This paper represents my own work in accordance with University regulations.

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Abstract

This thesis offers an analysis of default decisions in a market with considerable information asymmetry. We first develop a mechanism design framework to study the credit rationing problem in the market for income-contingent loans. Our empirical work follows the theoretical results by examining the determinants of default for student loan debtors. We add to the limited knowledge of student loan default by presenting a probit model of default probability for over two thousand borrowers of income-contingent student loans backed by the federal government. The exercise illustrates how borrower characteristics largely determine default probabilities across multiple specifications. We analyze the implications of this exercise by elucidating how borrower risk is perceived by government-sponsored agencies, which serve to assist creditors in originating income-contingent loans in an illiquid market. Looking at debt issues in the secondary loan market, we provide a decomposition of the origination costs associated with raising capital and bringing the debt instruments to market. The results suggest that borrower risk is priced into the cost of debt issuance and government agencies are cognizant of repayment uncertainty. Upon reconciling the theoretical and empirical results, we provide commentary on the role of government intervention in providing liquidity for inefficient markets.

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loan providers in the case of delinquency in Section 3.4, where lenders receive some alternative form of repayment upon default.

3.2.4 Equilibrium

In this market, a bank can lend to a student or alternatively invest in a safe asset, such as a U.S. Treasury note, to obtain a certain future payment Γ. We define r as the interest rate charged to student borrowers by the bank, whose value is the same for all students as banks are unable to ascertain the expected return on each student's education and ability to repay. Because lenders cannot observe the exact δ of individual students, we let λ to be the average repayment probability $1-\delta$ of all student borrowers, given by $\lambda = E[1-\delta]$. To be incentivized to lend, banks must expect a high enough likelihood of repayment from students to achieve its required rate return Γ. The return Γ on the alternative safe investment in Treasuries therefore must equal the average repayment on a student loan λr. Accordingly, the equilibrium condition is denoted as

$$\Gamma = \lambda r \tag{1}$$

The equilibrium condition represents the locus of market loan rates and default probabilities that provide banks the required rate of return on their debt contracts.

3.2.5 Comparative Statics and Investment Conditions

Our mechanism design in the private student loan market generates comparative statics that are useful for the empirical exercises in the market for government guaranteed loans. We examine credit allocation through comparative statics, similar to Patrinos (2000) and Jaffee and Russell (1976), for the student loan market specifically. Each potential student chooses whether or not to borrow at the market loan rate r and invest in human capital, describing an investment condition. The student takes out the loan if and only if $I > r(1-\delta)$ as I represents his expected return on his human capital investment, $1-\delta$ is his repayment probability, and $r(1-\delta)$ is the expected cost of borrowing. Figure 2 illustrates the investment area that describes this investment condition.

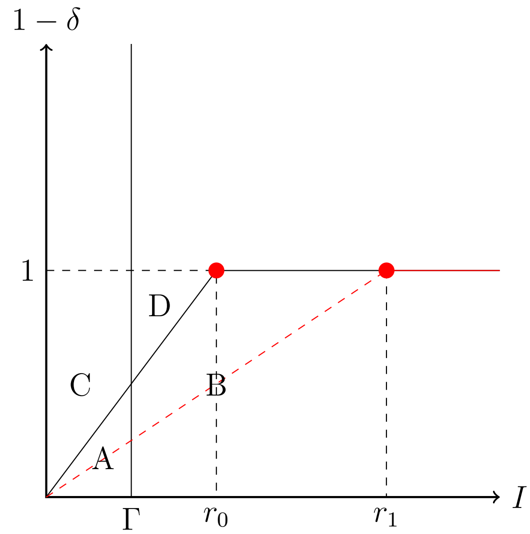

Figure 2: Areas of investment for student debtors and creditors

The market loan rate r produces an investment boundary for the (δ, I) distribution of student borrowers. Students with (δ, I) characteristics of areas A and B decide to invest in their education and take out a loan. Students in areas C and D are not willing to invest. An increase in the borrowing interest rate r from r_0 to r_1 reduces areas A and B, as depicted by the area between the I-axis and red lines, producing a new investment boundary. As Jaffee and Russell (1976) reveal, the increase in interest rate unequivocally reduces the number of loans and drives out student borrowers. The investment condition $I > r(1-\delta)$ implies that investment decisions change in response to loan rate changes in this market. To illustrate a further point of market inefficiency, the students that fall out of the market due to the interest rate increase have low δ, given any I. The converse is unfortunately true, where a decrease in interest rate encourages students with high δ to enter the market. These two effects are represented by an area D reduction and an area A expansion respectively. The comparative statics is consistent with the intuition provided by Kodde and Ritzen (1985) in their treatment of market dynamics for income-contingent loans.

3.2.6 Second Equilibrium Condition

Given that λ is the average probability of repayment of the student population that invests, λ is contingent on the investment criteria based on expected return in future earnings. Incorporating the result of the investment condition $I > r(1-\delta)$, the second equilibrium condition becomes

$$\lambda(r) = \mathbb{E}[1 - \delta \mid I > r(1 - \delta)] \tag{2}$$

The conditional function $\lambda(r)$ is well-defined for any distribution of students with varying (δ, I) characteristics. This equation becomes useful in our theoretical interpretation in Section 8 where we examine how heterogeneity in default probability affects market efficiency.

3.3 Social Planner Perspective

We follow Lucas and Moore (1975) in considering the perspective of the social planner to address this uneconomical credit market. As the above investment condition illustrates inefficiency in the student loan market, the perspective of the social planner also illuminates an inefficient market allocation. The social planner makes an investment if and only if return I is greater than the opportunity cost of investing in a safe asset λ. Credit is allocated efficiently in areas B and C, as loans in B are socially efficient and originated, and loans in C are socially inefficient and avoided. However, students in area D should borrow but instead drop out of the market, and students in area A should not borrow but instead enter the market. It is clear that no interest rate r can eliminate areas D and A, and therefore no rate charged by a bank can provide a first-best solution for loan contracts in this market.

3.3.1 Microfoundations

The comparative statics show that the private provision of student loans will not only lead to an under-provision of funds for students, in the form of higher interest rates or no loans offers at all, but also a socially inefficient allocation where riskier students take out loans and relatively less risky students do not take out loans. Overall, this leads to a lower level of human capital, particularly for those who need it most, therefore widening income inequality. The result highlights the need of government intervention. We revisit this argument in Section 9.

3.3.2 Credit Rationing with Asymmetric information

Unfortunately, the first-best solution is only possible in a world with perfectly symmetrical information. The presence of information asymmetry, where students hold private information about their probability of default, yields socially inefficient investments. As outlined above and in Patrinos (2000), the student debtor criterion of investment is

$$I > r(1 - \delta)$$

Substituting the first equilibrium condition $\lambda r = \Gamma$, the investment condition becomes

$$I > \left(\frac{1 - \delta}{\lambda}\right) \Gamma$$

Assuming no private information concerning the borrower's likelihood of repayment, $\lambda = (1 - \delta)$ and the student invests in his education based on the new investment condition $I > \Gamma$. This new borrowing criteria eliminates area A and leads to investments in area D, leading to a socially optimal result. On the other hand, the presence of asymmetric information concerning the borrower's repayment probability leads to investments in area A and aversion in area D, which is socially detrimental. In such a world, relatively high δ borrowers in area A take out loans while those with relatively low δ avoid investing. Evidently, the presence of information asymmetry prevents the market from reaching the first-best solution. The reason behind this is that offering more loans would increase the risk exposure of lenders and underwriters.

3.3.3 Market Equilibrium and Disequilibrium

The two market equilibrium conditions collectively determine the market interest rate r charged by banks. Figure 3 depicts the equilibrium conditions with the LC curve representing the lending condition $\lambda r = \Gamma$ and the BC curve representing the borrowing condition $\lambda(r) = \mathbb{E}[I \mid I > r(1-\delta)]$.

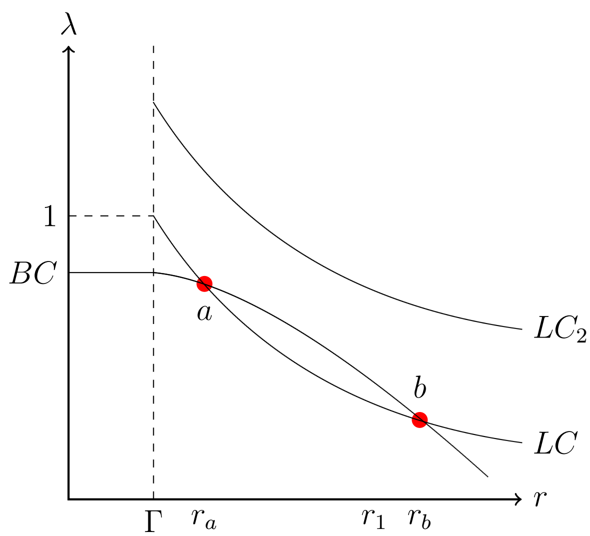

Figure 3: Equilibrium and disequilibrium in the student loan market

As $r \to 0$, the average repayment probability λ approaches the expected repayment probability $1 - \delta$ as more students are satisfied with the borrowing interest rate and enter the market. In essence, the λ-intercept of the BC curve is equivalent to $\mathbb{E}[1-\delta] < 1$. As $r \to \infty$, $\lambda \to 0$ because less borrowers are satisfied with the interest rate, according to their investment condition $I < r(1-\delta)$. To exacerbate the situation, borrowers of relatively low δ fall out of the market, represented by a reduction in area B of Figure 2, which pushes down the λ even further. The LC curve is defined by the first equilibrium condition $\lambda r = \Gamma$ or $\lambda(r) = \dfrac{\Gamma}{r}$.

3.3.4 Frozen Credit Market

Disequilibrium is also possible in this market, as elucidated by Rothschild and Stiglitz (1976) and Kindleberger (1978) and evidenced by Booij et al. (2012), where there is no exchange of student loans. We demonstrate a lack of equilibrium in the circumstance that the two equilibrium conditions do not cross, as illustrated by the LC_2 curve in Figure 3. There is no market equilibrium when the borrowing and lending curves do not cross, as the creditors do not expect a high enough likelihood of repayment from the student population, no matter what r they charge, in order to achieve the safe asset return. This scenario can be treated as a *frozen credit market* where no human capital is invested.

Figure 3 reveals that two values of r can satisfy both equilibrium conditions, exhibited by points a and b. However, one must recognize that only point a denotes a significant equilibrium point. If the bank charges an interest rate above r_a, they anticipate a higher λ than they require to achieve their required safe asset return Γ. Thus, lenders are encouraged to charge r_a where they expect a higher return λr on their loan, suggesting that point a is an established equilibrium. Upon examining an interest rate below r_b such as r_1, the BC curve is above the LC curve and the banks expect a higher λ than they would need to be incentivized to lend. Banks can therefore charge a lower interest rate r_1 with a higher expected repayment probability.

Therefore, we rule out the second equilibrium point b as an unstable equilibrium.

3.3.5 Limitations of Theory

We maintain the assumption of exogeneity of each student's default probability, which is a simplifying assumption that is admittedly unrealistic. Although we construct a model where the student's default behavior is exogenous for each student in order to simplify the interpretation, one can also account for moral hazard and model students with varying degrees of corruption. In this case, repayment probabilities may be affected because a morally hazardous student may attempt to avoid repayment illegally. The model can also be made more complete by modeling all students as trustworthy. Such students would only default when their expected earnings are insufficient for loan repayment *ex-post*. With the assumption of default exogeneity, we maintain non-linearity of default probability and borrower characteristics, for which we test in Section 7.3.

3.4 Lending Procedure Idiosyncrasies

Here we detail the unique institutional aspects of the lending procedure for student loans. Once the university's cost to the individual student is determined, the institution does not play a substantial role in dictating the loan amount. Although the student loan is issued to the student and facilitated by the school, the package is financed by a bank and repayments are made to the bank or another student loan service provider. Therefore, we assert that institutional characteristics do not have significant effects on the default behavior of students, as student loan lending operates externally of the educational institutions. This assertion is tested in our empirical exercise later on the paper.

Another distinctive feature of the student loan market is the absence of collat-

8 Theoretical Interpretation

This section focuses on fitting the model with the data. We revisit Section 3 to provide a theoretical interpretation of the observables in our empirical regressions.

8.1 Heterogeneity of Default Probability

The mechanism design model illustrates how a population of heterogeneous borrowers face an inefficient allocation of student loans from private lenders. In Section 6.2, we observe a statistically significant relationship between borrower attributes and default behavior. Therefore, we deduce that heterogeneity in borrower attributes leads to heterogeneous default probabilities. From the perspective of educational institutions, a population of heterogeneous borrowers is a desirable environment, ergo examining the effect of heterogeneous default probability on our economy is an important next step. Here we provide a numerical analysis of the effect of heterogeneous default probability on the optimal loan allocation.

Suppose δ denotes a normal distribution from δ_0 to δ_1. From the second market equilibrium condition described by Equation 2, we derive the equation for the BC curve. The borrower condition which considers average repayment probability is

$$\lambda(r) = \begin{cases} \frac{((1-\delta_0)+(1-\delta_1))}{2} & \text{if } 0 < r < \frac{I}{1-\delta_1} \\ \frac{((1-\delta_0)+\frac{I}{r})}{2} & \text{if } \frac{I}{1-\delta_1} < r < \frac{I}{1-\delta_0} \end{cases} \tag{13}$$

The junction of the first market equilibrium condition, determined by lender motives, and the modified second equilibrium condition, determined by borrower motives, helps ascertain the new equilibrium. From Equation 1 and Equation 13 we solve the interest rate and therefore the optimal amount of credit.

$$\left(\frac{1}{\frac{(1-\delta_1)}{(1-\delta_0)} - 1} \right) L = \frac{2 - 2(\frac{\Gamma}{I})}{2(\frac{\Gamma}{I}) - 1} \tag{14}$$

The key determinant of the equilibrium number of loans made is the ratio of repayment probabilities $\dfrac{(1-\delta_1)}{(1-\delta_0)}$. As the population of borrowers become more heterogeneous in their likelihoods of repayment, the number of loans L goes down. As repayment probability becomes more homogeneous, L goes up. Therefore, heterogeneity in default probability amongst students decreases the optimal number of loans and thereby negatively impacts market efficiency.

8.1.1 Suboptimal Allocation with Heterogeneous Default Behavior

Our empirical results demonstrate that certain borrower characteristics are significant in determining default probability. Accordingly, heterogeneity in borrower characteristics precipitates heterogeneity in default behavior to a significant extent, assuming non-collinearity and relatively little interaction between regressors. We contend that borrower attribute heterogeneity is inevitable especially due to the motivation of educational institutions to admit diverse student bodies. Per Equation 14, the heterogeneity in default probability amongst student populations decreases the optimal number of loans.

8.2 Liquidity Concerns and the Role of Government

We demonstrate that heterogeneity in default probability decreases the number of loans that would be optimal for private lenders. Evidently, private banks cannot provide sufficient liquidity if the student population is too heterogeneous and dissimilar in their repayment behavior. This result emphasizes the need for government intervention to ensure the availability of enough credit in the market for would-be borrowers, by injecting liquidity or buttress private student loans with federal guarantees. Amidst inefficiencies in this credit market, federal intervention is necessary to allow students to go to college and invest in human capital.

8.2.1 Differing Constraints

The federal government faces a much different asymmetric information problem than private lenders. Although information asymmetry discourages private lending and induces market inefficiency, a imperfect information is benign to the government. Public lenders, including federally-sponsored agencies or federally guaranteed originators, are not constrained by revenue neutrality. Conversely, private lenders must make loans that preserve their revenue levels and therefore require a high enough repayment probability to compensate for the opportunity cost of a safe asset return Γ as captured in Equation 1. Again using the social planner's perspective, the government does not require knowledge of repayment probability to make a useful loan. The government only requires that $I > \Gamma$, while private lenders are apathetic to the expected return of the loan for the student. To summarize, private lenders are concerned with repayment probability $1 - \delta$ and apathetic to expected return I. Conversely, the government is concerned with expected return I and apathetic to repayment probability $1 - \delta$. Heterogeneous $1 - \delta$ is benign from the government's standpoint.

8.3 Perspective of Information Asymmetry

As evidenced by the model in the theoretical section of this paper, the student loan market is only able to achieve the first-best solution when there is perfect information. With the presence of asymmetrical information, which is often the case in practical terms, loans face greater default probability across the borrower population, and the market becomes extremely inefficient. In these circumstances, federal involvement in providing liquidity can buttress such an uneconomical environment. However, unobservable heterogeneity in default probability among the student population is necessary in order to warrant government intervention as illuminated by Mankiw (1986). As discussed above, the empirical exercise of this paper demonstrates that a set of borrower characteristics are key determinants of default probability, and therefore heterogeneous borrowers induce heterogeneous repayment likelihoods. The heterogeneity of borrowers characteristics, which is a realistic assumption as discussed above, elicits heterogeneity in default probability, subsequently negatively impacting private loan origination and stressing the importance of federal assistance.

Our empirical results in Section 6.3 sheds light on how informed this federal assistance is in reality. The exercise examines the relationship between debt issuance fees and parameters of default risk and supports the analysis of Boot et al. (1991). The results of our linear regressions imply that borrower riskiness is observed by creditors and issuers involved in the corrective federal intervention.

The presence of other options of nonrepayment exacerbates the asymmetric information problem. Deferment and forbearance are more common than default in earlier stages, such as 5 years into entering the repayment schedule. Moreover, the timing of entering default affects the relative human capital debt burden, as borrowers who default earlier rather than later face lower total discounted payments. Evidently, variance in both type and timing of nonrepayment behavior induce information frictions and default behavior heterogeneity. Considering the theoretical framework presented in Section 3, these information asymmetries and heterogeneous default behaviors lend themselves to further market inefficiency.

The theoretical considerations of this paper offer guidance as to the results we observe. Chapman and Ryan (2002) assert that federal guarantees on student loans

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