Online Appendix for "Job Search under Debt: Aggregate Implications of Student Loans"

=== *Not for Publication* ===

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Contents

A Supplementary information on Quantitative Analyses

A.1 Calculating The Model-Implied Elasticities

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

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

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

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

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

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

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

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

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

A.2 College Entry and Borrowing

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

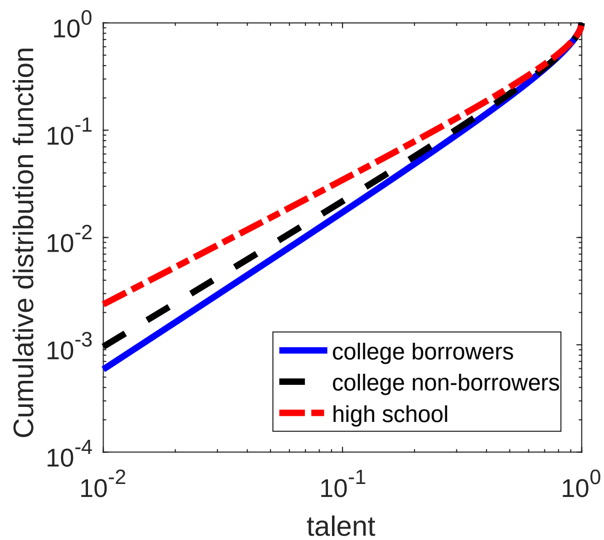


Figure OA.1: Model-implied talent distribution for high school and college graduates.

A.3 Illustration of Value Functions

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

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

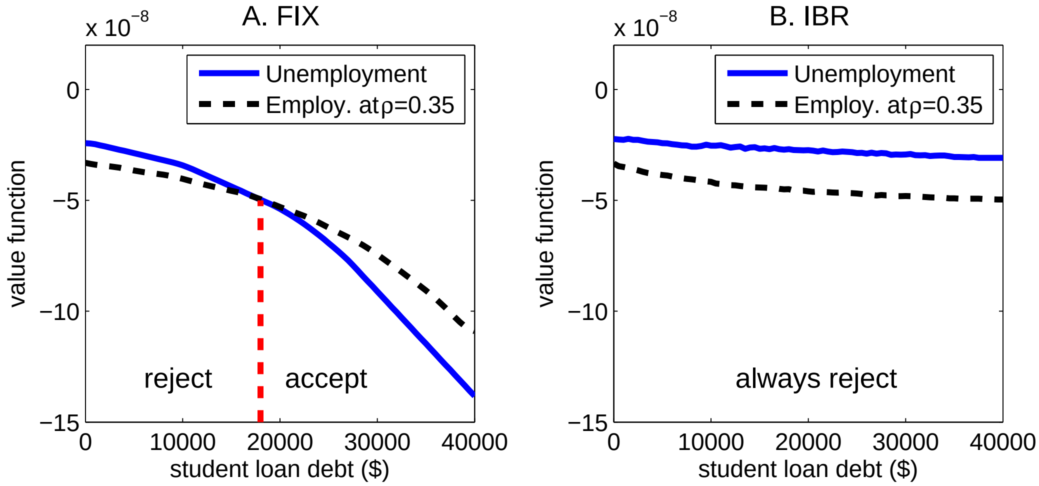


Figure OA.2: An illustration of the value functions under the fixed repayment plan and IBR.

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

A.4 Wage Function

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

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

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

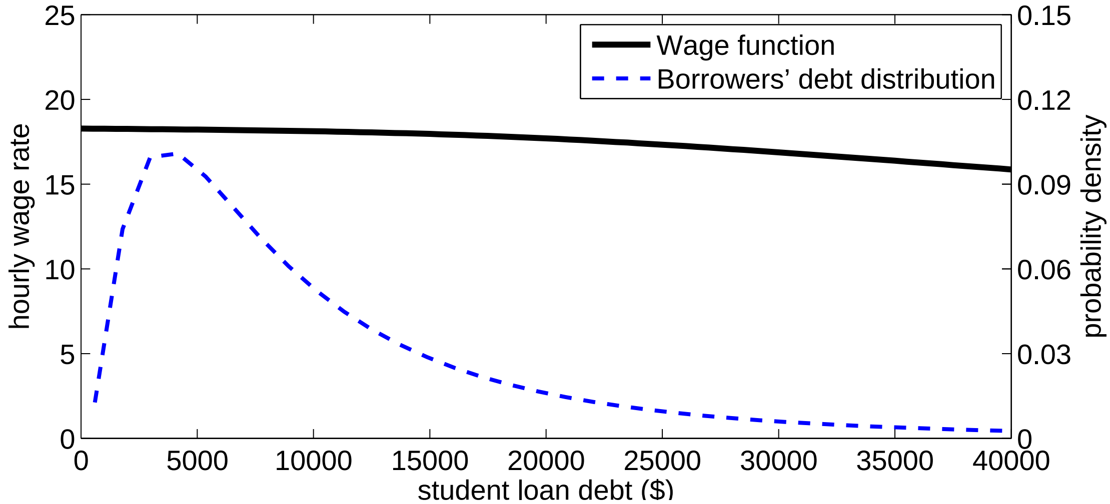


Figure OA.3: An illustration of the wage function under the fixed repayment plan.

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

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

A.5 Value Functions of Employed Workers

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

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

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

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

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

B Mechanism and Channels

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

B.1 Environment

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

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

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

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

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

B.2 Fixed Repayment Contract

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

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

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

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

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

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

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

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

can be written as

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B.3 Income-Based Repayment Contract

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

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

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

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

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

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

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

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

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

B.4 Proofs

B.4.1 Proof of Proposition B.1

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

□

B.4.2 Proof of Proposition B.2

Proof. Rearranging equation (B.4),

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

Take the first derivative,

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

Denote

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

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

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

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

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

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

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

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

B.4.3 Proof of Proposition B.3

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

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

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

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

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

C Data

The details of the data construction are listed below.

C.1 Construction of Main Empirical Variables

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

C.3 Suggestive Evidence

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

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

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

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

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

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

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

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

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

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

D Estimation and Numerical Methods

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

D.1 Estimating Standard Errors

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

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

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

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

D.2 Numerical Method

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

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

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

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

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

Table OA.4: Discretization of state space.

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

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

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

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

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

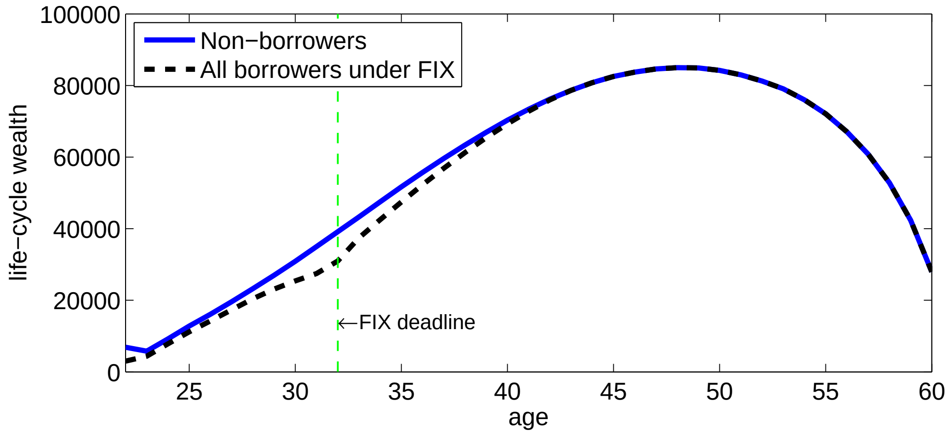
(4). Compute the equilibrium unemployment rate $\overline{u}$ using equation (2.29) and the aggregate level of search intensity Q using equation (2.24). Compute the probability of contacting a worker h using the free entry condition (2.28).

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

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

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

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



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

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

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

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

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

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

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

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

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

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

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