Job Search under Debt:
Aggregate Implications of Student Loans

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Abstract

This paper investigates the implications of student loan debt on labor market outcomes. I begin by analytically demonstrating that individuals under debt tend to search less and end up with lower-paid jobs. I then develop and estimate a quantitative model with college entry, borrowing, and job search using NLSY97 data to evaluate the proposed mechanism under the fixed repayment plan and the income-based repayment plan (IBR). My simulation suggests that the distortion of debt on job search decisions is large under the fixed repayment plan. IBR alleviates this distortion and improves welfare. In general equilibrium, debt alleviation achieved through IBR effectively offers a tuition subsidy that increases college entry and encourages firms to post more jobs, further improving welfare.

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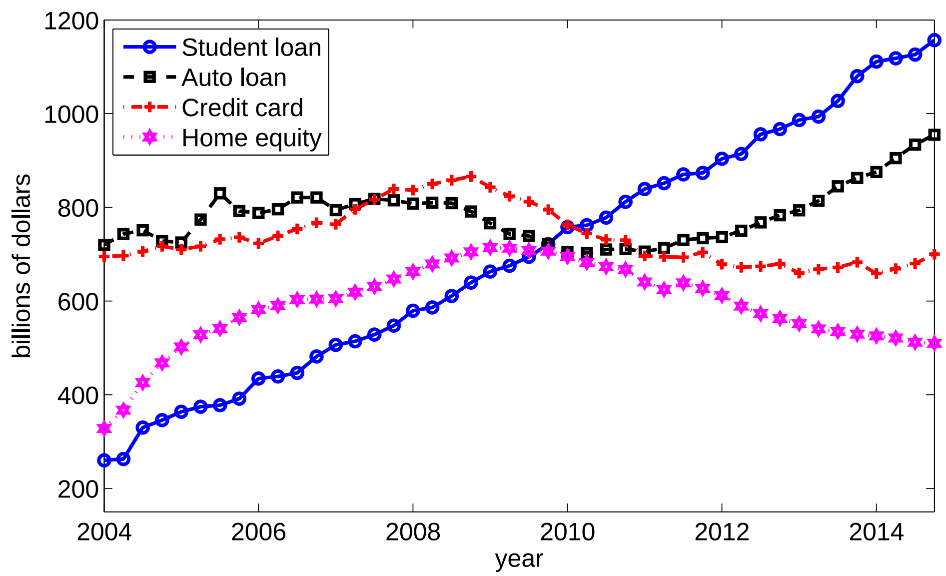
1 Introduction

Americans are more burdened by student loan debt than ever. Over the past decade, student loans have more than quadrupled to surpass $1.2 trillion, becoming the second largest type of consumer debt in the U.S. (see Figure 1). The increasing number of people facing difficulties paying off these debts has led many to wonder whether student loans might generate broader effects throughout the entire economy. Specifically, concerns about debt repayment presumably affect students' job search decisions after college. Despite the potential importance of student loans, little is known about their implications on labor market outcomes.



Source: Federal Reserve Bank of New York Consumer Credit Panel (a representative sample drawn from anonymized Equifax credit data).

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

In this paper, I fill this gap by theoretically and quantitatively investigating the underlying channels and tradeoffs. I contribute to the existing literature in three ways: (1) by illustrating a mechanism through which student debt burden induces borrowers to search less and end up with lower-paid jobs; (2) by developing a structural model that incorporates college entry, borrowing, and job search to quantify the mechanism; (3) by applying the model to evaluate a realistic income-based repayment plan (IBR) introduced in 2009 and examine the potential general equilibrium implications.

My main quantitative exercise suggests that the distortion of student debt on job search decisions could be large under the fixed repayment plan, and that it is very much relieved by IBR. Debt alleviation achieved by IBR benefits poorer and more indebted borrowers more, and on average, it is equivalent to cutting student debt by half. One-third of debt alleviation is attributed to better job matches. Moreover, adopting IBR also brings two general equilibrium effects that encourage college entry and job postings, effectively offering a tuition subsidy that is much less costly to the government.

The mechanism is closest to that of Herkenhoff, Phillips and Cohen-Cole (2016), who show that credit-constrained job seekers tend to be less picky in job search. In this paper, I emphasize that student debt repayment generates a similar risk and liquidity effect that induces borrowers to search less. My quantitative model incorporates college entry and borrowing decisions into an equilibrium quantitative search model (Krusell, Mukoyama and Sahin, 2010; Herkenhoff, 2015; Lise and Robin, 2017; Lise, Meghir and Robin, 2016). The model is developed with rich features to match a set of labor market characteristics, and it departs from most of the existing equilibrium search models along three dimensions. First, I introduce college entry and borrowing decisions to study the potential general equilibrium effects. Second, I model student loan debt as a distinct variable, instead of focusing on net worth, to study the implications of different repayment policies. Third, I introduce elastic labor supply for employed workers to capture the potential adverse incentive effects of IBR. As a result, workers and firms bargain over wage rates instead of wage income.

My first key result illustrates and quantifies the mechanism through which debt repayment influences job search decisions. I show that with fixed repayment, more indebted agents set lower reservation wages in job search. This result comes from the fact that search risks are not perfectly insured in an incomplete market. Intuitively, there is a *risk channel* due to the tradeoff between risks and returns because marginally raising the reservation wage increases both expected income and search risks. When debt is higher, the agent becomes more risk averse due to lower consumption, which pushes her to avoid search risks by setting a lower reservation wage. Moreover, because the credit market is imperfect, there also exists a *liquidity channel* from repayment. The liquidity channel reinforces the risk channel and further reduces the reservation wage, substantially increasing the effect of the debt burden.

To evaluate the quantitative implications of this mechanism, I estimate the quantitative model based on 1997-2013 panel data from NLSY97 using the Method of Simulated Moments (MSM). The model is able to capture the positive correlation between talent and debt, endogenous student debt distribution, and various labor market characteristics observed in the data. I validate the model by conducting two sets of out-of-sample tests related to the proposed mechanism. First, I check whether the model can reproduce the differential wage income between borrowers and non-borrowers observed in the data. Second, I check whether the model-implied structural estimates of several related elasticities are in line with the micro estimates in related literature.

I then use the estimated model to evaluate the life-cycle implications of student loans under the fixed repayment plan. On average, borrowers' unemployment duration is 7.6% (1.8 weeks) shorter and they earn 4.2% less ($2,008) annually in the first 10 years after graduation compared to non-borrowers due to inadequate job search. Even after debt has been paid off, borrowers still spend less time on job search and earn relatively less. This lasting effect is attributed to lower savings and the low job-to-job transition rate in the labor market. During the first 10 years after graduation, borrowers accumulate significantly less wealth compared to non-borrowers due to lower wage income and debt repayment. The lower savings would continue affecting borrowers' job search decisions through a similar mechanism in the following years. Moreover, borrowers are stuck at less productive jobs for a while because the estimated search intensity for employed workers is relatively low.

These results suggest that existing studies that do not consider endogenous job search might overestimate the welfare benefit of student debt on improving college entry. While providing student debt enables students from low-income families to attend college and realize the college wage premium, the debt burden after college would distort borrowers' job search decisions, reducing their wage income. According to my simulation, the average annual wage premium of college attendance is about $17,192 for a non-borrower, but the premium is reduced by $2,008 for an average borrower. The 11.7% difference reflects the after-college impact of the debt burden on job search decisions. The debt burden also potentially has aggregate implications on output and productivity by affecting job search decisions. As the simulation suggests, average output and match quality (measured by job productivity) among young borrowers are 3.8% and 2.9% lower compared with non-borrowers. My model suggests a relatively large aggregate effect precisely because of the mismatch in the timing of the benefits and the costs of college attendance, i.e., under the standard fixed repayment plan, student loans are due when borrowers have the lowest capacity to pay. One remedy is to insure risks using income contingent loans.

My second key result illustrates and quantifies the effect of IBR on the reservation wage and welfare. Theoretically I show that income contingency raises the reservation wage through both the risk channel and the liquidity channel. The potential costs of income contingency come from the distortion on labor supply, due to the canonical tradeoff between insurance and the incentive to work. I use my quantitative model to assess the implication of IBR introduced in 2009. Under this realistic plan, borrowers are eligible to repay 15% of their monthly discretionary income, and all the remaining outstanding debt will be forgiven after 25 years of repayment.

I first analyze what would happen in partial equilibrium. If borrowers are unexpectedly allowed to enroll in IBR, my simulation suggests that they would conduct more adequate job search and get matched with jobs that are 1.7% more productive. As a result, their output and wage income increase by 1.3% and 1.9% ($897) in the first 10 years after graduation. The higher wage income already nets out the adverse incentive effect on labor supply, which is small because IBR does not generate much debt forgiveness for borrowers due to the long repayment period. Therefore, instead of taxing borrowers' income, IBR merely restructures payments inter-temporally. The average debt alleviation achieved by IBR is equivalent to cutting the amount of debt by half. One-third of the debt alleviation is attributed to better job matches, while the remainder is attributed to better consumption smoothing. There is a large distributional effect: borrowers who are poorer and more indebted benefit more after switching to IBR.

In general equilibrium, debt alleviation after college would also affect agents' college entry and borrowing decisions. After the economy adopts IBR, more students would choose to enter college by borrowing student debt. The college entry rate increases by 6.1% with an increase in the fraction of borrowers from 62.2% to 67.5%. I find that enrolling borrowers in IBR brings an effect on college entry similar to a tuition subsidy of $2,252. However, this tuition subsidy is much less costly from the government's perspective because most borrowers can repay their debt under IBR.

The increase in college entry rate in turn affects firms' job posting decisions. Since college graduates are also more productive, the increase in firms' profits incentivizes more job postings, increasing the equilibrium job contact rate by 6% for unemployed workers. My simulation suggests that switching from the fixed repayment plan to IBR would increase young agents' welfare by about 2.4%. Through a decomposition, I show that the increase in welfare attributed to better job search and insurance, more college entry and borrowing, and more job postings are 0.8%, 1.1%, and 0.5%, respectively.

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; Bloemen and Stancanelli, 2001; Algan et al., 2003; Silvio, 2006; Browning, Crossley and Smith, 2007; Chetty, 2008). Recently, researchers have started considering the labor market implication of other consumption smoothing mechanisms such as intra-household insurance (Kaplan, 2012; Guler, Guvenen and Violante, 2012), credit access (Herkenhoff, 2015; Herkenhoff, Phillips and Cohen-Cole, 2016), housing market (Brown and Matsa, 2016), mortgage modifications (Mulligan, 2009; Herkenhoff and Ohanian, 2015; Bernstein, 2016), and default arrangements (Dobbie and Song, 2015; Herkenhoff and Ohanian, 2015; Dobbie and Song, 2016). My paper contributes to this research agenda by explicitly modeling and quantitatively evaluating the implication of student debt on job search behavior and the consumption smoothing mechanism offered by different repayment plans.

This paper contributes to the large literature on student loans (see Lochner and Monge-Naranjo, 2016, for a recent survey). An extensive body of this literature focuses on the impact of financial aid during college (e.g., Keane and Wolpin, 2001; Abbott et al., 2016). However, much less is known about the impact of student loans on labor market outcomes after college. The empirical evidence is inconclusive.[1] In this paper, I take a structural approach to highlight one plausible mechanism that could influence indebted students' job search decisions. Abbott et al. (2016) develop a rich general equilibrium model with heterogeneous agents to evaluate education policies. My model focuses less on college participation but more on job search decisions. Instead of analyzing further expansions of government-sponsored loan limits, I use the model to evaluate income-based repayment plans, which have been argued to offer risk-sharing benefits with minimal incentive costs (see Stiglitz, Higgins and Chapman, 2014, for a review). My analyses elucidate the channels through which income contingency influences the outcome of job search. There are studies using structural models to assess income-driven repayment plans (Dearden et al., 2008; Ionescu, 2009; Joensen and Mattana, 2016; Ionescu and Ionescu, 2014), but none of them account for search risks in the labor market, which is the focus of my paper.[2]

This paper also relates to the burgeoning literature on the connection between household debt and labor market outcomes. To my knowledge, previous research has discussed three plausible mechanisms. First, household credit could affect the labor market via the aggregate demand channel (Eggertsson and Krugman, 2012; Mian and Sufi, 2014; Guerrieri and Lorenzoni, 2015; Midrigan and Philippon, 2016). Second, households with mortgage debt engage in risk shifting by searching for higher-paid but riskier jobs because they are protected by limited liability (Donaldson, Piacentino and Thakor, 2016). Third, borrowers tend to work in high-paid industries (Rothstein and Rouse, 2011; Luo and Mongey, 2016). My

[1] For example, Minicozzi (2005) suggests that higher educational debt is associated with higher initial wages and lower wage growth rates. Field (2009) finds that debt induces NYU law school admits to work in private sector law jobs. Based on a natural experiment in an elite university, Rothstein and Rouse (2011) find that indebted students receive higher initial wages as they are more likely to work in high-paid industries. Luo and Mongey (2016) try to generalize these findings to a nationally representative sample. Recently, Gervais and Ziebarth (2016) explore a regression kink design in need-based federal student loans and find a negative effect of student loans on earnings. Using data from NLSY97 and Baccalaureate and Beyond, Weidner (2016) finds that indebted students tend to accept jobs quicker and select jobs in unrelated fields, leading to lower wage income.

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

paper proposes that borrowers are less picky and more likely to have lower earnings, consistent with recent evidence from Gervais and Ziebarth (2016) and Weidner (2016).

2 Program Description

In the U.S., student loans play a very significant role in higher education. About 60% of college students borrow to help cover costs. In 2014, the number of borrowers surpassed 43 million, with an average balance of about $27,000. Student loans are split into federal loans and private loans, with the former constituting 80% of the total volume. This paper focuses on federal loans because of their importance.

Student loans are arguably more burdensome compared to other loans because repayment usually starts immediately after students leave college, aside from a 6-month grace period offered by Federal Stafford Loans. Moreover, student loans can only be discharged through bankruptcy if borrowers prove "undue hardship" through a court determination. As a result, the insurance provided by consumer bankruptcy (Livshits, MacGee and Tertilt, 2007) is generally absent in student debt.

One prominent feature of student debt is that the federal student loan program allows borrowers to choose among different repayment plans.[3] The standard repayment plan is the default option for student loan borrowers. Under this plan, monthly payments are fixed and made for up to 10 years. As of 2013, 88% of federal direct loan borrowers repay their debt under the standard repayment plan (Dynarski and Kreisman, 2013). In addition to the standard plan, the federal student loan program has been offering income-driven repayment plans. The income-based application now includes four different income-driven repayment plans. The main feature of these plans is that borrowers make payments contingent on their income instead of the balance of outstanding debt, and the remaining debt is forgiven after a certain number of payments.[4] Although the first income-driven repayment plan has been made available since 1994, the take-up rate was below 1% until 2008 due to various behavioral issues (Dynarski and Kreisman, 2013). As suggested by The Executive Office of the President of the United States (2016), continuing to expand enrollment in income-driven repayment plans remains a key priority for the administration.[5] A more detailed description of the federal loan program can be found in Online Appendix F.

[3]This paper seeks to understand the implications of the standard fixed repayment plan and the income-driven repayment plan on students' job search behavior. In reality, federal student loan borrowers also have the option to enroll in graduated repayment plan under which monthly payments start out low and increase every two years, or extended repayment plans which allow an extension of repayment period up to 30 years. This paper does not emphasize these plans because of the low take up rate.

[4]All of these plans are 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 these plans borrowers do not need to repay more than the amount borrowed. However, there is cross-subsidization under TPO as participants are required to make payments until the debt of an entire "cohort" is repaid.

[5]In fact, the Obama administration has used several tools to increase enrollment, such as behavioral "nudges", improved loan servicer contract requirements, efforts associated with the President's Student Aid Bill of Rights, a student debt challenge to gather commitments from external stakeholders, and increased and improved targeted outreach to key borrower segments who would benefit from income contingency. The participation rate in income-driven repayment plans has quadrupled over the last four years, from 5% in 2012 to 20% in 2016. In April 2016, the administration announced a series of new actions to further expand enrollment in income-driven repayment plans.

3 Mechanism and Channels

In this section, I build a partial equilibrium model based on McCall (1970) with several simplifying assumptions to shed light on the mechanism linking the debt burden to labor market outcomes under two stylized repayment contracts. These assumptions will be made more realistic when conducting quantitative analyses in the next section.

3.1 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.[6]

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.

3.2 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.[7]

[6]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 $\beta(1 + r) = 1$.

[7]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

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,

$$W(w) = \frac{u(w-s)}{1-\beta}. \tag{3.1}$$

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

$$U = u(\theta - s) + \beta \int_{\theta}^{\overline{w}} \max\{W(w), U\} dF(w). \tag{3.2}$$

Equation (3.1) 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., $U = W(w^*_{FIX})$:

$$u(w^*_{FIX} - s) = u(\theta - s) + \frac{\beta}{1-\beta} \int_{w^*_{FIX}}^{\overline{w}} [u(w-s) - u(w^*_{FIX} - s)] dF(w). \tag{3.3}$$

The RHS of equation (3.3) 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.

3.2.1 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 (3.3) 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 1.

Proposition 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 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 implication 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 1 incorporates both a risk channel and a liquidity channel.

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).

It is worth noting that the risk channel and the liquidity channel 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 channel. 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 channel.

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 (see Online Appendix D.2 for the proof).

3.3 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.[8] 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:*

$$\alpha I(w^*_{IBR}) = \frac{S}{\beta}, \tag{3.4}$$

where w^*_{IBR} is the agent's optimal reservation wage under the income-based repayment contract:

$$u((1-\alpha)w^*_{IBR}) = u((1-\alpha)\theta) + \frac{\beta}{1-\beta}\int_{w^*_{IBR}}^{\overline{w}} \left[u((1-\alpha)w) - u((1-\alpha)w^*_{IBR})\right] dF(w). \tag{3.5}$$

I call equation (3.4) 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 (3.5), which can be thought of as the incentive compatibility constraint.[9]

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,

[8] I incorporate these features in section 4 when quantitatively evaluating IBR.

[9] Since the income-based repayment contract does not specify the reservation wage, this naturally introduces an inefficiency because the agent does not internalize the effect of her reservation wage on expected repayment. The welfare implication of this inefficiency is discussed in Online Appendix D.4.

because equity contracts encourage activities with high returns and high risks. This result is summarized in the following proposition.

Proposition 2. *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 1 and 2 jointly imply that with CRRA utility, the fixed repayment of debt reduces the reservation wage and IBR alleviates this distortion.

3.3.1 Channels Determining the Reservation Wage

I now elucidate the exact channels through which IBR influences the reservation wage. In the next section, I will enrich the model with additional ingredients informed by these channels to develop a quantitative model for my empirical analysis.

Let us focus on the disposable wage, which is wage income net of debt repayment. Denote $F_{IBR}(w)$ and $F_{FIX}(w)$ as the disposable wage offer distribution under IBR and the fixed repayment contract; thus

$$F_{IBR}(w - \alpha w) = F_{FIX}(w - s) = F(w), \forall w \in [\theta, \overline{w}] \tag{3.6}$$

Denote $\tilde{w}^*_{IBR}$ and $\tilde{w}^*_{FIX}$ as the associated disposable reservation wages. By definition,

$$\tilde{w}^*_{FIX} = w^*_{FIX} - s, \tag{3.7}$$

$$\tilde{w}^*_{IBR} = (1 - \alpha) w^*_{IBR}. \tag{3.8}$$

IBR has a less risky disposable wage offer distribution because of better risk sharing. Using the single-crossing property of $F_{IBR}(w)$ and $F_{FIX}(w)$, I show that IBR is second-order stochastic dominant over the fixed repayment contract.

Lemma 1. *The disposable wage offer distribution under IBR,* $F_{IBR}(w)$*, strictly second-order stochastically dominates that under the fixed repayment contract,* $F_{FIX}(w)$*:*

$$\int_0^x F_{IBR}(w)dw \leq \int_0^x F_{FIX}(w)dw, \forall x. \tag{3.9}$$

By applying integration by parts twice, I decompose the difference in the disposable reservation wage under the two contracts into three channels:

Proposition 3. *The difference in the disposable reservation wage between IBR and the fixed repayment contract is* *characterized by the following decomposition:*

$$
\begin{aligned}
u(\tilde{w}^*_{IBR}) - u(\tilde{w}^*_{FIX}) = & \underbrace{(1-\beta)\left[u((1-\alpha)\theta) - u(\theta - s)\right]}_{\text{liquidity channel, (+)}} \\
& + \underbrace{\beta\left[\int_{\tilde{w}^*_{IBR}}^{\infty}\left(\int_0^w F_{IBR}(x)dx\right)u''(w)dw - \int_{\tilde{w}^*_{FIX}}^{\infty}\left(\int_0^w F_{FIX}(x)dx\right)u''(w)dw\right]}_{\text{risk channel, (+)}} \\
& + \underbrace{\beta\left[u'(\tilde{w}^*_{IBR})\int_0^{\tilde{w}^*_{IBR}} F_{IBR}(w)dw - u'(\tilde{w}^*_{FIX})\int_0^{\tilde{w}^*_{FIX}} F_{FIX}(w)dw\right]}_{\text{optionality channel, (-)}}. \qquad (3.10)
\end{aligned}
$$

The RHS of equation (3.10) consists of three channels. The first term captures a liquidity channel. The agent repays less during unemployment under IBR, thus $u((1-\alpha)\theta) > u(\theta - s)$. This implies that the first term is positive, contributing to a higher reservation wage.

The second term captures the risk channel. IBR generates a less risky wage offer distribution according to Lemma 1. Because the agent is risk averse, she would raise the reservation wage to pursue a higher expected return when there are fewer risks in job search. Therefore, the second term is also positive, contributing to a higher reservation wage.

The third term captures the difference in the option value of staying unemployed under the two repayment contracts. Intuitively, the agent has a larger option value of staying unemployed when the wage offer distribution is more dispersed. This is because lower wages would be turned down, and higher wages are more likely to be drawn from a more dispersed wage offer distribution. Thus the optionality channel contributes to a lower reservation wage.

4 Quantitative Model

In section 3, I developed a stylized framework to understand the channels through which the debt burden influences the agent's reservation wage under different repayment contracts. However, the model is not rich enough to match data and conduct quantitative analyses. In this section, I develop a quantitative model to address these issues. In order to highlight the implication of the debt burden on job search decisions, the model intentionally places more emphasis on the labor market relative to the decisions made during college study. In the following, I first give an overview of the model, then I introduce college entry and borrowing decisions. Next, I characterize the post-college life related to job search in the labor market and student loan repayment. Finally, I formulate the recursive dynamic programming problems and define the stationary competitive equilibrium.

4.1 Overview

Compared to the partial equilibrium theoretical framework, the quantitative model has the following additional ingredients.

(1). I introduce college entry decisions to capture the potential equilibrium effects through which IBR influences college entry and borrowing decisions by alleviating the debt burden after college.

(2). I introduce age-specific labor productivity to capture the hump-shaped life-cycle earnings profile. Under the fixed repayment plan, borrowers are required to repay debt immediately after college graduation while earnings are low. Thus capturing the life-cycle earnings profile will increase the effect of the debt burden through the liquidity channel.

(3). I introduce loan default that allows borrowers to delay repayment. Default provides some sort of insurance, which mitigates the effect of the debt burden through the risk channel and the liquidity channel.

(4). I introduce on-the-job search and job separation. Both features reduce the value of staying unemployed through the optionality channel. Thus without these ingredients, the model would over-estimate the effect of the debt burden on job search, as the importance of searching for jobs by staying unemployed would be exaggerated.[10]

(5). I introduce nonlinear income taxes. Introducing income taxation is important for the quantitative implication of IBR, because progressive taxation provides partial insurance, and the distortion on labor supply from income-contingency increases with the income taxes facing indebted agents.[11]

(6). I introduce vacancy posting to endogenize the matching rate and the wage offer distribution. I do this to capture potential general equilibrium responses on the firm side after a large-scale policy change on student debt.

4.2 College Entry and Borrowing

There is a continuum of agents of measure one in each cohort who live for T periods. 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 $\mho(a, b_0)$.[12] In the following, I describe the agent's problem using age index t.

At the beginning of the life, the agent decides whether to enter college after drawing a monetary cost k and a non-monetary utility benefit/cost e randomly from cumulative distributions $\Pi(k)$ and $\Upsilon(e)$. The monetary cost k captures the tuition fees and living expenses net of scholarships and parental transfers received during college study. The utility benefit/cost captures unobserved preference heterogeneity, efforts, or any psychic costs related to college study.

[10] In the extreme case, if searching during unemployment is as efficient as searching during employment, then the reservation wage is always equal to UI benefits (Lise, 2013), and the proposed mechanism is absent. Therefore, it is important to introduce these realistic features and ask the data to determine the relative efficiency.

[11] As Stiglitz (2015) points out, the adverse incentive effects from IBR are likely to be small, so long as income tax rates and repayment rates combined are not too large.

[12] The assumption that all cohorts of agents are born with the same initial distribution of wealth and talent enables a stationary equilibrium, in which the distribution of agents at a given age is the same across cohorts, although different cohorts reach the same age in different periods.

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

$$z(a, n, t) = A_n a g(t), \tag{4.1}$$

The value of parameter A_n varies with education level. The difference $A_1 - A_0$ captures the college premium. $g(t)$ is a deterministic trend, which is the same across all agents and only depends on age t.[13] Following Bagger et al. (2014), I assume the deterministic trend $g(t)$ to be cubic,

$$g(t) = \mu_0 + \mu_1 t + \mu_2 t^2 + \mu_3 t^3. \tag{4.2}$$

Parameters μ_0, μ_1, μ_2, μ_3 are estimated to match the life-cycle earnings profile. The assumption that labor productivity depends on age instead of the number of periods in employment greatly simplifies the problem as z_t is homogeneous within the same cohort conditional on the same talent.

As I show below, in the labor market, agents' characteristics can be summarized by five state variables: wealth b, student debt s, talent a, education level n, and age t. Denote $U(b, s, a, n, t)$ as the value of unemployed workers. The college entry decision is made by comparing the value of entering college, $U(\max\{b_0 - k, 0\}, \max\{k - b_0, 0\}, a, 1, 1) - e$, and the value of not entering college $U(b_0, 0, a, 0, 1)$ at $t = 1$.

4.3 Labor Market

Agents have per-period utility $u(c, l)$ and discount factor β. I model $u(c, l)$ using GHH preferences (Greenwood, Hercowitz and Huffman, 1988),

$$u(c, l) = \frac{1}{1-\gamma}\left(c - \phi \frac{l^{1+\sigma}}{1+\sigma}\right)^{1-\gamma}, \tag{4.3}$$

where c and l are consumption and labor supply.

Agents are matched pairwise to jobs, which are created by firms. Following the standard in the literature on search-theoretic models, each firm only creates one job vacancy, thus I do not distinguish between firms and jobs. Jobs are heterogeneous in productivity ρ. There are no productivity shocks, therefore job productivity is constant for a worker-job match until the match breaks up.

Jobs are either vacant or matched with workers and workers are either unemployed or matched with jobs. To simplify notations, I denote $\Omega = (b, s, a, n, t)$ as the worker's characteristic. Denote $\phi^u(\Omega)$ as the PDF of unemployed workers, $\phi^e(\Omega, \rho)$ as the PDF of employed workers matched with jobs whose productivity is ρ, and $v(\rho)$ as the PDF of vacancies. Denote $\Phi^u(\Omega)$, $\Phi^e(\Omega, \rho)$, and $V(\rho)$ as their CDFs. Denote N_v as the number of vacancies and $\overline{u}$ as the unemployment rate.

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

The number of type-ρ vacancies is

$$N_v(\rho) = N_v v(\rho). \tag{4.4}$$

Because each generation has measure one, and there are T overlapping generations, the number of type-ρ jobs in the economy is

$$N(\rho) = (1 - \overline{u})T \int \phi^e(\Omega, \rho) d\Omega + N_v(\rho). \tag{4.5}$$

The total number of jobs is

$$N = \int N(\rho) d\rho. \tag{4.6}$$

When a worker Ω is matched with a job ρ, they jointly produce a flow of output using the following production technology:

$$F = z(a, n, t)\rho l. \tag{4.7}$$

Matching Job search is a random matching process. Agents contact jobs at endogenous rates that depend on their search intensity and the number of vacancies. I allow for on-the-job search and assume that unemployed agents have search intensity h^u and employed agents have search intensity h^e following Lise and Robin (2017).[14] Denote H as the aggregate level of search intensity contributed by both unemployed and employed agents:

$$H = h^u \overline{u} T + h^e (1 - \overline{u}) T. \tag{4.8}$$

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

$$M = \chi H^{\omega} N_v^{1-\omega}, \tag{4.9}$$

where χ and ω are two parameters governing the matching efficiency. From a vacancy's perspective, the probability of contacting a worker is

$$q = M / N_v. \tag{4.10}$$

The job contact rates for unemployed workers and employed workers are

$$\lambda^u = h^u M / H; \quad \lambda^e = h^e M / H. \tag{4.11}$$

Denote $W(\Omega, \rho, w)$ as the value of an employed agent Ω in job ρ at wage rate w, $U(\Omega)$ as the value of an unemployed agent Ω, and $J(\Omega, \rho, w)$ as the value of a filled job ρ that pays wage rate w. The value of a vacancy is zero due to the free entry condition. When an agent and a job meet each other, a match is formed if there exists wage rate w, such that the worker is willing to accept the job and the firm is

[14] The assumption that search intensities are different during unemployment and employment is standard in the search literature. For example, Postel-Vinay and Robin (2002) estimate a model with on-the-job search and find that job contact rates are uniformly higher during unemployment across a wide range of occupations.

willing to hire the worker. Thus the participation constraints are

$$W(\Omega, \rho, w) \geq U(\Omega) \text{ and } J(\Omega, \rho, w) \geq 0. \tag{4.12}$$

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

$$w^u(\Omega, \rho) = \underset{w}{\operatorname{argmax}} [W(\Omega, \rho, w) - U(\Omega)]^{\xi} J(\Omega, \rho, w)^{1-\xi}, \tag{4.13}$$

where ξ represents the worker's bargaining power.[15]

On-the-Job Search and Poaching I adopt the sequential auction framework of Postel-Vinay and Robin (2002) to model the wage determination during on-the-job search. The firm's participation constraint (4.12) implies that the highest wage rate that firm ρ can offer to worker Ω is its marginal product of labor, $z\rho$. Because $W(\Omega, \rho, w)$ is increasing in the wage rate, $W(\Omega, \rho, z\rho)$ is the highest value that firm ρ can offer to worker Ω. I define this as the the maximal employment value.

Definition 3. *The maximal employment value, denoted by $\overline{W}(\Omega, \rho)$, is the value of worker Ω being employed by firm ρ when the wage rate is set equal to the marginal product of labor $z\rho$,*

$$\overline{W}(\Omega, \rho) = W(\Omega, \rho, z\rho). \tag{4.14}$$

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

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

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

First, if $\rho > \rho'$, the worker currently employed at job ρ' will transfer to job ρ and the old job ρ' will become the negotiation benchmark due to Bertrand competition. This grants the worker an outside

[15] Note that the usual linear sharing rule (Pissarides, 1994) is no longer a solution to the Nash Bargaining problem due to the introduction of several features, e.g., risk-averse agents, labor supply, and on-the-job search. Therefore, the wage rate is determined by solving the full maximization problem.

option value that is equal to the maximal employment value of ρ'. The new wage rate will be set according to

$$w^e(\Omega, \rho, \rho') = \underset{w}{\operatorname{argmax}}[W(\Omega, \rho, w) - \overline{W}(\Omega, \rho')]^{\xi} J(\Omega, \rho, w)^{1-\xi}, \tag{4.15}$$

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

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

$$w^e(\Omega, \rho', \rho) = \underset{w}{\operatorname{argmax}}[W(\Omega, \rho', w) - \overline{W}(\Omega, \rho)]^{\xi} J(\Omega, \rho', w)^{1-\xi}. \tag{4.16}$$

Reservation Productivity Equation (4.15) nests equation (4.13), if we treat an unemployed agent Ω as being employed in a fictitious job $\rho_u(\Omega)$, such that $\overline{W}(\Omega, \rho_u(\Omega)) = U(\Omega)$. Hence, the negotiation benchmark for an unemployed agent is $\rho_u(\Omega)$ and the wage rate satisfies

$$w^u(\Omega, \rho) = w^e(\Omega, \rho, \rho_u(\Omega)). \tag{4.17}$$

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

Definition 4. *The reservation productivity for an unemployed agent Ω is a fictitious job with productivity $\rho_u(\Omega)$ such that the agent is indifferent between accepting the job or staying unemployed, i.e.,*

$$\overline{W}(\Omega, \rho_u(\Omega)) = U(\Omega). \tag{4.18}$$

For any reservation productivity $\rho_u(\Omega)$, the corresponding marginal product of labor, $Az\rho_u(\Omega)$, can be considered as the reservation wage of an unemployed agent Ω. It is difficult to obtain a formal proof on how the reservation productivity changes with the level of student loan debt, but the intuition is exactly the same as what is discussed in section 3. Therefore, indebted agents set lower reservation productivity and search for a shorter time.

4.4 Repayment, Default, and Taxes

Repayment As noted in section 2, most federal student loan borrowers repay under the fixed repayment plan during my sample period. Therefore, I only consider the fixed repayment plan when estimating the model.

I assume that student loan borrowers make fixed payments every period after college graduation until the 10th year. This is consistent with the terms specified in the standard 10-year fixed repayment plan. The interest rate for the fixed repayment plan is variable before July 1, 2006, and fixed thereafter.

For simplicity, I consider a fixed interest rate r^s. Hence, the annual payment is given by:

$$y_t^{fix} = \frac{r^s}{(1+r^s)\left[1 - \frac{1}{(1+r^s)^{10-(t-1)}}\right]} s_t, \quad \text{for } t <= 10. \tag{4.19}$$

When conducting my quantitative analyses, I consider what would happen if borrowers are allowed to enroll in IBR. In reality, the interest rate does not depend on repayment plans. IBR passed by Congress in 2009 has three main features: (1) borrowers are required to repay 15% of their discretionary income, which is defined as the difference between pre-tax income and 150% of the poverty guideline;[16] (2) the monthly payment is capped by the amount under the 10-year fixed repayment plan, based on the outstanding loan balance when the borrower initially entered IBR. This implies that the repayment under IBR is never more than the 10-year fixed repayment plan amount. (3) the repayment period is 25 years and the remaining balance will be forgiven at the end. To reflect these features, I model the annual payment under IBR by:

$$y_t^{ibr} = \min\Big(0.15\max(w_t l_t - pov, 0), \quad y_1^{fix}, \quad s_t\Big), \quad \text{for } t <= 25, \tag{4.20}$$

where minimizing over the term y_1^{fix} captures the repayment cap, and the term s_t ensures that the borrower will never repay more than the amount owed. I set the poverty guideline based on the average individual poverty level for the 48 contiguous states (excluding Hawaii and Alaska) and the District of Columbia. The inflation-adjusted poverty level is quite stable over time, and the 150% poverty level is set to be $pov = \$15,650$ corresponding to its average value between 1997-2013 measured in 2009 dollars.

Default Unlike other loans, student loans are practically non-dischargeable after default (and bankruptcy). I assume that borrowers incur a cost η if they default on their loans. In the year following the default, borrowers negotiate a new repayment plan that has the same repayment period as the fixed repayment plan.[17] Modeling default in this way ensures that default time is not a state variable. As a result, in my model default delays the repayment by one year, but the payment in the following years will increase. Moreover, I do not allow repeated default given the complexity of the current setup.[18] If agents default at time t_{def}, the annual payment thereafter is

$$y_t^{def} = \begin{cases} 0, & \text{for } t = t_{def}. \\ \frac{r^s}{(1+r^s)\left[1 - \frac{1}{(1+r^s)^{10-(t-1)}}\right]} s_t, & \text{for } t_{def} < t <= 10. \end{cases} \tag{4.21}$$

[16] Borrowers are required to repay 10% of their discretionary income if they are new borrowers on or after July 1, 2014. The repayment period is 20 years for new borrowers.

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

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

It is also possible that deeply indebted agents may not be able to honor the payment if they have been unemployed for a long time. While this is theoretically possible, it rarely happens in simulations because very few agents take on large debt. If this involuntary delinquency happens, I assume that agents have to repay all earnings (up to a consumption floor specified below) in every following period until all the past payments required under the fixed repayment plan are repaid.

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

$$\tilde{E} = \varkappa (wl)^{1-\tau}, \tag{4.22}$$

where wl is the pre-tax wage income.

In the U.S., UI benefits are also taxable, thus the formula for unemployed workers is $y = \varkappa \theta^{1-\tau}$. 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 rate of progressivity because it reflects the elasticity of after-tax income with respect to pre-tax income. When $\tau = 0$, the tax system has a flat marginal tax rate $1 - \varkappa$, and when $\tau > 0$, the tax system is progressive.

In the baseline simulation, I assume that the tax revenue is collected to finance the UI benefits and a non-valued public consumption good G:

$$(1-\overline{u})T \iint wl[1-\varkappa(wl)^{-\tau}]\phi^e(\Omega,\rho)d\Omega d\rho = \overline{u}T \int \varkappa\theta^{1-\tau}\phi^u(\Omega)d\Omega + G. \tag{4.23}$$

When conducting the quantitative analyses in section 6, I take the value of G from the baseline as exogenously given. When evaluating IBR, I adjust the parameter $\varkappa$ to balance the budget:

$$(1-\overline{u})T \iint wl[1-(\varkappa-\Delta\varkappa)(wl)^{-\tau}]\phi^e(\Omega,\rho)d\Omega d\rho = \overline{u}T \int (\varkappa-\Delta\varkappa)\theta^{1-\tau}\phi^u(\Omega)d\Omega + G + \text{Forgiveness}. \tag{4.24}$$

The implied value of $\Delta\varkappa$ captures the increase in overall tax level in order to finance the debt forgiveness.

4.5 Value Functions

The timing of events in the labor market is the following. At the beginning of age t, firms post vacancies at cost ν and existing matched jobs separate at rate κ. Vacancies and agents meet each other at Poisson rates, λ^u, λ^e, and q. Agents then make default decisions (if not yet in default) and repay student loan debt. At the end of age t, unemployed agents receive UI benefits θ, and employed agents supply labor l and negotiate wage rates w with firms based on their negotiation benchmarks' productivity. After receiving income, agents pay income taxes and choose consumption c_t. Following Hubbard, Skinner and Zeldes (1995), I introduce a consumption floor $\underline{c}$ to model means-tested benefits.

Instead of using the wage rate w as a state variable for an employed worker, the discussions in subsection 4.3 suggest that the negotiation benchmark's productivity is a natural state variable. Therefore, the state variables are worker characteristic Ω, job productivity ρ, and the negotiation benchmark's productivity ρ'. The value of an employed worker and the value of a job immediately after search and matching can be written as $W(\Omega,\rho,\rho')$ and $J(\Omega,\rho,\rho')$ before default. I add superscript d to represent value functions and variables after default. Below I present the value functions of each participant after default. The value functions for the non-default case are presented in Online Appendix E.1.

Unemployed Workers An unemployed worker who has defaulted has value

$$\begin{aligned} U^d(\Omega_t) = \max_{c_t,l_t} \quad & u(c_t,l_t) + \beta\left[\lambda^u \int_{x\geq\rho_u^d} W^d(\Omega_{t+1},x,\rho_u^d)dV(x) + [1-\lambda^u+\lambda^u V(\rho_u^d)]U^d(\Omega_{t+1})\right], \\ \text{subject to} \quad & b_{t+1} = (1+r)(b_t - y_t^{def}) + \varkappa\theta^{1-\tau} - c_t, \\ & s_{t+1} = (1+r^s)(s_t - y_t^{def}), \\ & c_t \geq \underline{c}, \\ & b_{t+1} \geq 0, \end{aligned} \tag{4.25}$$

where r is the interest rate on deposit and ρ_u^d is the reservation productivity for the unemployed worker Ω_{t+1} who has defaulted. In the objective function, the term $u(c_t,l_t)$ represents the realized utility at age t; the first term in the squared bracket represents the expected value of entering the labor market at age $t+1$; and the second term represents the value of staying unemployed, which could happen when the productivity draw is less than the reservation productivity, $\rho_u^d(\Omega_{t+1})$.

Following Acemoglu and Shimer (2000) and Krusell, Mukoyama and Sahin (2010), I impose the borrowing constraint, $b_{t+1}\geq 0$, so that agents do not have access to other credit apart from student loans. Relaxing this constraint enables the model to parsimoniously capture other types of loans, e.g., consumption loans. I provide a sensitivity analysis for the credit limit in Online Appendix G.

Employed Workers The value of defaulted employed workers at job ρ, with negotiation benchmark ρ', is given by

$$\begin{aligned} W^d(\Omega_t,\rho,\rho') = \max_{c_t,l_t} \quad & u(c_t,l_t) + \beta\Bigg\{\kappa U^d(\Omega_{t+1}) + (1-\kappa)\Bigg[[1-\lambda^e+\lambda^e V(\rho')]W^d(\Omega_{t+1},\rho,\rho') \\ & +\lambda^e\Bigg(\int_{x\geq\rho} W^d(\Omega_{t+1},x,\rho)dV(x) + \int_{\rho'<x<\rho} W^d(\Omega_{t+1},\rho,x)dV(x)\Bigg)\Bigg]\Bigg\}, \\ \text{subject to} \quad & b_{t+1} = (1+r)(b_t - y_t^{def}) + \varkappa[w^{e,d}(\Omega_t,\rho,\rho')l_t]^{1-\tau} - c_t, \\ & s_{t+1} = (1+r^s)(s_t - y_t^{def}), \\ & c_t \geq \underline{c}, \\ & b_{t+1} \geq 0, \end{aligned} \tag{4.26}$$

In problem (4.26), the first term in the curly bracket captures exogenous job separations at rate κ, in which case the worker becomes unemployed in period $t+1$, and receives $U^d(\Omega_{t+1})$. The job is maintained with probability $1-\kappa$, and the three cases resulting from on-the-job search are captured by the second term. With probability λ^e, the worker gets contacted by a new job x. If the new job's productivity x is larger than the current job ρ, the worker moves to the new job and her current job becomes the new negotiation benchmark. If she samples a job with productivity larger than the current negotiation benchmark but smaller than her current job's productivity, she will stay at the current job with an updated negotiation benchmark. Finally, she may stay with the current job with an unchanged negotiation benchmark either when she is not poached by a new job or the new job's productivity is lower than her current negotiation benchmark.

Filled Jobs and Match Surplus The value of a job filled by a worker who has defaulted is,

$$\begin{aligned} J^d(\Omega_t, \rho, \rho') &= [Az_t\rho - w^{e,d}(\Omega_t, \rho, \rho')]I^d(\Omega_t, \rho, \rho') \\ &+ \beta(1-\kappa)\left[\lambda^e \int_{\rho' < x < \rho} J^d(\Omega_{t+1}, \rho, x)dV(x) + [1 - \lambda^e + \lambda^e V(\rho')]J^d(\Omega_{t+1}, \rho, \rho')\right], \end{aligned} \tag{4.27}$$

where the first term in the square bracket represents the case in which the poaching job results in a wage increase by raising the negotiation benchmark. The second term represents the case in which the worker does not receive a competitive outside offer.

The match surplus relative to unemployment is given by

$$Surplus^d(\Omega_t, \rho, \rho') = W^d(\Omega_t, \rho, \rho') - U^d(\Omega_t) + J^d(\Omega_t, \rho, \rho'). \tag{4.28}$$

4.6 Stationary Competitive Equilibrium

To close the model, I describe the free entry condition and define the stationary equilibrium.

Free Entry Condition The cost of vacancy creation is ν. Following Lise, Meghir and Robin (2016), I assume that once the firm pays the cost, a job is created with productivity ρ being randomly drawn from a CDF $F(\rho)$. Vacancies last for one period; thus if the created vacancy is not filled by a worker in the current period, the vacancy will be destroyed. This immediately implies that the equilibrium vacancy distribution $V(\rho)$ is the same as $F(\rho)$. In equilibrium, the free entry condition requires that the cost of vacancy creation is equal to its expected value,

$$\begin{aligned} \frac{\nu}{q} &= \frac{\overline{u}Th^u}{H}\left[\iint_{\rho > \rho_u^d} J^d(\Omega, \rho, \rho_u^d)\phi^u(\Omega, 1)d\Omega dF(\rho) + \iint_{\rho > \rho_u} J(\Omega, \rho, \rho_u)\phi^u(\Omega, 0)d\Omega dF(\rho)\right] \\ &+ \frac{(1-\overline{u})Th^e}{H}\left[\iiint_{\rho > \rho'} J^d(\Omega, \rho, \rho')\phi^e(\Omega, \rho', 1)d\Omega d\rho' dF(\rho) + \iiint_{\rho > \rho'} J(\Omega, \rho, \rho')\phi^e(\Omega, \rho', 0)d\Omega d\rho' dF(\rho)\right], \end{aligned} \tag{4.29}$$

where $\phi^u(\Omega, d)$ represents the PDF conditional on whether unemployed agents have defaulted ($d = 1$) or not ($d = 0$). Thus, $\phi^u(\Omega) = \phi^u(\Omega, 0) + \phi^u(\Omega, 1)$. Similarly, for employed agents, $\phi^e(\Omega, \rho) = \phi^e(\Omega, \rho, 0) + \phi^e(\Omega, \rho, 1)$.

Equation (4.29) states that a new vacancy meets an agent with probability q. Conditional on a meeting, the vacancy meets an unemployed worker with probability $\overline{u}Th^u/H$ and is filled if the vacancy's productivity is above the reservation productivity, $\rho > \rho_u(\Omega)$. The vacancy meets an employed worker with probability $(1-\overline{u})Th^e/H$ and is filled if the vacancy's productivity is above the worker's current job's productivity, $\rho > \rho'$.

In the stationary equilibrium, the flows in and out of unemployment balance each other out. The unemployment rate $\overline{u}$ is determined by the following equation:

$$(1-\overline{u})\kappa = \overline{u}\lambda^u \left[\int [1 - V(\rho_u^d)]\phi^u(\Omega, 1)d\Omega + \int [1 - V(\rho_u)]\phi^u(\Omega, 0)d\Omega \right], \tag{4.30}$$

where the LHS represents the flow into unemployment due to exogenous separations of employed agents at rate κ, and the RHS represents the flow into employment when unemployed agents contact jobs whose productivity is above their reservation productivity.

Equilibrium Definition Below I define the stationary competitive equilibrium.

Definition 5. *The stationary competitive equilibrium consists of stationary distributions of unemployed agents, $\phi^u(\Omega)$, employed agents $\phi^e(\Omega, \rho)$, vacancies $V(\rho)$, the number of vacancies N_v, and unemployment rate $\overline{u}$, such that:*

(1). *The job contact rates for agents and firms are determined by the Cobb-Douglas meeting technology according to (4.10-4.11).*

(2). *All unemployed agents Ω make consumption and default decisions by solving problem (4.25) depending on their default status.*

(3). *All employed agents Ω at job ρ with negotiation benchmark ρ' receive wage income and make consumption, labor supply, and default decisions by solving problem (4.26) depending on their default status.*

(4). *Wage rates, $w^e(\Omega, \rho, \rho')$ and $w^{e,d}(\Omega, \rho, \rho')$, are determined by Nash bargaining specified in (4.15) and (4.17).*

(5). *The equilibrium number of vacancies N_v and the vacancy distribution $V(\rho)$ are determined by the free entry condition (4.29).*

(6). *The equilibrium unemployment rate $\overline{u}$ is determined to balance flows in and out of unemployment, as specified in (4.30).*

5 Data, Estimation, and Validation Tests

In this section, I first introduce the data. Then I present the estimation procedures of my quantitative model. Finally, I conduct two validation tests to check the external validity of the model.

5.1 Data

My empirical analysis uses panel data from the National Longitudinal Survey of Youth 1997 (NLSY97). This is a nationally representative survey conducted by the Bureau of Labor Statistics. In round 1, 8,984 youths were initially interviewed in 1997. Follow-up surveys were conducted annually. Almost 83% (7,423) of the round 1 sample were interviewed in round 15 (2011-2012). Youths were born between 1980 and 1984. Their ages ranged from 12 to 18 in round 1 and were 26 to 32 in round 15. The survey contains extensive information on each youth's labor market behavior and documents the amount of education loans borrowed during college, which makes NLSY97 an ideal data set for studying the implications of student loan debt on job search decisions.

My analysis focuses on high school and college graduates. I do not include college dropouts because it is not clear when they enter the labor market. I drop youths who have ever served in the military or attended graduate schools because they are not in the same position as the other youths in my sample when it comes to making labor market decisions. I also drop youths who received the bachelor's degree before 1997 due to the lack of labor market information upon college graduation. This leaves me with a sample of 1,721 high school graduates and 1261 college graduates. I construct the variables used in structural estimation following the steps illustrated in Online Appendix A.

5.2 Estimation

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

5.2.1 Parametrization

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

$$\mho_{b_0}(b_0) = \frac{1}{\zeta}\left(1 + \varphi\frac{b_0 - \underline{b}}{\zeta}\right)^{-\frac{1+\varphi}{\varphi}}. \tag{5.1}$$

The marginal distribution of talent follows a flexible beta distribution with parameters f_1^a and f_2^a. To capture the potential correlation between initial wealth and talent, I use the Frank copula, where the single parameter ϑ governs the dependence between the CDF of the marginal distribution of wealth,

$\mho_{b_0}(b_0)$, and the CDF of talent, $\mho_a(a)$[19]:

$$C(u,v) = \mathbb{P}(\mho_{b_0}(b_0) \leq u, \mho_a(a) \leq v) = -\frac{1}{\vartheta}\log\left[1 + \frac{(e^{-\vartheta u}-1)(e^{-\vartheta v}-1)}{e^{-\vartheta}-1}\right]. \tag{5.2}$$

I assume that the monetary cost k and non-monetary utility 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 monetary costs of college entry are non-negative, I set $k = 0$ for negative draws.

Following Lise, Meghir and Robin (2016) and Jarosch (2015), I assume that job productivity follows a flexible Beta distribution on support $[0, 1]$ with parameters f_1^{ρ}, f_2^{ρ}.

5.2.2 Externally Determined Parameters

Table 1 presents the values for externally determined parameters. The three parameters governing the initial wealth distribution, $(\underline{b}, \zeta, \varphi)$, are estimated directly using MLE to match the empirical distribution of wealth (see panel A of Figure 3).

Table 1: Parameters determined outside the model.

Parameter	Description	Value	Source
$\underline{b}$	Location parameter	0	Estimated from NLSY97
ζ	Scale parameter	223.0	Estimated from NLSY97
φ	Shape parameter	1.52	Estimated from NLSY97
$\varkappa$	Overall tax level	2.17	Estimated from March CPS 1997-2008
τ	Rate of tax progressivity	0.11	Estimated from March CPS 1997-2008
γ	Risk aversion	3	Hubbard, Skinner and Zeldes (1995)
σ	Elasticity of labor supply	2.59	Keane (2011), Frisch elasticity=0.33
r	Annual risk-free rate	4.5%	Real interest rate between 1997-2008
r^s	Interest rate on student loans	6.6%	Ionescu (2009), risk premium=2.1%
β	Discount factor	0.96	Standard practice
ω	Meeting technology	0.5	Pissarides and Petrongolo (2001)
ξ	Bargaining parameter	0.5	Hosios condition
θ	UI benefits	\$8,000	40% of average 6-month wage income
$\underline{c}$	Consumption floor	\$900	AFDC, food stamps, and WIC
T	Number of years working	38	Real-life working age of 23 to 60

The fiscal parameters $\varkappa$ and τ are identified using the regression coefficients obtained from regressing log individual after-tax earnings $\tilde{E}_i$ on log individual pre-tax earnings E_i:

$$log(\tilde{E}_i) = log(\varkappa) + (1-\tau)log(E_i) + \varepsilon_i \tag{5.3}$$

The pre-tax earnings data are obtained from March CPS 1997-2008. I use the NBER's TAXSIM program

[19] The use of 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.

to compute after-tax earnings as earnings minus all federal and state taxes. The estimated values are $\varkappa = 2.17$ and $\tau = 0.11$.

I take advantage of the existing findings to determine the values of γ and σ. I choose γ according to the literature that is most closely related to this paper. In particular, I set $\gamma = 3$ consistent with the precautionary savings literature (e.g., Hubbard, Skinner and Zeldes, 1995). Since the value of γ is the most important parameter that determines the quantitative implication of the debt burden, I provide a sensitivity analysis using other values of γ in Online Appendix G. The tax-modified Frisch elasticity of labor supply with respect to pre-tax wage rates is $(1-\tau)/(\sigma+\tau)$. Thus I set $\sigma = 2.59$, which implies that the tax-modified Frisch elasticity is 0.33, broadly consistent with microeconomic evidence (Keane, 2011). The elasticity of labor supply determines the distortionary effect of IBR, I provide a sensitivity analysis using other values of σ in Online Appendix G.

I set the annual risk-free rate to be $r = 4.5\%$, corresponding to the average real interest rate in the U.S. between 1997-2008 (source: World Development Indicators). I set the interest rate on student loans to be $r_s = 6.6\%$, which implies a risk premium consistent with the annualized mark-up over the Treasury bill rate, 2.1%, set by the government for subsidized loans issued before 2006 (Ionescu, 2009). Following the standard practice, I set the annual discount rate to be $\beta = 0.96$.

I set the matching parameter to be $\omega = 0.5$, which lies in the middle of existing estimates using information on the flow of hires and the stock of unemployment and job vacancies (Pissarides and Petrongolo, 2001). One way to determine the bargaining parameter is to follow the Hosios efficiency condition (Shimer, 2005; Krusell, Mukoyama and Sahin, 2010), thus I set the bargaining parameter to have the same value $\xi = 0.5$.

In the U.S., UI benefits generally pay eligible workers between 40%-50% of their previous pay. The standard time-length of unemployment compensation is 6 months, although during the recent recession, Congress passed the emergency benefit program to extend the duration to 73 weeks. In my model, unemployed agents receive UI benefits every year. Therefore, I choose a relatively lower value of UI benefits to account for this discrepancy. I set $\theta = \$8,000$, which amounts to roughly 40% of the average 6-month income.

Means-tested benefits include Aid to Families with Dependent Children (AFDC), food stamps, and Women, Infants, Children (WIC). In my sample, the percent of youths who had ever received AFDC, food stamps, and WIC by 2013 are 1.3%, 8.4%, and 6.3%. About 11.5% of youths had ever received any means-test benefits during my sample period, with a median monthly benefit level of $150. Because the take-up rate is far from universal, following Kaplan (2012), the annual consumption floor is set to be $900, half of the median value of means-tested benefits.

Between 2002-2012, the average retirement age is around 60. I set $T = 38$, which corresponds to a real-life working age of 23 to 60.

5.2.3 Internally Estimated Parameters

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

Labor Market Moments Parameters A_0 and A_1 in equation (4.1) determine the labor productivity of high school and college graduates. Their values are identified to match the average wage income among high school and college graduates.

Table 2: Model fit for targeted moments.

Labor Market Moments	**Model**	**Data**
Mean of wage income among high school graduates in first 5 years	\$26,364	\$26,736
Mean of wage income among college graduates in first 5 years	\$40,354	\$40,619
Mean of employment duration (year)	2.2	2.2
Mean of unemployment duration (week)	27.2	27.2
Mean of job tenure (year)	1.5	1.5
Variance of log wage income	0.180	0.155
Skewness of log wage income	0.068	-0.174
Mean of log wage increase upon job-to-job transitions	0.132	0.150
Variance of log wage increase upon job-to-job transitions	0.023	0.042
Vacancy to unemployment ratio	0.409	0.409
Average hours worked per year	1,731	1,729
Life-cycle earnings profile	see Figure 2	
College and Debt Moments	**Model**	**Data**
Fraction of agents with a bachelor's degree	41.4%	42.2%
Unexplained variance in college entry decisions $(1 - R^2)$	0.64	0.64
Correlation between talent and student debt	0.05	0.04
Default rate	9.65%	9.26%
Student debt distribution upon college graduation	see Figure 3	

Note: This table presents model fit for targeted moments. The life-cycle earnings profile is constructed using March CPS 1997-2008 data. The default rate is constructed by Yannelis (2015) using a random 1% sample of NSLDS. The vacancy to unemployment ratio is constructed using JOLTS data between 2001-2013. The remaining moments are constructed using the sample from NLSY97.

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

The search intensity during employment h^e is normalized to be 1. The search intensity during unemployment h^u and the parameter governing matching efficiency χ are identified from the average unemployment duration and the average duration of job tenure. In the data, the average unemployment duration is 27.2 weeks and jobs last for about 1.5 years on average. Because job separations could either result in a transition into unemployment or a transition into another job, the small difference between the average employment duration and the average job tenure implies that on-the-job search is much less efficient compared to searching during unemployment.[20]

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

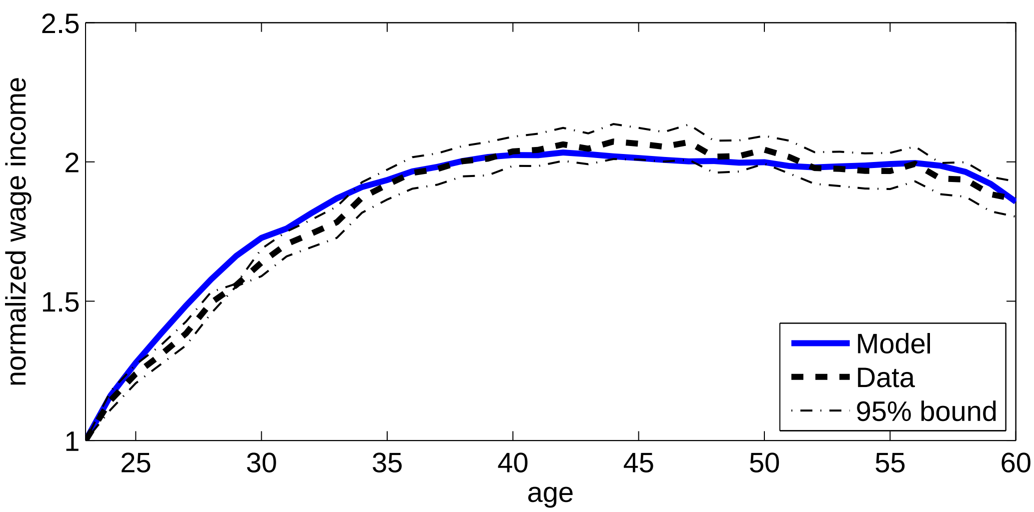
[20]In the extreme case where the average employment duration is equal to the average job tenure, there is no job-to-job transitions, which implies the absence of on-the-job search. On the other hand, if the average job tenure is much shorter than the average employment duration, it means most of the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

productivity of matched worker job pair is given by $z\rho$. The symmetric roles played by worker productivity z and job productivity ρ suggest that it is impossible to separately identify the parameters f_1^a, f_2^a governing the marginal distribution of talent and the parameters f_1^ρ, f_2^ρ governing the marginal distribution of vacancy's productivity if we only use moments from the cross-sectional log wage income distribution. Note that upon job-to-job transitions, worker productivity remains the same but job productivity increases. Therefore, the mean and variance of log wage increase upon job-to-job transitions are informative about the value of parameters f_1^ρ, f_2^ρ. In the data, there are unmodeled sources of variation that affect the dispersion of the log wage income distribution, thus I adjust for these sources of variation when constructing the variance and skewness (see Online Appendix A.3). The cross-sectional log wage income residuals have variance 0.155 and skewness -0.174. The log hourly wage rate rises by about 15.0% upon job-to-job transitions on average with a variance of 0.042.

The flow cost of vacancy creation ν is identified from the vacancy to unemployment ratio. The Job Openings and Labor Turnover Survey (JOLTS) collected job openings information since December 2000 in the United States. I estimate the vacancy to unemployment ratio to be 0.409 using the data between 2001-2013. This estimate is smaller than the estimate of 0.539 provided by Hall (2005), who uses data between 2001-2002.

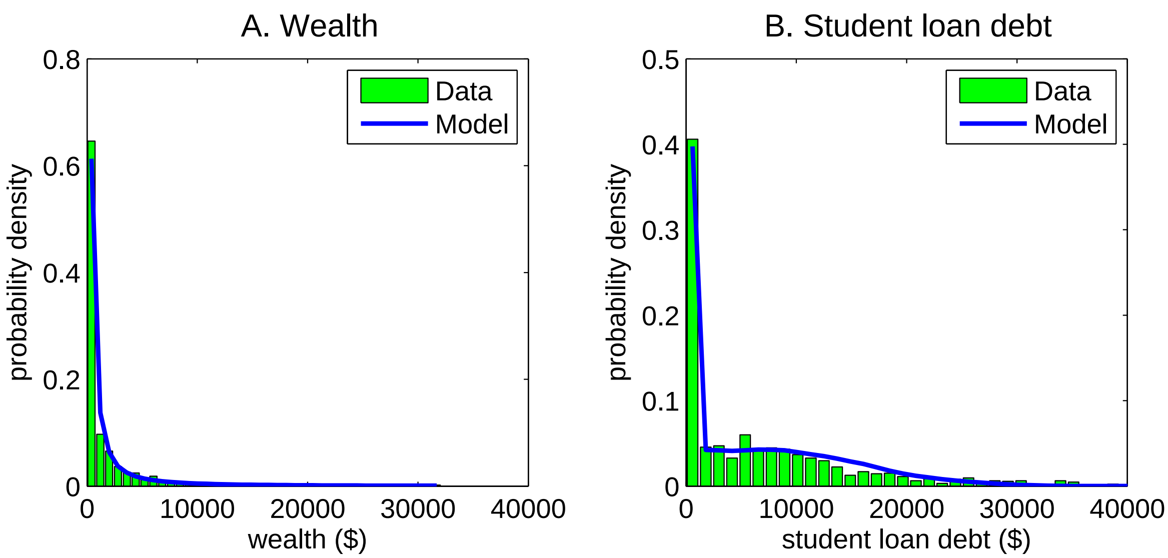
Parameter ϕ is a scale factor of labor supply, which is identified from the average number of hours worked in each year. In the data, people with full-time jobs work for roughly 1,729 hours per year on average.

Parameters μ_0, μ_1, μ_2, and μ_3 are identified to match the average wage income in each year between ages 23-60. Because NLSY97 does not provide individual labor market histories at this length, I construct the life-cycle earnings profile using March CPS 1997-2008 data. I use 38 moments to capture the full life-cycle earnings profile (see Figure 2).



Note: This figure compares the targeted moments of life-cycle earnings profiles between model and data. The solid line represents the earnings profile generated by the model. The dashed line represents the earnings profile in the data, constructed using March CPS 1997-2008 data.

Figure 2: Comparing life-cycle earnings profiles between model and data.



Note: This figure plots the model-generated marginal distribution of wealth and student loan debt. I assume that the exogenous marginal distribution of wealth follows a generalized Pareto distribution, whose parameters are directly estimated using MLE. The endogenous student debt distribution upon college graduation is generated by model simulations.

Figure 3: The distribution of initial wealth and student loan debt upon college graduation.

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

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

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

The two parameters (μ_k, σ_k) capturing the net-monetary costs of college study are identified to match the distribution of student loan debt upon college graduation. In the data, about 61.6% of college graduates have outstanding student loans with a mean of $11,873. To fully account for the variation, I use 40 equally spaced moments to capture the empirical histogram of student debt distribution (see panel B of Figure 3).[21]

[21] 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 $12,505. Data from IPEDS documents that during 2001-2004, the annual college tuition for a four-year college is between $989-$2,520 depending on state category and the national average cost of room and board is $6,532 (Johnson, 2013). This implies a total college cost of $10,488-$16,612.

Estimation In total, I choose 93 moments that are sufficient to identify the 21 parameters. I estimate the set of parameters Ξ using MSM:

$$\hat{\Xi} = \underset{\Xi}{\operatorname{argmin}}\, L(\Xi) \tag{5.4}$$

Table 3: Parameters estimated jointly using MSM.

	Labor Market Parameters	Value	Standard Error
A_0	Productivity (high school)	25.1	3.1
A_1	Productivity (college)	40.0	2.6
κ	Exogenous job separation rate	0.31	0.04
h^u	Search intensity during unemployment	4.82	0.56
h^e	Search intensity during employment	1	N/A
χ	Matching efficiency	0.69	0.10
f_1^a	Talent distribution	1.52	0.35
f_2^a	Talent distribution	0.45	0.11
f_1^ρ	Vacancy productivity distribution	1.41	0.28
f_2^ρ	Vacancy productivity distribution	0.52	0.09
ν	Flow cost of vacancy creation	49,535	3,569
ϕ	Labor supply scaling factor	6.3×10^{-8}	0.3×10^{-8}
μ_0	Constant term in worker's ability	0.836	0.007
μ_1	Linear term in worker's ability	0.087	0.002
μ_2	Square term in worker's ability	-3.9×10^{-3}	0.2×10^{-3}
μ_3	Cubic term in worker's ability	5.5×10^{-5}	0.4×10^{-5}
	College and Debt Parameters	**Value**	**Standard Error**
μ_e	Mean of non-monetary college cost	3.0×10^{-9}	0.6×10^{-9}
σ_e	Standard deviation of non-monetary college cost	5.1×10^{-8}	1.0×10^{-8}
ϑ	Correlation between talent and initial wealth	0.47	0.15
η	Default cost	3.0×10^{-8}	0.4×10^{-8}
μ_k	Mean of monetary college cost ($)	12,505	1,238
σ_k	Standard deviation of monetary college cost ($)	15,406	2,429

Note: This figure presents parameter values estimated jointly using MSM following the two-step estimation procedure detailed in Online Appendix C. Standard errors are computed by bootstrapping.

The objective function is given by

$$L(\Xi_2) = [\hat{m}_N - \hat{m}_S(\Xi)]^T \hat{\Theta}^{-1} [\hat{m}_N - \hat{m}_S(\Xi)]. \tag{5.5}$$

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 matched well (see Table 2).

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

$$Q(\hat{\Theta}) = (\nabla^T \hat{\Theta} \nabla)^{-1} \nabla^T \hat{\Theta} \widehat{COV} \hat{\Theta}^T \nabla (\nabla^T \hat{\Theta}^T \nabla)^{-1}, \tag{5.6}$$

where $\widehat{COV}$ is the variance-covariance matrix of $\hat{m}_N$; and $\nabla = \frac{\partial \hat{m}_S(\Xi)}{\partial \Xi}|_{\Xi=\hat{\Xi}}$ is the Jacobian matrix of the simulated moments evaluated at the estimated parameters.[22] The first derivatives are calculated numerically by varying each parameter's value by 1%. The standard errors of $\hat{\Xi}_2$ are given by the square root of the diagonal elements of $Q(\hat{\Theta})$. Table 3 presents the internally estimated parameters.

5.3 Validation Tests

I conduct two validation tests to provide a type of out-of-sample evaluation of the structure imposed by the quantitative model. First, I check whether the model can replicate several non-targeted moments in the data. Second, I check whether the model can produce several elasticity measures that are consistent with micro estimates in related literature.

5.3.1 Non-Targeted Moments

As an initial exercise, I check whether the model can replicate the difference in average wage income between non-borrowers and borrowers observed in the data. Figure 4 compares the average wage income after college graduation for non-borrowers and all borrowers in the data and model.[23]

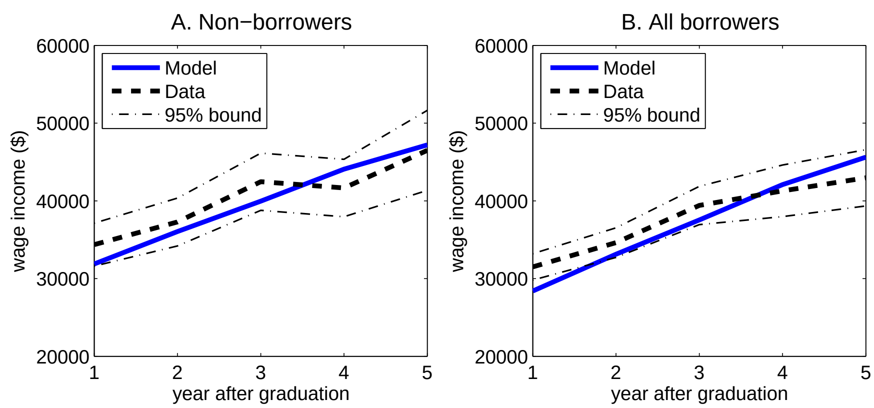


Figure 4: Comparing non-targeted moments: annual wage income in the first five years.

Next, I check whether the model can replicate the regression coefficients observed in the data. Based on the NLSY97 sample, I first explore the implication of debt on job search decisions by regressing the duration of the first unemployment spell (Dur_i) after college graduation on the amount of student loan debt (s_i) and control variables X_i including parental wealth, parental education, gender, race, AFQT score, marital status, the cubic age polynomials, and the county of residence in the graduation year:

$$Dur_i = \alpha + \beta_1 s_i + \beta_2 X_i + \varepsilon_i. \tag{5.7}$$

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

[23] When constructing the moments in the data, I use adjusted data after partialling out the unmodelled covariates that are potentially correlated with both wage income and student loan debt (see Online Appendix A.3).

Table 4: Comparing reduced-form regression estimates: actual data vs simulated data.

	Uemp. duration		**Wage income**	
	First spell	First year	Second year	Third year
Actual data				
"Impact" coefficient	-2.08***	-2,067**	-2,152**	-2,619**
Standard error	(0.68)	(890)	(865)	(1,309)
Simulated data				
"Impact" coefficient	-1.83**	-2,411**	-2,122*	-1,810*
Standard error	(0.70)	(914)	(1,254)	(1,121)
Chow test p-value	0.81	0.83	0.85	0.83

Note: The "impact coefficient" is the coefficient on student loan debt, recorded in units of $10,000. The regressions using actual data also control for parental wealth, parental education, gender, race, AFQT score, marital status, the cubic age polynomials, and the county of residence in graduation year. The Chow test is used to test whether the coefficients from actual data and simulated data are equal to each other. ***, **, indicate significance at the 1 and 5 percent level. Full regression tables of actual data are in Online Appendix A.4.

I then explore the implication of debt on wage income by regressing the annual wage income in the first three years after college graduation on the amount of student loans:

$$Wage_{i,t} = \alpha_t + \beta_{1,t} s_i + \beta_{2,t} X_{i,t} + \varepsilon_{i,t}, \quad \text{for } t = 1, 2, 3. \tag{5.8}$$

Turning to the model, I simulate the same number of college graduates over their life cycles based on the equilibrium policy functions, job contact rates, randomly drawn wage offers from $F(\rho)$, and separation shocks at rate κ. I do this 500 times to create 500 simulated datasets. I regress the duration of the first unemployment spell and annual wage income on the amount of student loan debt controlling for individual talent for each simulated dataset to construct the mean and standard errors of the estimates. Table 4 compares the regression results of the model to the data and shows that the model does generally quite well in replicating the results. In particular, a $10,000 increase in the amount of student loans reduces unemployment duration by about 1.8 weeks, and reduces the annual wage income by about $2,000 in the first three years after college graduation. The final row reports the p-value of the Chow test, where the null is no structural break between the actual and simulated data. The Chow test shows formally that the regression estimates from the model are statistically similar to those in the data at a 5% significance level.

5.3.2 Comparison to Micro Estimates

I now check whether the model can produce elasticity measures that are consistent with the micro estimates in related literature. When conducting the following experiments, I focus on partial-equilibrium counterfactual simulations in which the job contact rates and fiscal parameters are fixed, so that the elasticities are estimated in a context consistent with the setting in which the micro estimates are obtained. Note that all the elasticities I structurally estimate are based on global elasticities, although some of the micro estimates are local elasticities (see Table 5).

I begin by examining whether the model-implied elasticity of unemployment duration with respect to UI benefits matches the micro estimates using U.S. data. The positive effect of unemployment insurance

Table 5: Comparison to micro estimates.

	Model	**Micro Estimates**	**Source**
UI on unemp. dur.	0.49	0.35-0.9	Card et al. (2015)
UI on res. wage	6.4%	4%	Feldstein and Poterba (1984)
Credit on unemp. dur.	0.7 week	0.15-3 weeks	Herkenhoff, Phillips and Cohen-Cole (2016)
Credit on reemploy. wage	1.4%	0.8%-1.7%	Herkenhoff, Phillips and Cohen-Cole (2016)

Note: This figure compares the model-implied structural estimates with micro estimates. The elasticity of unemployment duration with respect to UI benefits is estimated by simulating the counterfactual with UI benefits θ being increased by 25%, from \$8000 to \$10000, corresponding to a 10% increase in UI replacement rate, from 40% of 6-month earnings to 50%. The effect of UI benefits on the reservation wage also estimated from this counterfactual. The duration and earnings replacement elasticities with respect to unused credit limit are estimated from newly laid off agents due to exogenous job separations in the model. The counterfactual simulation relaxes credit constraints for these agents by 10% of their wage income in previous jobs. The elasticity is estimated using the average difference in unemployment duration and wage income between the baseline economy and the counterfactual economy with relaxed credit constraints.

on unemployment duration is one of the most robust empirical findings. The effect of UI benefits is also delivered from a channel related to job seekers' liquidity constraints, as Chetty (2008) argues that the liquidity effect accounts for 60% of the impact of UI. To estimate the elasticity, I simulate a counterfactual by increasing UI benefits θ by 25%, from \$8000 to \$10000, corresponding to a 10% increase in UI replacement rate, from 40% of 6-month earnings to 50%. 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 0.49. 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.

Next, I check whether the model-generated responses of the reservation wage and average wage income to UI benefits are in line with the micro estimates. 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, 6.4%. 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 4.1% following a 10% increase in the UI replacement rate.

Finally, I use the model to estimate the elasticities of unemployment duration and earnings to relaxed borrowing constraints for displaced workers. I then compare these structural estimates with the micro estimates of Herkenhoff, Phillips and Cohen-Cole (2016). 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 increased by 0.8% to 1.7%.

To evaluate the impact of access to credit on job search and wage income, I isolate agents newly laid off due to exogenous job separations in the model. Denote their prior wage income as $Inc_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})$ 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, $Dur(\Omega)$, and wage income, $Inc(\Omega, \rho, \rho')$. Finally, I run a counterfactual in partial equilibrium to obtain the unemployment duration, $Dur^\Delta(\Omega)$, and wage income, $Inc^\Delta(\Omega, \rho, \rho')$ if these agents were provided with 10% unused credit during unemployment, i.e., the borrowing constraint is relaxed from $b \geq 0$ to $b \geq -0.1 Inc_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})$.

Following Herkenhoff, Phillips and Cohen-Cole (2016), I estimate the duration and earnings elasticity using the following formulas:

$$\epsilon_{dur} = \sum_{I_\kappa} \frac{Dur^\Delta(\Omega) - Dur(\Omega)}{10\%}, \tag{5.9}$$

$$\epsilon_{inc} = \sum_{I_\kappa} \frac{[Inc^\Delta(\Omega, \rho, \rho') - Inc(\Omega, \rho, \rho')]/Inc_{-1}(\Omega_{-1}, \rho_{-1}, \rho'_{-1})}{10\%}. \tag{5.10}$$

The structural estimates of ϵ_{dur} and ϵ_{inc} are 0.13 year and 0.14. Therefore, the model predicts that in response to a 10% increase in unused credit, unemployed workers will take 0.7 week longer to find a job that on average pays 1.4% more wage income, roughly in line with the micro estimates of Herkenhoff, Phillips and Cohen-Cole (2016).

6 Quantitative Analyses

In this section, I use the estimated model to conduct quantitative analyses. First, I illustrate the college entry and borrowing decisions under the fixed repayment plan. Second, I present the effect of student debt burden on labor market outcomes in partial equilibrium. Finally, I conduct the full general equilibrium analyses to shed light on the welfare implications of student loan debt.

6.1 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 (4.1). 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 5 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.

6.2 Student Debt on Labor Market Outcomes

In this subsection, I compare the labor market statistics between non-borrowers and normalized borrowers. I first use the model to look at the life-cycle implications of student loan debt under the two repayment plans. I then conduct two counterfactual analyses to evaluate and dissect the effects of IBR.

The difference in the composition of talent suggests that, all else equal, borrowers are also more likely to have higher earnings after leaving school because they are on average more talented. Therefore, the talent difference generates a selection effect that would confound the effect of the debt burden on earnings. To isolate the direct effect of student debt burden on labor market outcomes, in this subsection, I focus on borrowers with normalized talent (I call them normalized borrowers hereafter). Specifically, I normalize the talent of all student loan borrowers by a factor of 0.991 such that the mean talent of

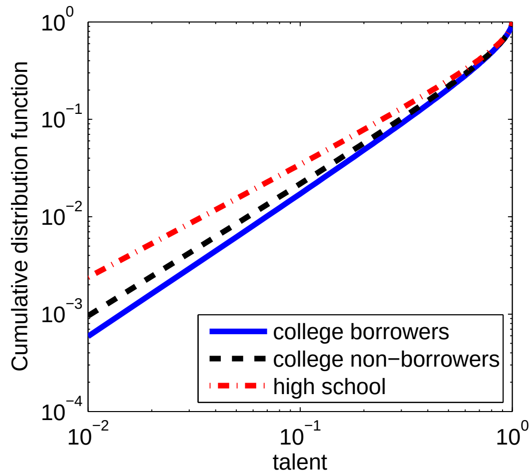


Figure 5: Model-implied talent distribution for high school and college graduates.

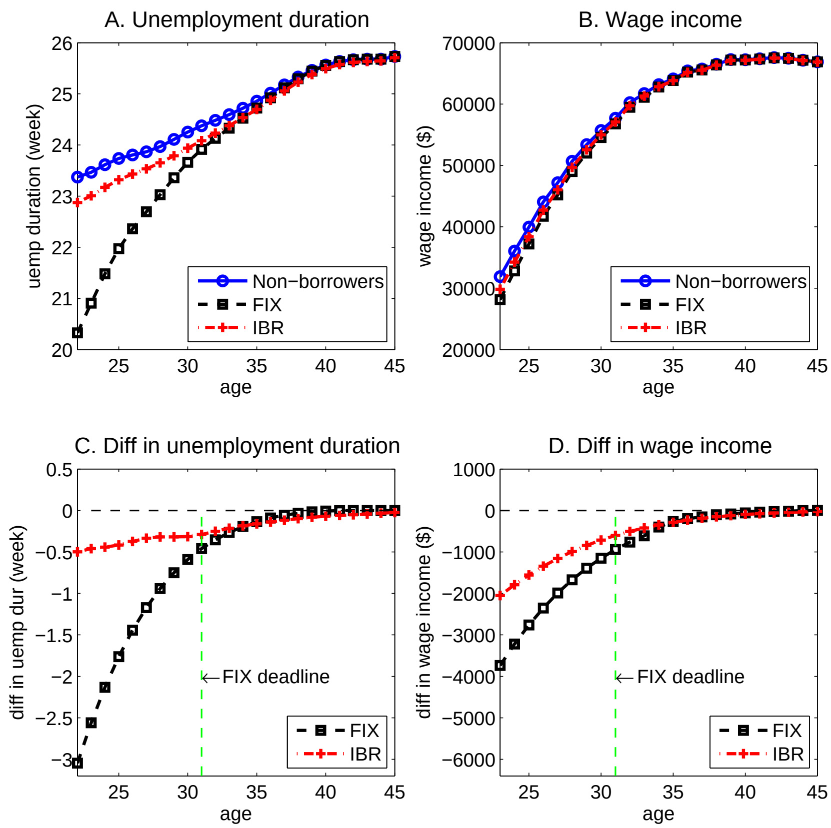
borrowers is equal to the mean talent of non-borrowers. Relatedly, when evaluating IBR, I consider what would happen to normalized borrowers if they are unexpectedly allowed to enroll in IBR to cleanly quantify the direct insurance effect of IBR. Therefore, the analysis in this section does not consider the three general equilibrium effects after the economy adopts IBR: (1) the change in college entry and borrowing decisions; (2) the change in firms' job posting decisions; (3) budget balancing adjustments in fiscal tax parameters. The endogenous difference in talent composition and the general equilibrium effects are considered in subsection 6.3.

6.2.1 Life-Cycle Outcomes

To evaluate the long-term effect of the debt burden, I simulate the model and track the movements of average unemployment duration and wage income over the life cycle for a single generation. In Figure 6, I plot these aggregate statistics for non-borrowers and normalized borrowers under the fixed repayment plan and IBR.

Panels A and C show that non-borrowers on average spend 3 weeks more when searching for their first jobs compared to normalized borrowers under the fixed repayment plan. The inadequate job search translates into a negative effect on wage income. Panels B and D indicate that non-borrowers on average earn about $3,700 more relative to normalized borrowers in the first year after college graduation.

Figure 6 also reveals that at age 32, even after debt has been paid off, normalized borrowers under the fixed repayment plan still spend less time on job search and earn relatively less. This long-term effect of the debt burden is attributed to lower savings. Between ages 22-31, borrowers accumulate significantly less wealth compared to non-borrowers due to lower wage income and debt repayment. The average wealth among normalized borrowers at age 31 is about $8,000 lower compared to that of non-borrowers. Although there no longer exists any pressure from debt repayment after age 32, the lower wealth would continue affecting borrowers' job search decisions through a mechanism similar to that of debt repayment. This asset accumulation channel is likely to be empirically relevant as Elliott, Grinstein-Weiss and Nam (2013*a*,*b*) provide evidence that households with outstanding student loan



Note: This figure plots the life-cycle unemployment duration and wage income for non-borrowers and normalized borrowers under the two repayment plans. In panels A and B, the blue solid line plots the average unemployment duration and wage income for non-borrowers. The black dashed line plots the average unemployment duration and wage income for normalized borrowers under the fixed repayment plan. The red dash-dotted line plots the average unemployment duration and wage income for normalized borrowers under IBR. Panels C and D plot the difference in unemployment duration and wage income between non-borrowers and normalized borrowers under the two repayment plans.

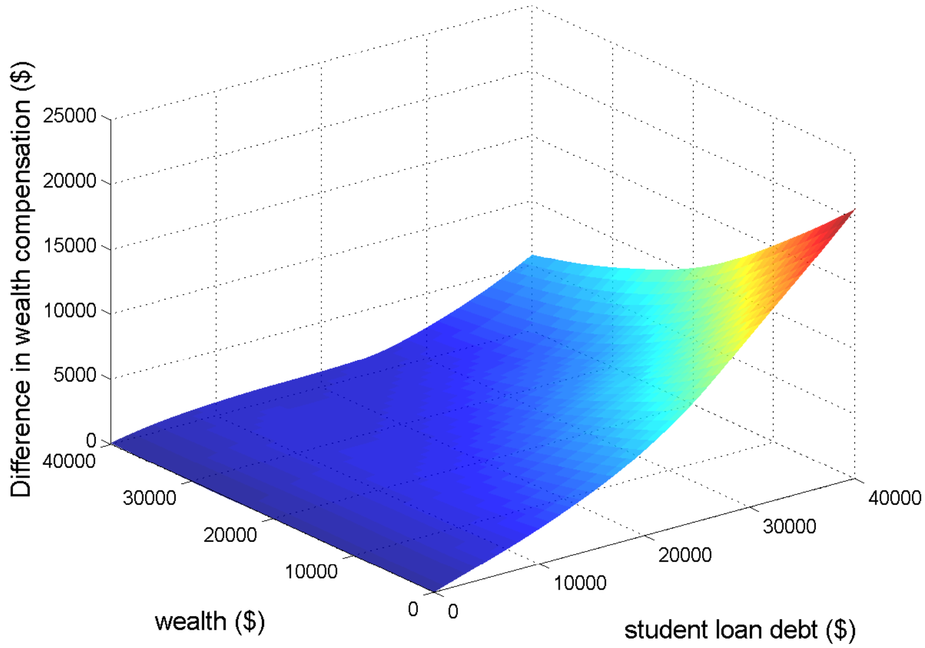
Figure 6: Simulated life-cycle unemployment duration and wage income.

debt have fewer assets. In addition, because of the low search intensity for employed workers, borrowers are stuck at their lower-paid jobs for a relatively longer time. In other words, "first jobs" matter precisely because job-to-job transitions are rare in both my model and data.

IBR significantly alleviates the distortion of the debt burden on job search decisions. Immediately after college graduation, normalized borrowers under IBR on average spend 22.9 weeks searching for their first jobs, which is 0.5 week below the average of non-borrowers. As a consequence of longer job search, the difference in initial wage income is about $2,000 between non-borrowers and normalized borrowers under IBR.

6.2.2 Distributional Implications on Debt Alleviation

I now evaluate the distributional implications of IBR on alleviating the debt burden. Following Townsend and Ueda (2010), I proxy the debt burden using wealth compensation. In particular, for any borrower who just graduated from college, the student debt burden is measured as the amount of wealth that



Note: This figure illustrates the distributional effect of IBR. I measure the change in the debt burden caused by IBR using wealth compensation. For any borrower who just graduated from college, I calculate the least amount of wealth transfer that induces the borrower to switch from IBR to the fixed repayment plan. The figure plots the wealth compensation for borrowers of different levels of wealth and student loan debt. It is shown that borrowers who are poorer and more indebted benefit more by switching to IBR.

Figure 7: The simulated distributional effect of IBR.

should be transferred to the agent for her to have the same utility as a non-borrower of the same characteristics. In other words, the non-borrower would be indifferent about accepting the debt and the associated wealth compensation at the same time.

I measure the debt alleviation achieved by IBR by calculating the difference in wealth compensation between normalized borrowers under the fixed repayment plan and those under IBR.[24] To assess the distributional effect, I do this calculation for normalized borrowers of the average talent but different levels of wealth and student loan debt. Figure 7 illustrates that adopting IBR has significant distributional implications. Borrowers who are poorer and more indebted would benefit more by switching to IBR because they ask for larger wealth compensation. The implication of IBR's distributional benefits coincides with the characteristics of borrowers enrolled in income-driven repayment plans in reality. The Executive Office of the President of the United States (2016) documents that undergraduate-only borrowers in income-driven repayment plans have a median outstanding debt of $25,000 compared with $10,000 in the fixed repayment plan in 2015. Moreover, the average family income based on the first application for federal student aid is $45,000 for those in income-driven repayment plans compared with $57,000 in the fixed repayment plan.

[24]Therefore, the numbers reported in Figure 7 can be considered as the least amount of wealth compensation that induces the agent to switch from IBR to the fixed repayment plan.

Table 6: Evaluation of IBR.

	Non-borrowers	Normalized borrowers			Difference	
		FIX	IBR	IBR(w^*_{FIX})	IBR-FIX	IBR(w^*_{FIX})-IBR
Compensation ($)	N/A	6,274	3,003	4,214	-3,271	1,211
Unemp. dur.	23.8	22.0	23.4	22.4	1.4	-1.0
(week)		(-7.6%)	(-1.7%)	(-5.9%)	(5.9%)	(-4.2%)
Match quality	0.836	0.812	0.826	0.813	0.014	-0.013
		(-2.9%)	(-1.2%)	(-2.8%)	(1.7%)	(-1.6%)
Wage income	47,697	45,689	46,586	45,121	897	-1,465
($)		(-4.2%)	(-2.3%)	(-5.4%)	(1.9%)	(-3.1%)
Output	60,235	57,976	58,756	56,862	780	-1,894
($)		(-3.8%)	(-2.5%)	(-5.6%)	(1.3%)	(-3.1%)
Labor supply	1,737	1,724	1,711	1,695	-13	-16
(hour)		(-0.7%)	(-1.5%)	(-2.4%)	(-0.8%)	(-0.9%)

Note: This table compares the aggregate implications of the debt burden in the first 10 years after college graduation under the fixed repayment plan and IBR. Column "FIX" reports outcomes under the fixed repayment plan for normalized borrowers. Column "IBR" reports outcomes under IBR for normalized borrowers. Column "IBR(w^*_{FIX})" reports the effect of IBR when reservation wages are fixed at the values under the fixed repayment plan. Statistics in parentheses report the relative percent change using non-borrowers as the benchmark.

6.2.3 Average Effects on Borrowers

In this subsection, I evaluate the average effects of the fixed repayment plan and IBR on normalized borrowers' labor market outcomes. In particular, I calculate the average debt burden (measured by wealth compensation), unemployment duration, match quality (measured by job productivity), wage income, output, and labor supply for three groups of young agents: non-bororwers, normalized borrowers under the fixed repayment plan, and normalized borrowers under IBR between ages 23-32.

These results are reported in the first three columns of Table 6. Normalized borrowers have $10,370 debt on average and they ask for $6,274 wealth compensation under the fixed repayment plan and $3,003 under IBR. This suggests that allowing borrowers to have access to IBR would alleviate their debt burden by about half. Note that although there is debt forgiveness provided by IBR after 25 years, my simulation results indicate that almost the entire debt in the economy is repaid by most borrowers. This implies that the debt alleviation caused by IBR is almost entirely driven by insurance.

Table 6 also shows that non-borrowers spend 23.8 weeks on job search on average in their first 10 years. Normalized borrowers on average spend 1.8 weeks fewer when they are under the fixed repayment plan and about 0.4 week fewer under IBR.

In terms of match quality, normalized borrowers under the fixed repayment plan are on average matched with jobs that are 2.9% less productive relative to jobs associated with non-borrowers. IBR improves match quality by about 1.7% for normalized borrowers. The lower match quality translates to lower output and wage income. On average, normalized borrowers under the fixed repayment plan produce 3.8% and earn 4.2% ($2,008) less annually compared to non-borrowers in the first 10 years after college graduation. Note that at the estimated parameter values, normalized borrowers already need to repay about $1,500 every year under the fixed repayment plan. This suggests that debt repayment imposes a double burden on consumption. The indirect reduction in consumption due to inadequate job search is larger than the direct negative effect from debt repayment, which generates even larger consumption inequality between borrowers and non-borrowers.

IBR makes job search much more affordable, and as a result, output and wage income are increased by about 1.3% and 1.9% for normalized borrowers. Output increases precisely because IBR increases borrowers' reservation wages, implying that the increase in wage income is not entirely caused by a redistribution of profits from firms to workers.

The negative effect on labor supply introduced by IBR is not large. Normalized borrowers work for 1,724 hours on average under the fixed repayment plan, and for 1,711 hours under IBR. The reduction in labor supply after borrowers switch to IBR is 0.8%, which is much smaller than the value suggested by a simple back-of-the-envelope calculation, i.e., 15% (repayment ratio) $\times$ 0.33 (tax-modified elasticity of labor supply) $\approx$ 5%. The small negative effect on labor supply is due to the following reasons. First, because there is not much debt forgiveness in my simulation, the labor supply distortion of IBR is much smaller compared to that of income taxes. With income taxation, people have less incentive to supply labor because a fraction of income is reaped by the government. However, this is not the case for IBR if there is no debt forgiveness in the end. Intuitively, although increasing labor supply increases debt repayment in the current period, it lowers total repayment made in the future.[25] Second, the payment under IBR is capped by the amount under the fixed repayment plan. This implies that if borrowers' earnings are high enough to hit the repayment cap, then IBR would have no distortion on labor supply. Finally, there is a positive substitution effect from having better jobs. IBR improves the job quality of borrowers, which incentivizes them to increase labor supply. This partially offsets the negative substitution effect caused by proportional repayment.

Implication on College Premium My simulation suggests that considering endogenous job search decisions is important for the estimation of college wage premium. In my model, the average wage income for high school graduates is about \$30,505. If college entry is not financed by student debt, entering college increases average wage income to \$47,697, generating a college premium of \$17,192. If instead college entry is financed by student debt, under the fixed repayment plan, the college premium is reduced by about \$2,008, or 11.7%. This suggests that a naive estimate based on the average college premium might overestimate the welfare benefits of higher college entry rates caused by student debt because the debt burden also affects job search decisions after college. Moreover, my analysis implies that there is room for policy intervention. The adoption of IBR could potentially alleviate the debt burden and increase wage income. In the subsection 6.3, I conduct a full general equilibrium analysis to shed light on the welfare implication of student debt under the two repayment plans.

[25] This intuition can be more clearly illustrated in a two-period model. Suppose that the agent has utility $u(c_1, l_1) + u(c_2, l_2)$. The agent lives hand-to-mouth with no discounting and has to repay debt S under IBR with repayment ratio α. The budget constraints are $c_1 = (1-\alpha)wl_1$ and $c_2 = wl_2 - (S - \alpha wl_1)$. Taking the first order condition at $t = 1$, we obtain

$$wu_1((1-\alpha)wl_1, l_1) - \alpha w[u_1((1-\alpha)wl_1, l_1) - u_1(wl_2 - S + \alpha wl_1, l_2)] = u_2((1-\alpha)wl_1, l_1) \tag{6.1}$$

The second term on the LHS of equation (6.1) captures the distortion on labor supply. If instead the debt left at $t = 2$ is completely forgiven by the government, then the second term becomes $-\alpha wu_1((1-\alpha)wl_1, l_1)$, which makes IBR equivalent to income taxation at $t = 1$. This example suggests that if there is no debt forgiveness at the end of the IBR repayment period, the labor supply distortion of IBR would depend on the difference in the marginal utility of consumption across periods, which is much smaller than what the back-of-the-envelop calculation implies.

6.2.4 Isolate the Reservation Wage Effect

I now use the model to separately quantify the positive reservation wage effect induced by IBR. I conduct one additional experiment, in which borrowers are allowed to make payments according to IBR, but their reservation wages are fixed at the values under the fixed repayment plan. Therefore, in this experiment, IBR provides consumption smoothing but not job search benefits.

The simulation results are reported in column 4 of Table 6, "IBR(w^*_{FIX})". The wealth compensation is $4,214 on average for normalized borrowers if reservation wages are fixed. However, if reservation wages are allowed to adjust, the wealth compensation would be $3,003. Therefore, the adjustment in reservation wages caused by IBR on average contributes to a reduction in the wealth compensation by about $1,211. This implies that about one-third of the difference in the wealth compensation between the fixed repayment plan and IBR is attributed to the positive reservation wage effect, and the remaining is due to better consumption smoothing.

Moreover, it is not surprising that almost the entire improvement in match quality is caused by the positive response in reservation wages. When this channel is shut down, borrowers' average wage income and output become even lower than those under the fixed repayment plan. This highlights the standard tradeoff between welfare and output, namely, providing insurance increases welfare but potentially lowers output by distorting the incentive to work.

6.3 General Equilibrium Implications of Student Debt

In this subsection, I shed light on the general equilibrium implications of student debt, taking into account the change in college entry, borrowing, firms' job posting decisions, and fiscal tax parameters.

Table 7 reports the fraction of college graduates, average debt, wage income, output, match quality, job contact rate, and welfare for all young agents (between ages 23-32) in the economy. Column "FIX" presents the baseline simulation in which all student loan borrowers repay their debt under the fixed repayment plan. Column "IBR"-(1) presents the IBR counterfactual in which all borrowers repay under IBR.

In the baseline economy, 41.4% agents choose to attend college, among which about 62.2% finance their education by borrowing student debt, with an average amount of $10,370. When borrowers are allowed to repay under IBR, the reduction in repayment burden induces more agents to borrow student debt to attend college, increasing the college attendance rate by about 6.1%. Among college graduates, about 67.5% are borrowers with an average amount of $16,960 debt.

The adoption of IBR increases average wage income and output by 3.3% and 2.0%. The equilibrium job contact rate is also higher under IBR. This is because college graduates are more productive compared to high school graduates at any jobs. Thus the increase in college entry rate increases firms' profits, motivating firms to post more vacancies.[26]

Following Abbott et al. (2016), I measure the change in welfare by considering the percentage change of lifetime consumption for a newborn economic agent (at age t=0) before drawing her initial conditions

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

Table 7: General Equilibrium Implications of Student Debt.

	FIX	**IBR**		
		(1)	(2)	(3)
Fraction of college graduates	41.4%	47.5%	47.7%	41.4%
Fraction of borrowers	62.2%	67.5%	67.6%	62.2%
Average debt among borrowers ($)	10,370	16,960	17,013	10,370
Job contact rate	0.82	0.88	0.82	0.82
Wage income ($)	37,212	38,452	38,018	37,445
		(3.3%)	(2.2%)	(0.6%)
Output ($)	45,600	46,512	46,317	45,829
		(2.0%)	(1.6%)	(0.5%)
Welfare (%)		2.4%	1.9%	0.8%

Note: This table presents the general equilibrium implications of student debt for all young agents (between ages 22-32). Column "FIX" reports outcomes under the fixed repayment plan. Column "IBR"-(1) reports outcomes under IBR. Column "IBR"-(2) reports outcomes under IBR when the equilibrium job contact rates are set equal to those under the fixed repayment plan. Column "IBR"-(3) reports outcomes under IBR when the equilibrium job contact rates, the college entry, and borrowing decisions are set equal to those under the fixed repayment plan. Statistics in parentheses report the relative percent change using column "FIX" as the benchmark.

(wealth and talent). The last row of Table 7 indicates that switching from the fixed repayment plan to IBR increases the welfare of young agents by about 2.4%.

Decomposition It is clear from above analyses that IBR increases social welfare through three channels. First, borrowers conduct more adequate job search because of better insurance in the labor market. Second, debt alleviation achieved through IBR induces a general equilibrium effect that encourages college entry and borrowing. Third, improved education increases match-specific productivity and profits, motivating firms to post more jobs. I now run two additional counterfactual experiments to quantify the importance of these channels.

Column "IBR"-(2) reports outcomes under IBR when the equilibrium job contact rates are set equal to those under the fixed repayment plan. The difference between columns "IBR"-(1) and "IBR"-(2) is thus informative about the importance of more job postings. My simulation suggests that reducing the job contact rate from 0.88 to 0.82 for unemployed agents would reduce the wage income and output by about 1.1% and 0.4%. In terms of welfare, IBR increases consumption by an additional 0.5% by incentivizing firms to post more jobs.

Column "IBR"-(3) reports outcomes under IBR when the equilibrium job contact rates, the college entry, and borrowing decisions are set equal to those under the fixed repayment plan. Thus Column "IBR"-(3) quantifies the importance of better job search and insurance in the labor market, and the difference between columns "IBR"-(2) and "IBR"-(3) is informative about the importance of more college entry and borrowing. My simulation implies that insurance in the labor market increases wage income, output, and welfare by about 0.6%, 0.5%, and 0.8%, while more college entry and borrowing increases these statistics by about 1.6%, 1.1%, and 1.1%.

Connection to Tuition Subsidy Note that my debt burden analysis in Table 6 suggests that for an average borrower with $10,370 debt, introducing IBR would cut the debt burden by about half, from $6,274 to $3,003. This implies that if the average borrower under the fixed repayment plan chooses to enroll in IBR, loosely speaking, it is equivalent to having $\$10,370 \times \frac{3,003}{6,274} = \$4,963$ debt under the fixed repayment plan. Table 7 shows that switching from the fixed repayment plan to IBR would also increase the average debt amount to $16,960, implying an equivalent debt amount of $\$16,960 \times \frac{3,003}{6,274} = \$8,118$ under the fixed repayment plan. This further implies that the ex-ante effect of introducing IBR is similar to a tuition subsidy by an average amount of $\$10,370 - \$8,118 = \$2,252$ if borrowers finance their education using the fixed repayment plan.

If we treat the estimated monetary college cost, $\mu_k = 12,505$, as mainly reflecting tuition, then my estimation implies a college enrollment elasticity of $\frac{6.1\%/41.4\%}{2,252/12,505} = 0.82$ with respect to college price. In Online Appendix G, my sensitivity analyses indicate that the elasticity is around 0.58 if the risk aversion parameter γ is set to be 1.5. If agents are allowed to borrow 18.5% of income after graduation, the elasticity drops to about 0.72. The existing micro estimates surveyed by Leslie and Brinkman (1987) and Kane (2006) suggests that the elasticity is between 0.52 and 0.83. Therefore, my simple back-of-the-envelop calculation seems to suggest that the model-implied elasticity from providing IBR is in line with the existing estimates from micro studies.

In a related study, Johnson (2013) finds that relaxing borrowing constraints does not increase the college entry rate much compared to a tuition subsidy. In my model, agents do not face borrowing constraints when making college entry decisions. My model suggests that the constraint on college entry is more likely due to the repayment burden after college, when agents start searching for their jobs. Enrolling borrowers in IBR alleviates the debt burden, which is essentially similar to a tuition subsidy.

In contrast to a tuition subsidy, providing IBR is less costly from the government's perspective. My simulation suggests that almost every borrower can repay their debt within 25 years, and there is not much debt forgiveness in the end. As a result, the fiscal parameter $\varkappa$ is virtually unchanged during my simulation.[27]

7 Conclusion

In this paper, I develop a structural model with college entry, borrowing, and job search to evaluate the implication of student debt on labor market outcomes.

This paper contributes to existing literature in three ways. First, this paper proposes a mechanism through which the debt burden affects individuals' job search decisions and labor market outcomes. I illustrate that borrowers tend to be less patient in job search, and consequently, they are more likely to end up in lower-paid jobs. The exact effect of the debt burden also depends on the repayment schedule.

Second, this paper develops and estimates a quantitative framework that incorporates college entry and borrowing into an equilibrium search model. I estimate the model using NLSY97 data and apply the model to evaluate the aggregate and distributional implication of the mechanism.

[27] In fact, my simulation implies that tax revenue goes up slightly because the increase in college entry rate increases average taxable wage income.

Third, this paper applies the model to shed light on the implication of a realistic income-based repayment plan on welfare, wage income, and output. The counterfactual analyses also separately quantify the potential general equilibrium effects of IBR on inducing more college entry, borrowing, and job postings.

My main quantitative exercise suggests that the distortion of student debt on job search decisions could be large under the fixed repayment plan, and that it is very much relieved by IBR. Debt alleviation achieved by IBR benefits poorer and more indebted borrowers more, and on average, it is equivalent to cutting student debt by half. One-third of debt alleviation is attributed to better job matches. Moreover, adopting IBR also brings two general equilibrium effects that encourage college entry and job postings, effectively offering a tuition subsidy that is much less costly to the government.

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