\hat{\Omega}_t, 0^+) = \max_{c,\rho_u} \quad & u(c, 0) + \beta \left[\lambda_u \int_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 0^+, x, \rho_u) \mathrm{d}V(x) + [1 - \lambda_u + \lambda_u V(\rho_u)] U(\hat{\Omega}_{t+1}, 0^+) \right] \\ \text{subject to} \quad & b_{t+1} = (1+r)(b_t + \varkappa\theta^{1-\tau} - y_t) - c + \varpi_t, \\ & s_{t+1} = (1+r_s)(s_t - y_t), \\ & b_{t+1} \geq -\varsigma\theta, \end{aligned} \tag{2.19}$$

where r is the interest rate on deposit, and $\varsigma > 0$ represents the access to consumption loans proportional to current income.

[7] 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.

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

$$
\begin{aligned}
U(\hat{\Omega}_t, 0^-) = \max_{c,\rho_u,d'} \quad & u(c,0) + \beta d' \left[-\eta + \lambda_u \int_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 1, x, \rho_u) \mathrm{d}V(x) + [1 - \lambda_u + \lambda_u V(\rho_u)] U(\hat{\Omega}_{t+1}, 1) \right] \\
+\beta(1-d') & \left[\lambda_u \int_{x \geq \rho_u} W(\hat{\Omega}_{t+1}, 0^-, x, \rho_u) \mathrm{d}V(x) + [1 - \lambda_u + \lambda_u V(\rho_u)] U(\hat{\Omega}_{t+1}, 0^-) \right], \\
\text{subject to} \qquad b_{t+1} &= (1+r)(b_t + \varkappa\theta^{1-\tau} - y_t) - c + \varpi_t, \\
s_{t+1} &= (1+r_s)(s_t - y_t), \\
b_{t+1} &\geq -\varsigma\theta,
\end{aligned}
\tag{2.20}
$$

where $d' = 0, 1$ indicates the default decision.

With $d_t = 1$, the agent is in default and her status becomes 0^+ at $t+1$ with probability π:

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

Employed agents come across other jobs at the rate λ_e through on-the-job search. The default decisions of employed agents involve similar recursive formulations to those of unemployed agents. I thus illustrate the recursive problem with $d_t = 0^+$ below and leave the other two cases in Appendix A.6.

$$
\begin{aligned}
W(\hat{\Omega}_t, 0^+, \rho, \rho') = \max_{c,l} \quad & u(c,l) + \beta(1-\kappa) \Bigg[[1 - \lambda_e + \lambda_e V(\rho')] W(\hat{\Omega}_{t+1}, 0^+, \rho, \rho') \\
+\lambda_e & \left(\int_{x \geq \rho} W(\hat{\Omega}_{t+1}, 0^+, x, \rho) \mathrm{d}V(x) + \int_{\rho' < x < \rho} W(\hat{\Omega}_{t+1}, 0^+, \rho, x) \mathrm{d}V(x) \right) \Bigg] + \beta\kappa U(\hat{\Omega}_{t+1}, 0^+), \\
\text{subject to} \qquad b_{t+1} &= (1+r)[b_t + \varkappa(w_e(\Omega_t, \rho, \rho')l)^{1-\tau} - y_t] - c + \varpi_t, \\
s_{t+1} &= (1+r_s)(s_t - y_t), \\
b_{t+1} &\geq -\varsigma w_e(\Omega_t, \rho, \rho')l.
\end{aligned}
\tag{2.22}
$$

In principle, changes in wealth and student loans over time may result in endogenous separations where workers quit their jobs to more effectively search for new jobs. I do not explicitly account for endogenous separations in problem (2.22) because they rarely occur under my calibration due to the lack of idiosyncratic match-specific productivity shocks, which are emphasized by Bils, Chang and Kim (2011).

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

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

2.5 Stationary Competitive Equilibrium

To complete the model, I describe the equilibrium conditions that determine the endogenous job contact rates, vacancy distribution, and tax rates. Denote by $\phi_u(\Omega)$ the probability density function (PDF) of unemployed agents searching for jobs and by $\phi_e(\Omega, \rho, \rho')$ the PDF of employed agents matched with job ρ and negotiation benchmark ρ'. Because I am focusing on the stationary equilibrium, all these distributions are time invariant.

Matching Following Lise and Robin (2017), I assume that unemployed agents search with intensity q_u and employed agents search with intensity q_e.[8] Denote by Q the aggregate level of search intensity attributed to both unemployed and employed agents:

$$Q = q_u \overline{u} T + q_e (1 - \overline{u}) T, \tag{2.24}$$

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

[8]The assumption that agents search with different intensities 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 agents would spend more time searching for a job and accept one more hastily. This gives indebted agents 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 agents' reservation productivity.

number of vacancies created by firms. From a firm's perspective, the probability of contacting an agent is

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

The job contact rates for unemployed agents and employed agents 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 incurs a cost ν when creating a vacancy whose productivity ρ is randomly drawn from an exogenous distribution $F(\rho)$. Vacancies last for one period; thus if a created vacancy is not filled by an agent in the current period, it will disappear. 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 creation to be equal to its expected value, as follows:

$$\begin{aligned}\nu =&\frac{hT}{Q}\Bigg[\overline{u}q_u \iint\limits_{\rho''>\rho_u(\Omega)} J(\Omega,\rho'',\rho_u(\Omega))\phi_u(\Omega)\mathrm{d}\Omega\mathrm{d}F(\rho'') \\ &+(1-\overline{u})q_e \iiint\limits_{\rho''>\rho} J(\Omega,\rho'',\rho)\left(\int \phi_e(\Omega,\rho,\rho')\mathrm{d}\rho'\right)\mathrm{d}\Omega\mathrm{d}\rho\mathrm{d}F(\rho'')\Bigg].\end{aligned} \tag{2.28}$$

Equation (2.28) states that a new vacancy meets an agent with probability h, where the agent may either be unemployed or employed. In equilibrium, the number of agents becoming employed and that becoming unemployed 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 between the present value of debt borrowed at age $t=1$ and the present value of debt repaid by retirement age T. Thus

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

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:

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

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

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). *All agents Ω make college entry and borrowing decisions by solving problems (2.17-2.18).*

(2). *All unemployed agents Ω make consumption, job search, and default decisions by solving problems (2.19-2.21).*

(3). *All employed agents Ω holding job ρ with negotiation benchmark ρ' make consumption, labor supply, and default decisions by solving problems (2.22) and (A.3-A.4).*

(4). *Wage rates, $w_e(\Omega,\rho,\rho')$, are determined by Nash bargaining specified in (2.9-2.11).*

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

(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 the overall level of taxation, $\varkappa$, 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 and offer some suggestive evidence. Then I present the estimation procedures of my quantitative model. Finally, I check the external validity of the model.

3.1 Data

My analysis is based on the panel data from the NLSY97, a nationally representative survey conducted by the Bureau of Labor Statistics (BLS). In round 1, 8,984 youths were initially interviewed in 1997. These youths were born between 1980 and 1984. Follow-up surveys were conducted annually. The survey contains extensive information on each youth's labor market behavior and documents the amount of student loans borrowed during college, which makes the NLSY97 an ideal dataset for studying the implications of student debt on job search decisions.

I focus on youths with a high school diploma or a bachelor's degree. I drop youths who have served in the military or attended graduate schools because they would not be making labor market decisions in the same way as the other youths in my sample. I also drop youths who received their bachelor's degree before 1997 due to the lack of labor market information upon college graduation. This leaves me with a sample of 1,261 students with a bachelor's degree and 3,542 students with a high school diploma, among which 960 are college dropouts. I construct the variables used in structural estimation following the steps illustrated in Appendix B.

3.2 Suggestive Evidence

Identifying the causal effect of student debt on job search outcomes is difficult as borrowing decisions are endogenous and may be correlated with variables that influence job search outcomes. There are no obvious instruments for taking on student debt.[9] In this section, I take a control variable approach to provide suggestive evidence based on the college graduates in my NLSY sample. My results consistently suggest that student loan borrowers tend to be less picky in their job search than non-borrowers, as reflected by their shorter unemployment duration and lower wage income after graduation.

I begin by providing a selection of summary statistics for college graduates in Table 1. The average duration of the first unemployment spell after college graduation is shorter for borrowers than for non-borrowers. Non-borrowers are paid 2.7 dollars more per hour on average in their

[9] A few studies have used instrumental variables to overcome omitted variable bias. Zhang (2013) and Luo and Mongey (2016) use the generosity of institutional financial aid packages, as measured by the grant-to-loan ratio, as an instrument. The exclusion restriction is violated if students choose which institution to attend based on financial aid packages. Akers and Chingos (2014) use the variation in the number of concurrently enrolled siblings. Again, the exclusion restriction is violated if students' application for college is affected by their number of siblings in college. Chapman (2015) uses the variation in merit-based scholarships across states. However, these scholarships can only be used at in-state schools. Several studies have exploited plausible quasi-experimental variations on student debt. For example, Rothstein and Rouse (2011) exploit a "no-loans" policy in an elite university under which loans are replaced with grants. They find that indebted students are more likely to work in finance, banking, and consulting industries and receive higher wages. Gervais and Ziebarth (2017) explore a regression kink design in need-based federal student loans and find that borrowers with the average debt amount earn 5% less on average than non-borrowers.

Table 1: Summary statistics of college graduates from the NLSY97 sample.

	Non-borrowers	Borrowers	All
Observations	484	777	1,261
Mean liq. wealth upon graduation ($)	6,877	3,001	4,432
Mean student loans ($)	0	11,873	7,316
Mean unemp. duration (1st spell, weeks)	14.6	13.5	13.9
Mean hourly wage rate (1st job, $)	19.5	16.8	17.8
Mean annual wage income (1st year, $)	34,274	29,786	31,509
Mean annual wage income (2nd year, $)	37,487	32,535	34,436
Mean annual wage income (3rd year, $)	44,840	37,748	40,470
Mean annual wage income (4th year, $)	44,802	40,739	42,299
Mean annual wage income (5th year, $)	49,278	41,132	44,259
Finance, consulting, banking (1st job)	21.5%	16.1%	18.1%

first job than borrowers. Among the youths who work full time, the mean annual wage income is consistently lower for borrowers than non-borrowers in the first five years after college.

These summary statistics seem to suggest that student loan borrowers are less picky in their job search after graduation. To examine the effect of student debt, I regress the duration of the first unemployment spell after college graduation on the amount of student debt. In column (1) of Table 2, I control for a list of demographic characteristics likely observable to potential employers, including a cubic in age, gender and marriage dummies, an interaction term for married females, a set of four dummies for race (white, black, Hispanic, others), the duration of college study, a set of dummies for college major (physical science, social science, engineering, and others), and the county of residence in the graduation year. My estimate implies that a $10,000 increase in student debt is associated with an unemployment duration that is 1.41 weeks shorter. Ability likely determines both unemployment duration and student debt. In column (2), I additionally control for AFQT score, college GPA, SAT score, and ACT score as proxies for ability. I find that an extra $10,000 debt is associated with an unemployment duration that is 1.57 weeks shorter. In column (3), I further control for family's adjusted gross income, parents' education, and family's net worth as proxies for family socio-economic background. The effect of debt on unemployment duration remains significant. I evaluate the robustness of these results by estimating a set of Cox hazard models following the literature on UI benefits. Table 2 shows that the monthly unemployment exit hazard rate is about 5.4%-6.0% higher for an individual with $10,000 more student debt.

I continue to examine the effect of student debt on wage income. For individuals graduating in year t, I construct their (log) wage income in years $t+1$, $t+2$, and $t+3$ if they are employed full time in the given year. I then run a Mincer-style regression relating (log) wage income

Table 2: Duration of the first unemployment spell after college graduation.

	First unemployment spell			Cox hazard model		
	(1)	(2)	(3)	(1)	(2)	(3)
Loan amount (in $10,000)	-1.41	-1.57	-1.53	0.058	0.060	0.054
t-statistic	(-2.31)	(-2.30)	(-2.19)	(2.32)	(2.14)	(2.00)
Demographic controls	√	√	√	√	√	√
Ability controls		√	√		√	√
Family controls			√			√
County fixed effect	√	√	√	√	√	√
Observations	1,115	971	929	1,115	971	929
R^2	0.0278	0.0311	0.0492	-	-	-

after college graduation to debt level. Table 3 shows that conditional on being employed full time, those with $10,000 more student debt are associated with a wage income that is about 2.7%-4.0% lower in the first three years after graduation.

These estimates jointly suggest that student debt repayment induces borrowers to be less picky in their job search. They spend less time on job search and are more likely to end up with lower-paid jobs. My findings are consistent with the evidence from Weidner (2017) who exploits the effect of student debt in two nationally representative datasets and find that, for a $10,000 increase in student debt, wage income is about 1%-4% lower and graduates are 0.2% more likely to exit non-employment in a given week.

3.3 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

Table 3: The wage income after college graduation.

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

plan (i.e. setting $\delta = \infty$).[10] My estimation consists of three steps. First, I specify the parametric functional forms for several distributions. Second, I determine the values of a set of parameters without running simulations. These parameter values are either separately estimated or taken from the existing literature. Finally, I discuss the identification of the model's remaining parameters and estimate their values using MSM.

3.3.1 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 $f_{a,1}$ and $f_{a,2}$. To capture the potential correlation between initial wealth and talent, I use the Frank copula (see, e.g. Jarosch, 2015), where the single parameter ϑ governs the dependence between the CDF of the marginal distribution of wealth, $\mho_{b_0}(b_0)$, and that of talent, $\mho_a(a)$[11]:

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

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 the pecuniary costs of college entry are non-negative, I set $k = 0$ for negative costs. Following Lise, Meghir and Robin (2016) and Jarosch (2015), I assume that job productivity follows a flexible Beta distribution with parameters $f_{\rho,1}, f_{\rho,2}$.

3.3.2 Externally Determined Parameters

Table 4 presents the values of externally determined parameters. The three parameters governing the initial wealth distribution, $(\underline{b}, \zeta, \varphi)$, are estimated directly using maximum likelihood estimation (MLE) to match the empirical distribution of wealth (see Panel A of Figure 2).

The parameters $\varkappa = 1.66$ and $\tau = 0.11$ are identified using the regression coefficients obtained

[10]During my sample period, student loan borrowers had the option to enroll in the old income-contingent plan. 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.

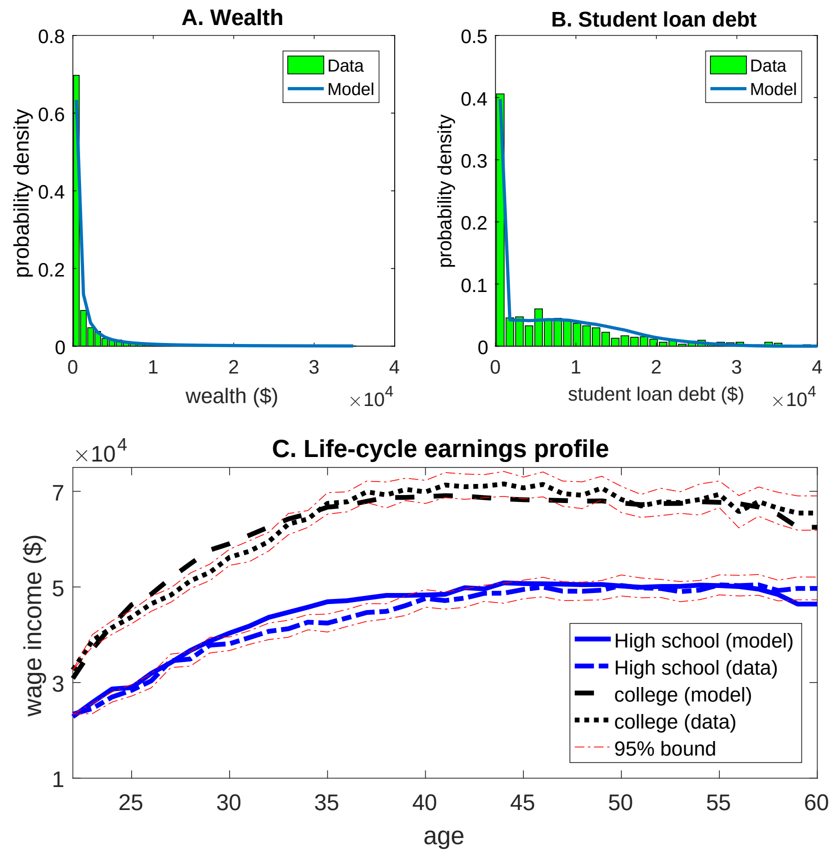


Figure 2: Comparing model results and actual data on initial wealth, student debt of college graduates, and life-cycle earnings profiles.

from regressing log individual after-tax earnings $\tilde{E}_i$ on log individual pre-tax earnings E_i:

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

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. I set $\gamma = 3$ consistent with the precautionary savings literature (e.g. Hubbard, Skinner and Zeldes, 1995). I set $\sigma = 2.59$, which implies that the tax-modified Frisch elasticity is $(1-\tau)/(\sigma+\tau) = 0.33$, broadly consistent with microeconomic evidence (Keane, 2011).

I set the monthly risk-free rate $r = (1 + 4.5\%)^{1/12} = 0.37\%$, corresponding to the average real interest rate in the U.S. between 1997 and 2008 (source: World Development Indicators). Following the standard practice, I set the monthly discount rate $\beta = 0.997$. Between 2002 and 2008, the average retirement age was around 60. I set $T = 468$, which corresponds to a real-life working age of 22 to 60 ($t = 1$ corresponds to the first month of age 22). In my sample, there

Table 4: 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	$\varkappa$	1.66	College completion rate	ψ	0.568
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 periods working	T	468	Grace period	t_0	7
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	Matching technology	ω	0.72
Consumption loans	ς	0.185			

are 2,221 college attendants among which 960 do not have a bachelor's degree. I thus set the college completion rate $\psi = 0.568$.

I set the matching parameter and bargaining parameter $\omega = \xi = 0.72$ following Krusell, Mukoyama and Sahin (2010). I set $\theta = \$650$, which means that yearly UI benefits roughly equal to 40% of the average six-month income.[12] Means-tested benefits include Aid to Families with Dependent Children (AFDC), food stamps, and Women, Infants, Children (WIC). In my sample, the percentage of youths who had received AFDC, food stamps, and WIC by 2009 are 1.5%, 8.7%, and 6.4%, respectively. About 11.8% of youths had received some sort of means-tested benefits during my sample period, with a median monthly benefit level of \$165. Because the take-up rate is far from universal, following Kaplan (2012), the monthly consumption floor is set $\underline{c} = \$100$. Kaplan and Violante (2014) estimate that the median ratio of credit limit to income is 18.5% for household members aged 22 to 59. I thus set $\varsigma = 0.185$.

The parameters t_0, t_{FIX}, t_{IBR}, ϱ, pov, π, and r_s are chosen to capture a realistic setting for federal student loan borrowers. I set $t_0 = 7$ as the non-repayment grace period is six months for most student loans. Under the standard fixed repayment plan, borrowers must repay all loans in 10 years. Thus I set $t_{\text{FIX}} = 126$. IBR passed by Congress in 2009 requires borrowers to repay 15% of their discretionary income every month for 25 years or until the loan is paid in full. Thus I set $t_{\text{IBR}} = 306$ and $\varrho = 0.15$. I set the poverty guideline, $pov = \$870$ per month, based on the average individual poverty guideline for the 48 contiguous states (excluding Hawaii and Alaska) and the District of Columbia between 1997 and 2008 measured in 2009 dollars. Following

[12] In the U.S., UI benefits generally pay eligible workers between 40%-50% of their previous pay for six months. In my model, unemployed agents receive UI benefits every month. Therefore, I choose a relatively low value of UI benefits to account for this discrepancy.

Ionescu (2009), I set $\pi = 0.083$ so that borrowers on average spend one year in default status. I set the interest rate on student loans $r_s = 0.53\%$, which implies a risk premium consistent with the annualized mark-up over the Treasury bill rate of 2.1%, set by the government for subsidized loans issued before 2006.

3.3.3 Internally Estimated Parameters

I now turn to the identification of internally estimated parameters.

Table 5: Model fit for targeted moments.

Targeted moments	Model	Data
Monthly employment to unemployment rate	1.8%	1.8%
Monthly unemployment to employment rate	28.8%	28.8%
Monthly job-to-job transition rate	2.6%	2.6%
Variance of log annual wage income	0.184	0.165
Skewness of log annual wage income	0.049	-0.147
Mean of log wage increase upon job-to-job transitions	0.133	0.145
Variance of log wage increase upon job-to-job transitions	0.031	0.044
Vacancy-to-unemployment ratio	0.409	0.409
Average hours worked per year	1,741	1,754
Life-cycle earnings profile	Panel C of Figure 2	
Fraction of agents attending college	46.1%	46.2%
Unexplained variance in college entry decisions ($1 - R^2$)	0.63	0.67
Correlation between talent and student debt	0.05	0.06
Two-year cohort default rate	9.49%	9.26%
Student debt distribution upon college graduation	Panel B of Figure 2	

Labor Market Moments The exogenous job separation rate κ is identified by the transition rate from employment to unemployment. The matching efficiency χ is normalized to one. The search intensity during employment q_e is identified by the job-to-job transition rate. The search intensity during unemployment q_u is identified by the transition rate from unemployment to employment. In the data, the monthly employment-to-unemployment rate is 1.8% and the monthly unemployment-to-employment rate is 28.8%. This implies that the average unemployment duration is about 15 weeks and the unemployment rate is about 6%, roughly in line with BLS statistics. The job-to-job transition rate in my sample is about 2.6%, consistent with the estimate of Fallick and Fleischman (2004).

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 a matched agent-job pair is given by $z\rho$. The symmetric roles played by agent productivity z and job productivity ρ suggest that it is impossible to separately identify the parameters $f_{a,1}$, $f_{a,2}$ governing the marginal distribution of talent and the parameters $f_{\rho,1}$, $f_{\rho,2}$ governing the marginal distribution of a vacancy's productivity if we only use moments from the cross-sectional log wage income distribution. Note that upon job-to-job transitions, agent 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 $f_{\rho,1}$, $f_{\rho,2}$. The cross-sectional log annual wage income residuals have variance 0.165 and skewness -0.147. The log hourly wage rate rises by about 14.5% upon job-to-job transitions on average with a variance of 0.044.[13]

The cost of vacancy creation ν is identified from the vacancy-to-unemployment ratio. The Job Openings and Labor Turnover Survey (JOLTS) has collected job openings information since December 2000 in the U.S. I estimate the vacancy-to-unemployment ratio to be 0.409 using the data between 2001 and 2008. This estimate is smaller than the estimate of 0.539 provided by Hall (2005), who uses data between 2001 and 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 1,754 hours per year on average.

Parameters $\mu_{n,0}$, $\mu_{n,1}$, $\mu_{n,2}$, and $\mu_{n,3}$ are chosen to match the average wage income in each year between the ages 22 and 60 for high school and college graduates. Because the NLSY97 does not provide such lengthy individual labor market histories, I construct the life-cycle earnings profile using March CPS 1997-2008 data (see Panel C of Figure 2). Following Rubinstein and Weiss (2006), I focus only on the stage in an individual's life by pooling the CPS data from different years and cohorts.[14]

College and Debt Moments The 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 decisions 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 smaller student loans. Therefore, the value of ϑ can be identified to match the correlation between individual AFQT score[15] and student debt upon college graduation. In the data, there is a slight positive correlation

[13] There are unmodeled sources of variation that affect the dispersion of the log wage income distribution. I adjust for these sources of variation when constructing the variance and skewness in the data (see Appendix B.2).

[14] The pooled data analysis is valid under stationary conditions, which would be violated if the wage structure underwent major changes during this period or the cohort quality changed substantially over time.

[15] 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 0.06 between AFQT and student debt 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 the 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 and 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 averaging \$11,873. I use 40 equally spaced moments to capture the histogram of student debt distribution (see Panel B of Figure 2).[16]

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

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

The objective function is given by

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

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 $\hat{m}_N$ using bootstrapping. Estimates are not sensitive to alternative choices of weighting matrices because most moments are closely matched (see Table 5). The estimation procedure and numerical algorithm are detailed in Appendix C.

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

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

where $\widehat{\mathrm{COV}}$ is the variance-covariance matrix of $\hat{m}_N$ and $\nabla = \frac{\partial \hat{m}_S(\Xi)}{\partial \Xi}\big|_{\Xi=\hat{\Xi}}$ is the Jacobian matrix of the simulated moments evaluated at the estimated parameters. $S = 500$ is the number of simulations. The first derivatives are calculated numerically by varying the value of each parameter by 1%. The standard errors of $\hat{\Xi}$ are given by the square root of the diagonal elements

for human capital skills in the human capital literature.

[16] 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) during college study. My indirect inference suggests that the average total college cost is about \$14,212. Data from IPEDS documents that during 2001-2004, the annual college tuition for a four-year college program was between \$989 and \$2,520 depending on state category, and the national average cost of room and board was \$6,532 (Johnson, 2013). This implies a total college cost of \$10,488-\$16,612.

Table 6: Parameters estimated jointly using MSM.

Labor market parameters	Symbol	Value	Std. error
Exogenous job separation rate	κ	0.018	0.003
Search intensity during unemployment	q_u	3.31	0.44
Search intensity during employment	q_e	0.87	0.28
Matching efficiency	χ	1	N/A
Talent distribution	$f_{a,1}$	1.46	0.34
Talent distribution	$f_{a,2}$	0.44	0.15
Vacancy productivity distribution	$f_{\rho,1}$	1.40	0.28
Vacancy productivity distribution	$f_{\rho,2}$	0.53	0.11
Cost of vacancy creation	ν	53,782	5,568
Labor supply scaling factor	ϕ	2.9×10^{-15}	0.4×10^{-15}
Constant term in agent's ability	$\mu_{0,0}, \mu_{1,0}$	0.665, 0.923	0.027, 0.045
Linear term in agent's ability	$\mu_{0,1}, \mu_{1,1}$	$6.12, 8.45(\times 10^{-3})$	$0.51, 0.76(\times 10^{-3})$
Square term in agent's ability	$\mu_{0,2}, \mu_{1,2}$	$2.34, 2.89(\times 10^{-5})$	$0.42, 0.55(\times 10^{-5})$
Cubic term in agent's ability	$\mu_{0,3}, \mu_{1,3}$	$2.90, 3.17(\times 10^{-8})$	$0.64, 0.89(\times 10^{-8})$
Mean of psychic cost	μ_e	1.1×10^{-6}	0.3×10^{-6}
Stdev. of psychic cost	σ_e	2.8×10^{-5}	0.6×10^{-5}
Talent and initial wealth correlation	ϑ	0.47	0.15
Disutility of default	η	1.4×10^{-5}	0.3×10^{-5}
Mean of pecuniary cost ($)	μ_k	14,212	1,797
Stdev. of pecuniary cost ($)	σ_k	15,275	2,640

of $Q(\hat{\Theta})$. Table 6 presents the internally estimated parameters. Given the estimated parameters, the implied equilibrium government spending is $G = 5.73 \times 10^5$, according to equation (2.31) with FGV $= 0$ under the fixed repayment plan. Through my quantitative analyses conducted in Section 4 below, the value of G is fixed and the parameter $\varkappa$ is adjusted to balance the government's budget in different counterfactual experiments.

3.4 External Validation

Comparison to Micro Estimates To provide some sort of out-of-sample validation, I first check whether the model can produce structural estimates of several elasticity measures that are consistent with the micro estimates from quasi-experimental variations. Student debt affects borrowers' job search decisions through a similar mechanism to that through UI benefits and access to credit affect 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 agents' job search outcomes to UI benefits and access to 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

Table 7: Comparison to micro estimates.

Elasticities	Model	Micro estimates
UI on unemployment duration	0.42	0.35 to 0.9
UI on reservation wage	6.1%	4%
Credit on unemployment duration	1.0 week	0.15 to 2.67 weeks
Credit on reemployment wage	2.1%	0.6% to 2.3%
Tuition elasticity	-0.69	-0.83 to -0.52

consistent with that in which the micro estimates are obtained. Table 7 presents the results. My model's structural estimate of the elasticity of UI is 0.42, which lies in the range of 0.35-0.9 estimated by Card et al. (2015). My model implies that reservation wages increase by about 6.1% following a 10% increase in the UI replacement ratio, a bit higher than the 4% estimated by Feldstein and Poterba (1984). Regarding the implication of access to credit, my model implies that unemployment duration increases by 1.0 week and reemployment wage increases by 2.1% if credit increases by 10% of income. These estimates are within the ranges of 0.15-2.67 weeks and 0.6%-2.3% estimated by 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 with respect to college tuition. My model gives an estimate of -0.69, which is also within the range of -0.83 to -0.52 summarized by Kane (2006).

Non-Targeted Moments I now check whether the effects of student debt implied by the model are consistent with those implied by OLS regressions in Tables 2 and 3. Using the estimated model, I simulate the same number of college graduates for one life cycle 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 8 shows that the model-implied estimates are comparable with the data.

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 college attendance.

Table 8: Model-implied regression estimates.

	First unemployment spell		Wage income		
Model	Duration	Exit rate	Year 1	Year 2	Year 3
Loan amount (in \$10,000)	-1.65	0.091	-0.040	-0.036	-0.031
t-statistic	(-2.09)	(2.28)	(-2.35)	(-2.40)	(-2.07)
Data					
Loan amount (in \$10,000)	-1.53	0.054	-0.035	-0.031	-0.032
t-statistic	(-2.19)	(2.00)	(-2.06)	(-2.38)	(-1.78)
Chow test p-value	0.78	0.66	0.70	0.75	0.80

Note: The coefficients and t-statistics of the data are obtained from specification (3) of Tables 2 and 3. 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 the 5% significance level.

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. Focusing on college graduates, Panel A of Figure 3 shows that borrowers tend to be less picky in their job search. At age 22, borrowers under the fixed repayment plan accept jobs with productivity above 0.654 (blue solid line), whereas non-borrowers have reservation productivity of about 0.715 (red dash-dotted line). Due to the lower reservation productivity, borrowers on average spend 1.8 weeks less searching for their first job than non-borrowers (Panel B) and earn about \$1,500 per year less at age 22 (blue solid line in Panel C).

Presumably after debt has been paid off at age 32, there should be no difference in reservation productivity between borrowers and non-borrowers. However, Panel A shows that the differences persist until age 40. This is because between the ages of 22 and 32, borrowers accumulate significantly less wealth than non-borrowers due to their lower wage income and the need to repay their debt. At age 32, the average wealth of borrowers is about \$9,000 lower than that of non-borrowers (see Appendix Figure A.4), consistent with the evidence from Elliott, Grinstein-Weiss and Nam (2013). Thus, although borrowers will have paid off their debt after age 33, they would still be less wealthy than non-borrowers, making them less picky in their job search (Rendon, 2006).

Borrowers are less picky in their 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 consume less and thus become more risk averse.[17] When that happens, they avoid search

[17]A lower consumption increases risk aversion if the utility function has decreasing absolute risk aversion, which is empirically relevant. Note that the utility function (2.1) in my model has constant relative risk aversion,

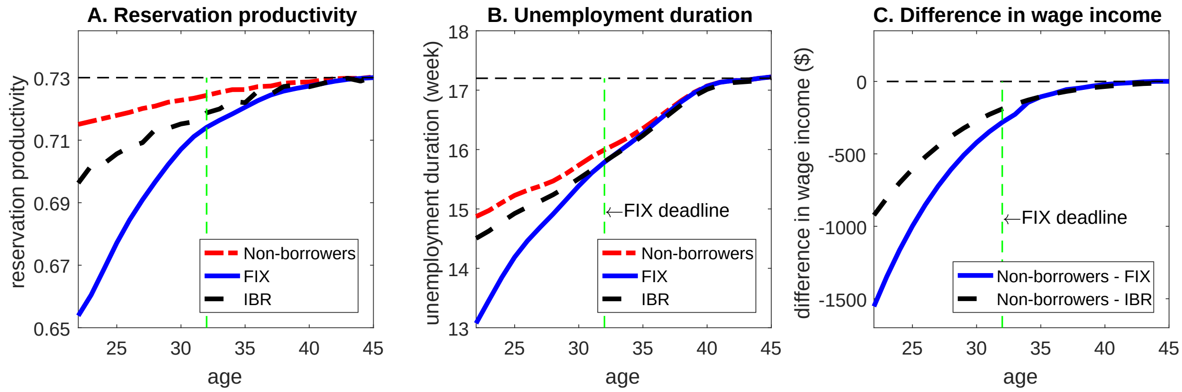


Figure 3: Simulated reservation productivity, unemployment duration, and wage income over the life cycle of agents.

risks by setting a lower reservation wage. In a perfect credit market, the quantitative effect on reservation productivity is small because debt represents just over one percent of lifetime earnings. However, as agents have limited access to credit in my model, the low income during unemployment implies that borrowers have strong incentive to accept a job quicker, implicitly transferring future wealth to the current period. In other words, the labor market offers its own version of insurance and credit provision through borrowers' endogenous job choices to minimize the effect of student debt.[18]

Income-Based Repayment Plan The significant difference in labor market outcomes between non-borrowers and borrowers has two major implications. First, borrowers' endogenous adjustment of reservation productivity offers an important self-insurance channel to alleviate the burden of debt repayment, which has not been discussed in the existing literature (e.g. Ionescu, 2009; Abbott et al., 2018). Second, the large difference in reservation productivity reflects the extent to which the burden of debt repayment reduces welfare. Therefore, we can get a sense of the welfare implications from different repayment plans by looking at how borrowers adjust their job search strategies.

I thus evaluate what would happen to labor market outcomes if student loan borrowers are enrolled in IBR immediately after college graduation without knowing the existence of the plan before making the decision on college attendance.[19] The black dashed lines in Figure 3 plot the

and thus decreasing absolute risk aversion.

[18]An alternative way to think about this mechanism is to consider continuing job search as an investment decision that pays off in the future. Liquidity constrained agents cut their time in job search, which is like firms cut investment (e.g. Bolton, Chen and Wang, 2011) when they are financially constrained.

[19]The exercise here ensures that making IBR available does not change the composition of borrowers. In Section 4.2, I analyze the implication of IBR on college attendance if the existence of the plan is known before making the college entry decision.

counterfactual simulation results. My model suggests that at age 22, borrowers under IBR on average spend 1.5 weeks more on their job search than borrowers under the fixed repayment plan and their average wage income is about $600 higher. Although borrowers under IBR still receive less wage income than non-borrowers, my results indicate that IBR significantly alleviates the debt burden relative to the fixed repayment plan.

Intuitively, agents who just graduated from college would be either unemployed or starting their jobs with modest earnings, as captured by the hump-shaped life-cycle earnings profile. Under the standard fixed repayment plan, student loans are due when borrowers are least able to pay, which forces borrowers to significantly lower their reservation productivity, and so they are more likely to end up with lower-paid jobs. IBR offers insurance to job search outcomes, allowing borrowers to better smooth consumption and conduct a more adequate job search.[20]

I continue to study the cross-sectional implications of IBR. Specifically, I sort borrowers with a college degree into five quintiles based on their student debt balance upon graduation. Table 9 presents the statistics for each group of borrowers averaged over ages 22-32. The average amount of debt is about $21,692 for the most indebted group (Q5). These borrowers' unemployment duration and wage income are 12.2 weeks and $44,748 under the fixed repayment plan, while those of non-borrowers are significantly higher, at 15.6 weeks and $47,112, respectively. The lower wage income results in lower consumption; the most indebted borrowers consume on average about $1,341 (28,637-27,296) less a year than non-borrowers. Under IBR, the most indebted borrowers are on average unemployed for about 0.8 weeks (15.6-14.8) less than non-borrowers. Their wage income and consumption are about $1,173 (45,921-44,748) and $594 (27,890-27,296) higher than if they borrowed 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 based on income is usually higher than the payment required by the fixed repayment plan due to a low debt balance (see equation 2.14). As a result, these agents are indifferent about being enrolled in IBR. Overall, the model suggests that IBR generates distributional effects toward benefiting more indebted borrowers. This coincides with the characteristics of those borrowers who are enrolled in IBR in reality. The Executive Office of the President of the United States (2016) documents that undergraduate-only borrowers under IBR had a much higher median outstanding debt than those under the fixed repayment plan in 2015.

Among college dropouts, my model implies that between the ages of 22 and 32, an average indebted dropout is unemployed for 13.6 weeks, whereas an average dropout without debt is unemployed for 15.1 weeks. In other words, the former is unemployed for about 1.5 weeks

[20] 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.

Table 9: Distributional effects of IBR on labor market outcomes.

		College graduates						Dropouts	
		Q1	Q2	Q3	Q4	Q5	Non-borrowers	Borrower	Non-borrowers
Average debt ($)		3,815	7,128	10,385	14,272	21,692	0	11,458	0
Uemp. duration	FIX	15.6	15.5	14.7	13.7	12.2	15.6	13.6	15.1
(week)	IBR	15.6	15.5	15.4	15.0	14.8		14.8	
Wage income ($)	FIX	47,085	46,932	46,328	45,850	44,748	47,112	30,478	31,456
	IBR	47,079	47,006	46,527	46,373	45,921		31,024	
Job productivity	FIX	0.917	0.915	0.908	0.899	0.892	0.917	0.877	0.892
	IBR	0.917	0.916	0.914	0.912	0.910		0.890	
Consumption ($)	FIX	28,630	28,610	28,374	27,902	27,296	28,637	18,199	18,678
	IBR	28,627	28,619	28,457	28,197	27,890		18,545	

less than the latter. This significantly lowers wage income by $978 (31,456-30,478), which further reduces consumption by $479 (18,678-18,199). Offering IBR to borrowers who fail college increases their average consumption by about $346 (18,545-18,199), suggesting the importance of insuring student loan borrowers against the risk of failing to complete college. These results are consistent with the conclusion drawn from the assessment of loan forgiveness policies for college dropouts (Chatterjee and Ionescu, 2012).

4.2 General Equilibrium Implications of IBR

My analyses above 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 section, I evaluate the effect of IBR by assuming that borrowers know what repayment plans are available to them before making borrowing and 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. I focus on the stationary equilibrium, taking into account the three general equilibrium effects after a policy change, including: (1) a change in college entry and borrowing decisions; (2) a change in firms' job posting decisions; and (3) a change in the overall tax level $\varkappa$ to meet the government's budget constraint (2.31).

Table 10 presents the simulation results. In column IBR-(i), I adjust the switching disutility δ to achieve the 20% IBR enrollment rate in 2016. It is shown that offering IBR increases the college entry rate from 46.1% to 48.6%. College attendance increases because more agents borrow student loans to finance their education, as reflected by the increase in the fraction of borrowers from 61.7% to 65.3%. Among borrowers, the average amount of debt increases

Table 10: General Equilibrium Implications of Student Debt.

	FIX	IBR		No student	FIX
		(i)	(ii)	loans	no search
Fraction of college attendants	46.1%	48.6%	49.2%	37.4%	44.0%
Fraction of borrowers	61.7%	65.3%	66.2%	0%	58.9%
IBR enrollment rate	N/A	20%	34.6%	N/A	N/A
Avg debt of borrowers ($)	11,458	12,124	12,439	N/A	11,127
Job contact rate	0.42	0.44	0.44	0.37	0.39
Wage income ($)	34,973	35,628	35,849	33,052	34,644
Output ($)	42,026	42,510	42,695	39,674	41,756
Labor supply (hours)	1,627	1,633	1,635	1,600	1,625
Default rate	9.49%	1.39%	0.93%	N/A	12.42%
Debt forgiveness ($)	0	788	845	N/A	0
Average tax rate	31.4%	31.8%	31.9%	33.5%	31.6%
Welfare	N/A	0.45%	0.54%	-4.0%	-0.32%

from $11,458 to $12,124. Note that borrowers are in general more talented than non-borrowers, who are in turn more talented than high-school graduates (see Appendix A.2). The increase in 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 $655 (35,628-34,973) and $484 (42,510-42,026) respectively between the ages of 22-32. The equilibrium job contact rate is also higher under IBR. This is because college graduates are more productive than high school graduates at any jobs. Thus the increase in college entry rate increases firms' profits, motivating firms to create more vacancies.[21]

IBR largely reduces the two-year cohort default rate from 9.49% to 1.39% by allowing enrolled borrowers to postpone debt repayment when income is low. However, interest accrues and some borrowers may not be able to pay off their outstanding balance within the 25-year repayment period. On average, the debt forgiveness from IBR is about $788 per borrower. The average tax rate increases by 0.4% (31.8%-31.4%) to maintain a balanced budget.

Following Abbott et al. (2018), I measure the change in welfare by considering the percentage change of lifetime consumption for a newborn economic agent (at age $t = 0$) before her initial conditions (k, e, a, b_0) are determined. The last row of Table 10 indicates that providing IBR increases the average welfare by about 0.45%.

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

[21]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 dampens their incentive to create 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 34.6%. Many borrowers will still choose not to enroll because they think that the debt repayment will turn out to be the same anyway (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 as discussed above.

Table 11: Quantifying the effects of IBR through three channels.

	IBR-(i)			IBR-(ii)		
	(1)	(2)	(3)	(1)	(2)	(3)
Fraction of college graduates	48.6%	48.6%	46.1%	49.2%	49.2%	46.1%
Fraction of borrowers	65.3%	65.3%	61.7%	66.2%	66.6%	61.7%
Avg debt of borrowers ($)	12,124	12,151	11,458	12,439	12,458	11,458
Job contact rate	0.44	0.42	0.42	0.44	0.42	0.42
Wage income ($)	35,628	35,335	35,120	35,849	35,479	35,194
Output ($)	42,510	42,285	42,144	42,695	42,402	42,189
Labor supply (hours)	1,633	1,629	1,622	1,635	1,630	1,623
Default rate	1.39%	1.41%	1.42%	0.93%	1.02%	0.95%
Debt forgiveness	788	801	279	845	893	335
Average tax rate	31.8%	31.9%	31.9%	31.9%	32.1%	32.0%
Welfare	0.45%	0.28%	0.13%	0.54%	0.32%	0.14%

Evidently, my simulation indicates that IBR increases social welfare through three channels and each channel benefits a different group of agents. First, borrowers (both college graduates and dropouts) conduct a 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. This channel benefits those agents who would otherwise not attend college. Third, better education outcomes increase match-specific productivity and profits, motivating firms to create more jobs. This is a general equilibrium effect that presumably benefits every agent in the economy. To quantify the importance of these channels, I run two additional counterfactual experiments.

In Table 11, columns IBR-(i) and IBR-(ii) present the outcome variables when the IBR enrollment rate is 20% and 34.6% respectively. Taking IBR-(i) as an example, column (1) presents the full effect of IBR as in Table 10. 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 creating more jobs. My simulation suggests that reducing the job contact rate from 0.44 to 0.42 for unemployed agents would reduce the average wage income and output by about $293 (35,628-35,335) and $225 (42,510-42,285) respectively. In terms of welfare, IBR increases lifetime consumption by 0.17% (0.45%-0.28%) by incentivizing firms to create 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 conducting a better job search and labor market insurance for unemployed borrowers, and the difference between columns (2) and (3) is informative about the contribution of higher college attendance and more borrowing. My simulation implies that insurance of labor market outcomes increases borrowers' wage income by about \$382 on average. The average wage income, output, and welfare of all agents (both borrowers and non-borrowers) increase by about \$147 (35,120-34,973), \$118 (42,144-42,026), and 0.13% respectively. The higher college attendance and greater borrowing increase these statistics by about \$215 (35,335-35,120), \$141 (42,285-42,144), and 0.15% (0.28%-0.13%).

Column (3) also indicates that, if the only benefit of IBR comes from better insurance in the labor market, annual labor supply between ages 22-32 will on average reduce by 5 hours (1,627-1,622) compared to that under the fixed repayment plan. This is because IBR imposes an income-taxish distortion that reduces agents' incentive to work. Overall, my model suggests that the insurance from IBR dominates this adverse incentive effect and improves social welfare.

4.3 The Student Loan Program and Endogenous Job Search

My previous analyses indicate that IBR increases welfare relative to that under the standard fixed repayment plan, and borrowers change their job search decisions significantly for consumption smoothing and self-insurance. But what is the welfare implication of providing student loans in the first place? And to what extent does the insurance offered by the labor market increase welfare? I 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 student loans" of Table 10 tabulates the results. College attendance rate reduces significantly, from 46.1% to 37.4%. The average job contact rate, wage income, output, and labor supply all decrease because agents are less productive in general. The drop in tax revenue implies that the government has to increase the average tax rate from 31.4% to 33.5% to meet the budget constraint. The expected welfare of a newborn agent is reduced by 4.0%.

To evaluate the welfare implication of endogenous job search, I conduct a counterfactual experiment in which borrowers must choose the same reservation productivity (i.e. face the same income process) as non-borrowers of identical characteristics. The last column of Table 10 presents the results. Compared to the benchmark economy with the fixed repayment plan, college attendance drops by about 2.1% (46.1%-44.0%), as the burden of debt repayment increases when borrowers cannot adjust their job search strategies. As a consequence, the default rate increases by 2.93% (12.42%-9.49%) and the expected welfare of a newborn agent declines by about 0.32%.

Overall, my counterfactuals imply that the student loan program significantly increases welfare even when the fixed repayment plan is adopted. Although borrowers are less picky and more likely to work in lower-paid jobs, the change in job search strategies is itself an optimal response to the burden of debt repayment. Thus forcing borrowers to search for the same jobs as non-borrowers would reduce the former's welfare. On the other hand, the significant difference in job search strategies between borrowers and non-borrowers also reflects the large burden of debt repayment under the fixed repayment plan. The net positive welfare effect of IBR is thus reflected by the significant increase in borrowers' reservation productivity, which is again an optimal response to the reduced burden of debt repayment.[22] Allowing borrowers to change their job search strategies essentially makes income risk endogenous, which creates an important self-insurance channel when the credit and insurance markets fail them. Indeed, my simulation results indicate that the endogenous adjustment of job search strategies plays a quantitatively important role in assessing the welfare implications of the student loan program.

5 Robustness Checks

I conduct robustness checks for the main quantitative results reported in Table 10. For each robustness check, I reestimate the parameters in Table 6 to match the moments in Table 5.

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 3. I now reduce its value to 1.5, which is commonly used for heterogeneous-agent models with financial frictions (e.g. Buera and Shin, 2013; Moll, Townsend and Zhorin, 2016). Appendix Table D.2 indicates that when agents are less risk averse, providing IBR would have a smaller effect. The welfare of a newborn agent increases by just 0.26% as opposed to 0.45% in the baseline specification; college attendance, job contact rate, and wage income all increase by smaller amounts.

Elasticity of Labor Supply The elasticity of labor supply determines the extent to which IBR distorts labor supply through altering incentives. In my baseline specification, σ is set to 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 the tax-modified elasticities of labor supply of 1 and 0.01. As

[22] A related insight is drawn in the optimal UI literature, where Shimer and Werning (2007) show that a worker's after-tax reservation wage sufficiently reflects her welfare.

shown in Appendix Table D.3, when elasticity is 1, IBR barely increases welfare due to the large distortion of labor supply. The average annual labor supply under IBR is 30 hours (1,584-1,554) less than that under the fixed repayment plan. When elasticity is 0.01, Appendix Table D.4 shows that labor supply remains almost the same when borrowers switch to IBR. As a result, IBR alleviates the burden of debt repayment very effectively. The welfare of a newborn agent increases by 0.58% as opposed to 0.45% 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 D.5 indicates that excluding credit access would imply a slightly larger effect from IBR. The welfare of a newborn agent increases by 0.48% on average after introducing IBR as opposed to 0.45% in the baseline specification. Overall, the effect of having credit access proportional to current income is not very significant because agents cannot borrow much anyway due to their low income during unemployment.

Initial Endowments The model's computation complexity forces me to abstract from a number of additional aspects that might influence policy evaluations. In particular, the model takes the distribution of initial endowments as exogenously given. These endowments are the results of choices made by parents. Abbott et al. (2018) estimate that when federal loans are removed, inter vivos transfers increase by about 24% for the wealth-poor and 46% for middle-class households relative to the size of the loans. As a sensitivity analysis, I consider a crowding in/out effect equivalent to 35% of the relative change in loan size when evaluating IBR and the "No student loans" counterfactual. Appendix Table D.6 shows that IBR increases the college attendance and welfare by 2% and 0.40% as opposed to 2.5% and 0.45% in the baseline specification due to the crowding out effect on endowments. Moreover, the decrease in welfare is only about 1.1% when we close the federal student loan program because the increase in endowments partially offset the absence of student loans, only leading to a 1.8% decrease in college attendance rate. Note that my analysis here does not account for the welfare cost to parents of funding education, which is presumably high.

6 Conclusions

In this paper, I develop a structural model with college entry, borrowing, and job search to evaluate the implications of student debt on labor market outcomes. My estimated model suggests that student loans have significant effects on borrowers' unemployment duration and wage income under the fixed repayment plan. The key reason is that, when the credit and insurance markets are imperfect, the labor market offers its own version of insurance and credit provision. Thus ignoring the adjustment of 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 a more adequate job search. In addition to providing insurance against job search risks, IBR also increases social welfare by encouraging students to take out loans and attend college and by motivating firms to offer more jobs.

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Appendix

A Supplementary Information on Model Analyses

A.1 Calculating The Model-Implied Elasticities

In this appendix, I present the details on estimating the model-implied elasticities mentioned in Section 3.4.

To estimate the elasticity of unemployment duration with respect to UI benefits, I simulate a counterfactual by increasing the monthly UI benefits θ by 5%, from \$650 to \$682.5. I find that the average unemployment duration increases by about 0.32 weeks, implying that the elasticity of unemployment duration with respect to UI benefits is about 0.42 ($= \frac{0.32/15.35}{5\%}$). 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 those who quit their jobs. My model generates a larger response of 6.1% in the reservation wage.

Using administrative data from TransUnion and the Longitudinal Employer-Household Dynamics (LEHD), Herkenhoff, Phillips and Cohen-Cole (2016) find that increasing credit limits by 10% of prior annual earnings would increase the amount of time displaced workers take to find a job by 0.15 to 2.67 weeks. Among job finders, the replacement earnings increase by 0.6% to 2.3%. 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 annual wage income by $\text{Inc}_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})$ and the set of agents by I_κ. I then simulate these agents for a period of time until they find the next job and obtain unemployment duration $\text{Dur}(\Omega)$ and annual 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 annual wage income $\text{Inc}^\Delta(\Omega, \rho, \rho')$, assuming these agents are provided with 10% more 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 2.3 months and 0.21. Therefore, the model predicts that in response to a 10% increase in unused credit, unemployed agents will take about 1 week ($= 2.3 \times 4.4 \times 0.1$) longer to find a job that on average pays 2.1% ($= 0.21 \times 0.1$) 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 -0.83 and -0.52, 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 \$14,212 to \$14,923. The model implies that the college enrollment rate reduces from 46.1% to 44.5%, indicating that the implied-elasticity is -0.69 ($= \frac{(44.5-46.1)/46.1}{5\%}$).

A.2 College Entry and Borrowing

The model suggests 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 A.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 0.836, 0.830, and 0.812, respectively.

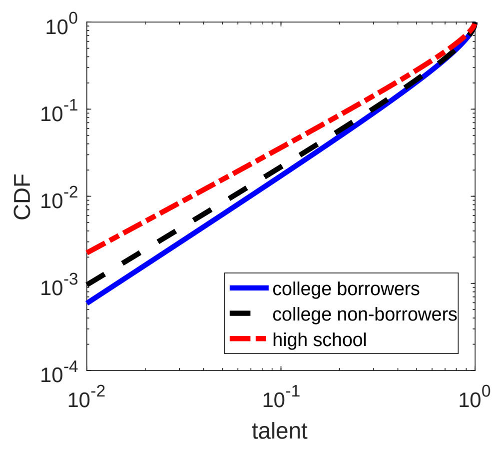

Figure A.1: Model-implied talent distribution for high school and college graduates.

A.3 Illustration of Value Functions

In this appendix, I illustrate the mechanism underlying IBR by plotting the value functions. In Panel A of Figure A.2, I plot the value function under the fixed repayment plan for an

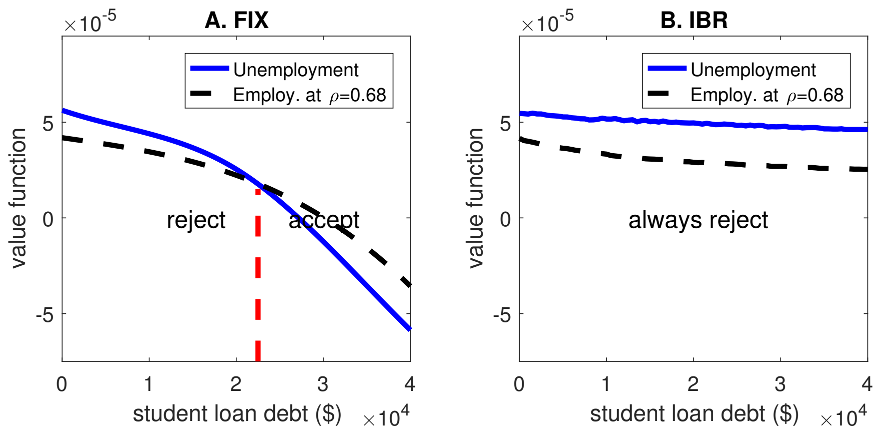

Figure A.2: Illustration of the value functions under the fixed repayment plan and IBR.

unemployed agent and the value function that could be achieved if the agent accepts a job with productivity $\rho = 0.68$ and negotiation benchmark $\rho' = 0.68$. Panel A illustrates the key mechanism of student debt by showing that the value function of being unemployed decreases at a higher rate with increasing debt than the value function of being employed. As a result, the two curves intersect. In this example, when the level of student debt is below $22,000, the agent rejects the job offer and stays unemployed. When the level of debt is above $22,000, the agent accepts 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 employed and unemployed agents. This is because IBR provides much better insurance. First, IBR allows agents to repay less when income is low, especially during unemployment. Second, debt is forgiven 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 ($\rho = 0.68$) and continues to look for a job.

A.4 Wage Function

The wage rate is renegotiated every period, reflecting the change in Ω. The assumption of Nash bargaining links agents' wage rates to their characteristics, implying that wealth, student debt, and labor productivity can influence income. One concern of applying Nash bargaining to model wage determination, however, is that the change in student debt could alter 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 influencing 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). On the one hand, a greater debt repayment reduces the value of the outside option $U(\Omega)$ more than

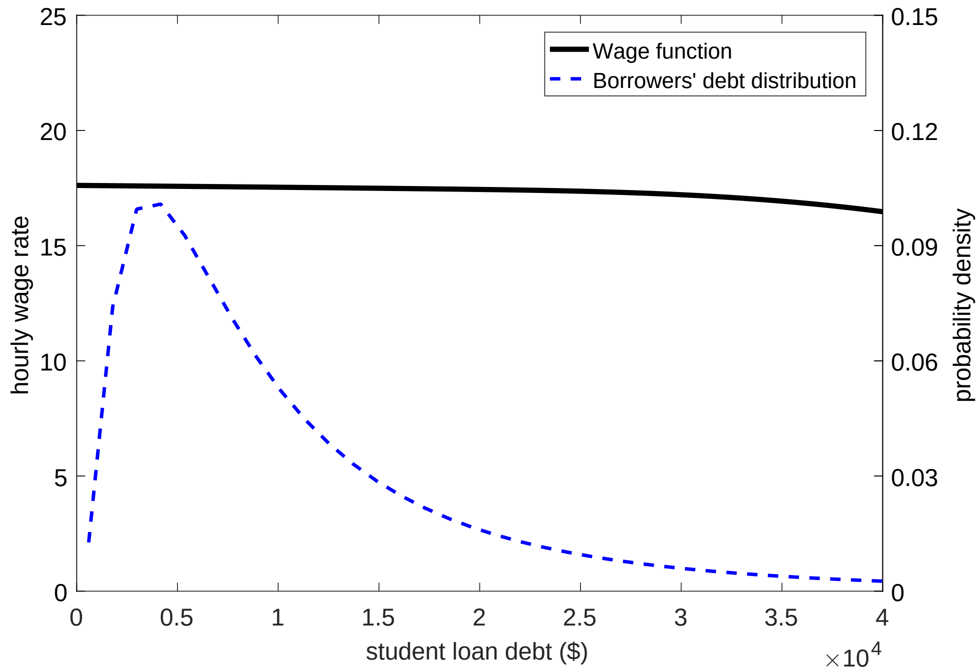

Figure A.3: Illustration of the wage function under the fixed repayment plan.

it reduces $W(\Omega, w, \rho)$ because the marginal value of liquidity is higher during unemployment. This increases an agent's surplus from the match, $W(\Omega, w, \rho) - U(\Omega)$, thus reducing the wage rate for the agent. On the other hand, a greater debt repayment increases the marginal value of liquidity for the agent in the current job due to a reduction in consumption. This increases the sensitivity of the agent's employment value to the wage rate, $\partial W(\Omega, w, \rho)/\partial w$, thus increasing the wage rate for the agent.[23]

In Figure A.3, I consider an agent having average wealth ($5,000) who holds a job with average productivity (0.905) and with the negotiation benchmark's productivity set to the reservation productivity (0.685). The figure shows that increasing the amount of student loan debt from $0 to the average amount ($10,385) reduces the wage rate by about 0.2% (from $17.60 to $17.57 per hour). For agents with other job productivities and negotiation benchmarks, the sensitivity of wage rates 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 column Q3 of Table 9, borrowers have a 1.7% (46,328/47,112-1) lower wage income than non-borrowers. This finding suggests that about 90% of the reduction in wage income is

[23] The bargaining channel could have a large impact 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 assets and Nash bargaining are small. In principle, the strength of the bargaining channel also depends on the agent'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.

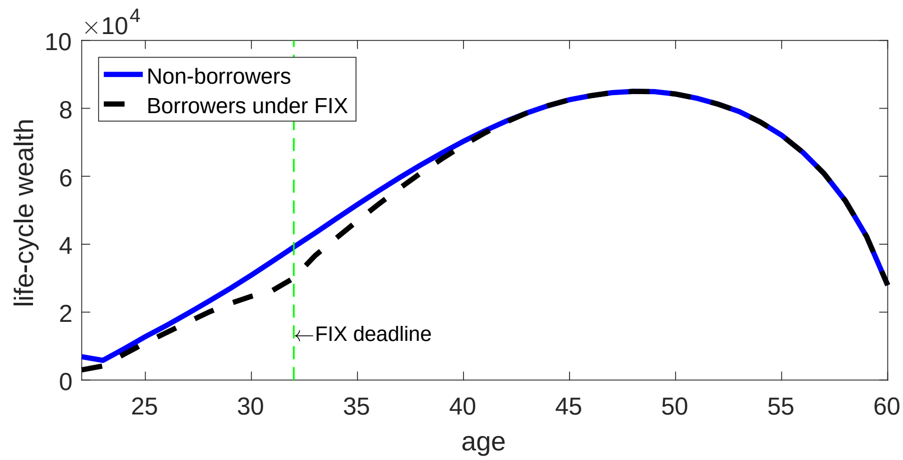

Figure A.4: Average wealth of non-borrowers and borrowers under the fixed repayment plan.

caused by the mechanism that reduces the reservation wage, and 10% is attributed to the Nash bargaining channel, which reflects the change in outside options.

Figure A.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 6%. However, these rare cases are not driving the quantitative results of my model, because most student loans are below \$20,000 according to the estimated distribution.

A.5 Wealth Dynamics

Figure A.4 plots the average wealth of borrowers and non-borrowers (with a college degree) over their entire life-cycle. It shows that borrowers accumulate significantly less wealth than non-borrowers when they are young. This explains why even after debt has been paid off, borrowers still spend less time on their job search and earn less than non-borrowers.

A.6 Value Functions of Employed Agents

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

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

$$
\begin{aligned}
W(\hat{\Omega}_t, 0^-, \rho, \rho') = \max_{c,l,d'} \quad & u(c,l) + \beta(1-d') \Bigg[(1-\kappa)\Bigg[[1-\lambda_e+\lambda_e V(\rho')]W(\hat{\Omega}_{t+1}, 0^-, \rho, \rho') \\
+\lambda_e \Bigg(\int\limits_{x\geq\rho} W(\hat{\Omega}_{t+1}, 0^-, x, \rho)\mathrm{d}V(x) + \int\limits_{\rho'<x<\rho} & W(\hat{\Omega}_{t+1}, 0^-, \rho, x)\mathrm{d}V(x)\Bigg)\Bigg] + \kappa U(\hat{\Omega}_{t+1}, 0^-)\Bigg] \\
& +\beta d' \Bigg[-\eta + (1-\kappa)\Bigg[[1-\lambda_e+\lambda_e V(\rho')]W(\hat{\Omega}_{t+1}, 1, \rho, \rho') \\
+\lambda_e \Bigg(\int\limits_{x\geq\rho} W(\hat{\Omega}_{t+1}, 1, x, \rho)\mathrm{d}V(x) + \int\limits_{\rho'<x<\rho} & W(\hat{\Omega}_{t+1}, 1, \rho, x)\mathrm{d}V(x)\Bigg)\Bigg] + \kappa U(\hat{\Omega}_{t+1}, 1)\Bigg], \\
\text{subject to} \qquad & b_{t+1} = (1+r)[b_t + \varkappa(w_e(\Omega_t, \rho, \rho')l)^{1-\tau} - y_t] - c + \varpi_t, \\
& s_{t+1} = (1+r_s)(s_t - y_t), \\
& b_{t+1} \geq -\varsigma w_e(\Omega_t, \rho, \rho')l,
\end{aligned}
\tag{A.3}
$$

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

$$
\begin{aligned}
W(\hat{\Omega}_t, 1, \rho, \rho') = \max_{c,l} \quad & u(c,l) + \beta\pi \Bigg[(1-\kappa)\Bigg[[1-\lambda_e+\lambda_e V(\rho')]W(\hat{\Omega}_{t+1}, 0^+, \rho, \rho') \\
+\lambda_e \Bigg(\int\limits_{x\geq\rho} W(\hat{\Omega}_{t+1}, 0^+, x, \rho)\mathrm{d}V(x) + \int\limits_{\rho'<x<\rho} & W(\hat{\Omega}_{t+1}, 0^+, \rho, x)\mathrm{d}V(x)\Bigg)\Bigg] + \kappa U(\hat{\Omega}_{t+1}, 0^+)\Bigg] \\
& +\beta(1-\pi) \Bigg[(1-\kappa)\Bigg[[1-\lambda_e+\lambda_e V(\rho')]W(\hat{\Omega}_{t+1}, 1, \rho, \rho') \\
+\lambda_e \Bigg(\int\limits_{x\geq\rho} W(\hat{\Omega}_{t+1}, 1, x, \rho)\mathrm{d}V(x) + \int\limits_{\rho'<x<\rho} & W(\hat{\Omega}_{t+1}, 1, \rho, x)\mathrm{d}V(x)\Bigg)\Bigg] + \kappa U(\hat{\Omega}_{t+1}, 1)\Bigg], \\
\text{subject to} \qquad & b_{t+1} = (1+r)[b_t + \varkappa(w_e(\Omega_t, \rho, \rho')l)^{1-\tau}] - c + \varpi_t, \\
& s_{t+1} = (1+r_s)s_t, \\
& b_{t+1} \geq -\varsigma w_e(\Omega_t, \rho, \rho')l,
\end{aligned}
\tag{A.4}
$$

B Data

B.1 Construction of Main Empirical Variables

Highest degree and college dropouts In each year, the NLSY97 collects the highest degree received at 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). I consider college dropouts as those who have ever enrolled in four-year college (SCH_COLLEGE_STATUS=3) but failed to obtain a bachelor's degree.

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

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

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 those 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 government-subsidized loans or other types of loans borrowed while the youth attended school in each term and at 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. But because students rarely repay student loan debt during college, I consider the total amount of student loans borrowed as the amount of student loan debt outstanding upon college graduation. To prevent the skewness of the debt distribution from having a large effect on the estimated means, the total amount of student loan debt is top coded at the 99th percentile ($49,280).

Last date enrolled I construct a "last-enrolled" variable to record the last date on which the youth was in school. I consider the youth to be in the labor market after this date. For college graduates and dropouts, 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 the last month that the youth was enrolled in college (SCH_COLLEGE_STATUS=3). For high school graduates, I use the date of receiving the high school degree 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.

Wage income The variable YINC_1700 documents income that the youth received from wages, salary, commissions, or tips from all jobs in the past year, before tax or any other deductions. 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 those 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 for 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 The variable CVC_ASSETS_FINANCIAL documents the value of financial assets when the youth reaches the ages of 18, 20, and 25. The financial assets include savings and checking accounts, money market funds, retirement accounts, stocks, bonds, and life insurance. I use the value of financial assets at age 18 to proxy for the net liquid wealth right before making the college entry decision. I do not include non-financial assets, e.g. housing and property values, farm operation, etc., because these assets are not as liquid. To prevent the skewness of the asset distribution from having a large effect on the estimated means, the net liquid wealth values are top coded at the 99th 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 having a 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. 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.

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.

Hourly wage rate The variable CV_HRLY_PAY documents the hourly rate of pay either on the last day of the job or on 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 successive jobs.

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

Parental wealth and education The variable CV_HH_NET_WORTH_P documents household net worth from parent interviews in 1997. I use this variable to proxy for parental wealth. The variables, 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 for parental education.

Gender, race, age, and AFQT score can be found from the variables, KEY!SEX, KEY!RACE_ETHNICITY, KEY!BDATE, and 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 four-digit business or industry code based on the 2002 Census Industry Codes for each youth between 1997 and 2013. Industry codes between 6870 and 6990 are classified as finance and banking jobs and those between 7270 and 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 the variable SCH_COLLEGE_STATUS, and the bachelor's degree receiving date, documented by the variable CVC_BA_DEGREE.

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 in each college each term since the date of the 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 seven 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 remaining 1254 youths, 1234 have their majors documented in at least one of the surveys between 1997 and 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 categorization 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 categories, 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 the ages of 22 and 60 is constructed using March CPS 1997-2008 from Acemoglu and Autor (2011) (available on David Autor's website).

B.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 distributions of talent and jobs' productivity 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 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:

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

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 Estimation and Numerical Methods

C.1 Estimating The Variance-Covariance Matrix

Because the vector of moments in the data can be computed without knowing the parameter values, $\widehat{\text{COV}}$ can be computed by bootstrapping the data directly without performing 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 using JOLTS, the default rate using NSLDS, and the remaining moments using the NLSY97. The covariance between moments constructed in different data sources is set to zero. Second, the moments in the NLSY97 are constructed using different numbers 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.

C.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 agents, and $\lambda_e = \frac{q_e}{q_u}\lambda_u$ for employed agents.

(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'.
- **(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 $\phi_e(\Omega, \rho, \rho')$.

Table C.1: Discretization of state space.

Parameters	**Value**	**Description**
n_b	2,000	Number of wealth grids
Δ_b	\$100	Length of wealth grids
$[\underline{b} \quad \overline{b}]$	$[\$0 \quad \$200,000]$	Range of wealth
n_s	500	Number of student loan debt grids
Δ_s	\$100	Length of student debt grids
$[\underline{s} \quad \overline{s}]$	$[\$0 \quad \$50,000]$	Range of student debt
n_ρ	50	Number of productivity grids
Δ_ρ	0.02	Length of productivity grids
$[\underline{\rho} \quad \overline{\rho}]$	$[0 \quad 1]$	Range of productivity
n_a	10	Number of ability grids
Δ_a	\$0.1	Length of ability grids

(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 agent 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 C.1), 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 perform 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 computation time by calculating these values in advance and storing 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 500GB of RAM to store the large number of decision rules and value functions.

D Robustness Check Tables

Table D.2: GE implications of student debt when risk aversion is low ($\gamma = 1.5$).

	FIX	IBR		No student	FIX
		(i)	(ii)	loans	no search
Fraction of college graduates	46.1%	47.7%	48.1%	39.2%	44.9%
Fraction of borrowers	61.6%	63.6%	64.3%	0%	60.1%
IBR enrollment rate	N/A	20%	32.7%	N/A	N/A
Avg debt of borrowers ($)	11,428	11,750	11,939	N/A	11,189
Job contact rate	0.41	0.43	0.43	0.36	0.39
Wage income ($)	35,274	35,659	35,798	33,722	35,006
Output ($)	43,142	43,413	43,510	41,228	42,967
Labor supply (hours)	1,632	1,631	1,634	1,615	1,630
Default rate	9.56%	1.20%	1.02%	N/A	11.89%
Debt forgiveness ($)	0	610	676	N/A	0
Average tax rate	31.7%	32.0%	32.1%	33.4%	31.8%
Welfare	N/A	0.26%	0.29%	-3.67%	-0.16%

Table D.3: GE implications of student debt when labor supply elasticity is high ($\sigma = 0.78$).

	FIX	IBR (i)	IBR (ii)	No student loans	FIX no search
Fraction of college graduates	46.2%	46.9%	47.2%	32.9%	43.3%
Fraction of borrowers	61.5%	62.4%	62.8%	0%	57.5%
IBR enrollment rate	N/A	20%	30.7%	N/A	N/A
Avg debt of borrowers ($)	11,254	11,589	11,720	N/A	10,770
Job contact rate	0.40	0.41	0.41	0.34	0.37
Wage income ($)	34,465	34,688	34,740	32,186	34,105
Output ($)	40,729	40,925	41,076	38,288	40,519
Labor supply (hours)	1,584	1,554	1,551	1,555	1,581
Default rate	9.44%	2.32%	1.14%	N/A	12.94%
Debt forgiveness ($)	0	1,198	1,324	N/A	0
Average tax rate	27.9%	30.8%	31.1%	29.9%	28.2%
Welfare	N/A	0.12%	0.14%	-4.87%	-0.39%

Table D.4: GE implications of student debt when labor supply elasticity is low ($\sigma = 88.9$).

	FIX	IBR (i)	IBR (ii)	No student loans	FIX no search
Fraction of college graduates	46.1%	48.9%	49.4%	38.7%	45.6%
Fraction of borrowers	61.9%	66.0%	67.0%	0%	59.9%
IBR enrollment rate	N/A	20%	34.9%	N/A	N/A
Avg debt of borrowers ($)	11,490	12,425	12,728	N/A	11,250
Job contact rate	0.42	0.45	0.46	0.37	0.40
Wage income ($)	34,670	35,582	35,827	33,022	34,422
Output ($)	44,292	45,255	45,478	42,450	44,108
Labor supply (hours)	1,633	1,634	1,634	1,631	1,633
Default rate	9.45%	1.77%	0.55%	N/A	12.13%
Debt forgiveness ($)	0	506	540	N/A	0
Average tax rate	31.7%	31.2%	31.0%	33.0%	31.8%
Welfare	N/A	0.58%	0.66%	-3.55%	-0.27%

Table D.5: GE implications of student debt when credit is unavailable ($\varsigma = 0$).

	FIX	IBR		No student	FIX
		(i)	(ii)	loans	no search
Fraction of college graduates	46.3%	49.1%	49.6%	35.9%	43.9%
Fraction of borrowers	61.9%	65.9%	66.6%	0%	58.8%
IBR enrollment rate	N/A	20%	34.8%	N/A	N/A
Avg debt of borrowers ($)	11,672	12,475	12,691	N/A	11,397
Job contact rate	0.43	0.45	0.46	0.36	0.38
Wage income ($)	35,156	35,876	36,090	32,915	34,734
Output ($)	42,375	42,909	43,027	39,988	42,133
Labor supply (hours)	1,630	1,637	1,639	1,611	1,627
Default rate	9.30%	1.62%	1.08%	N/A	12.79%
Debt forgiveness ($)	0	820	905	N/A	0
Average tax rate	31.5%	31.9%	32.0%	33.9%	31.8%
Welfare	N/A	0.48%	0.59%	-4.33%	-0.36%

Table D.6: GE implications of student debt when endowment responds to policy changes.

	FIX	IBR		No student	FIX
		(i)	(ii)	loans	no search
Fraction of college attendants	46.1%	48.1%	48.6%	44.3%	44.0%
Fraction of borrowers	61.7%	64.5%	65.7%	0%	58.9%
IBR enrollment rate	N/A	20%	32.6%	N/A	N/A
Avg debt of borrowers ($)	11,458	12,035	12,257	N/A	11,127
Job contact rate	0.42	0.43	0.44	0.41	0.39
Wage income ($)	34,973	35,514	35,682	34,578	34,644
Output ($)	42,026	42,390	42,545	41,702	41,756
Labor supply (hours)	1,627	1,631	1,634	1,622	1,625
Default rate	9.49%	1.24%	0.95%	N/A	12.42%
Debt forgiveness ($)	0	732	801	N/A	0
Average tax rate	31.4%	31.7%	31.8%	31.9%	31.6%
Welfare	N/A	0.40%	0.48%	-1.1%	-0.32%