Selection, Prepayment, and Default in P2P Borrowing*

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Abstract

Existing research states that an increase in interest rates discourages better borrowers more and so results in a higher default probability (Stiglitz and Weiss, 1981). By analyzing a recent adjustment in the pricing policy of a peer-to-peer lending platform, we observe the opposite. A reduction in the default ratio appeared after an interest rate rise. Furthermore, we find lenders on the platform are not necessarily better off with higher interest rates and lower default rates. To investigate the underlying mechanisms generating the counter-intuitive observations, we model a borrower's decision whether to join a peer-to-peer lending platform and, after taking up the loan, her per-period payment strategy in a dynamic model. We particularly study the trade-off a borrower faces when making repayment decisions. We emphasize one important strategy that a borrower could use – prepayment, and also consider the possibility of borrowers' inattention to this option. We document that the interest increase and rating adjustment have three different impacts on the performance of the platform: it not only affects borrowers' default probability, but also prepayment tendency, and the optimal decision as to whether take up the loan. Together these three features affect the expected returns for the lenders and so the overall performance of the platform could go either way with an increase in the interest rate.

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1 Introduction

The seminal work of (Stiglitz and Weiss, 1981) illustrates that an increase in interest rates discourages better borrowers more and thus results in a higher default probability. A recent adjustment in the pricing system on Prosper, one of the largest peer-to-peer lending platforms in the US, provides the ideal opportunity for testing such a proposition. Surprisingly, we find that the default rate may reduce after interest rates increase. Meanwhile, more borrowers tend to pay off their loans before they mature, i.e., prepayment increases. These opposing effects make a lender not necessarily better off after the adjustment. Such surprising results do not change after we control for an array of borrower and loan heterogeneity.

To understand and reconcile such counterintuitive results, we model a borrower's decision for using the platform and then investigate the trade-off a borrower faces to repay the loan in a dynamic model. Making financial decisions is complex and requires adequate knowledge. Indeed, numerous existing research (Simon, 2000; Deng and Quigley, 2006; Campbell, 2013; Andersen et al., 2015; Agarwal et al., 2017) shows that a significant percentage of borrowers lack the sophistication to make optimal financial decisions, especially the prepayment decisions. Estimating the residential mortgage data, Agarwal et al. (2016) showed that approximately 59% of borrowers fail to repay optimally.

Motivated by this fact, our model allows borrowers to be heterogeneous in their financial sophistication. Some borrowers are sophisticated such that in each period they consider all the possible amounts they can afford to pay back the loan. The rest of the borrowers are naive such that they are not sensitive to the potential prepayment option and only consider making regular payments or defaulting. Our model goes beyond the borrower's binary choice over whether to default or not, allowing the borrower to choose the repayment amount in each period. In other words, we incorporate in our model all three possible repayment strategies in loan markets: default, regular payment, and prepayment. In our model, a borrower starts with an endowment of a specific saving and receives an exogenous income shock at the end of each period. Once a borrower takes up the loan, she faces a two-period game and decides the amount to repay the loan in each period.

If she pays less than the regular monthly payment, the loan is defaulted and terminated. In other words, the borrower can no longer take future action and has to incur the default cost. On the other hand, if the borrower pays more than the regular monthly payment, then the additional amount reduces her principal balance, so it reduces the future interest amount and the potential default risks in the future. In this context, we find that the borrower always tries to avoid default in the second period, meaning that she will pay off the loan as long as she has sufficient funding. In the first period, her strategy is jointly determined by her financial sophistication, default cost, and saving amount. If the borrower is naive, she pays nothing when the default cost and initial savings are low and makes regular payments otherwise. If the borrower is sophisticated, she pays everything when the default cost and initial savings are sufficiently high, pays nothing when the default cost and initial savings are sufficiently high, and makes regular payments when in the middle of these two extremes.

Based on the repayment model, we then study the impact of Prosper's adjustment, which imposes two impacts on the market outcomes. First, an increase in interest rates affects each borrower's optimal repayment behaviors. Particularly, sophisticated borrowers are more likely to default and make prepayments while less likely to make regular payments. Similarly, naive borrowers also tend to default more while less likely to make regular payments. Second, the interest rate increase also changes borrower composition on the platform. Compared with sophisticated borrowers, naive borrowers are more likely to default and exit the market. Hence, with a higher interest rate, the ratio of sophisticated borrowers increases and results in lower overall default and regular payment probabilities, but a higher prepayment probability. Combining these two effects, we show the underlying mechanism of the counterintuitive pattern observed on Prosper. Also, we point out that the impact of interest on a peer-to-peer lending platform is jointly determined by the interest increase magnitudes and borrowers' composition in both sophistication and risks.

Our paper makes the following contributions to the existing literature. As far as we are concerned, this is the first paper that provides a complete micro-foundation to analyze borrowers' selection into platforms and the subsequent repayment decisions, including prepayments. This framework facilitates understanding the trade-off a borrower faces in the repayment decision. The majority of existing research has focused solely on how adverse selection affects borrowers' motivation in default, which occurs when borrowers undermine the loan agreement by stopping payments and creating principal and interest loss on lenders. Prepayment, which is also a critical type of borrowers' breakage of loan agreements on peer-to-peer lending, has received much less attention so far.

However, prepayments diminish borrowers' interest payments and thus the profitability of loans. Indeed, since most peer-to-peer lending platforms place no fee on prepayment, the prepayment percentage on peer-to-peer lending platforms, like Prosper, could be even much higher than that of default. This means borrowers' prepayment behaviors constitute an even more essential and dominant component on the peer-to-peer platforms than the default. With prepayments, lenders can no longer receive the expected interest paid on their principal, which lenders care about when they consider investing in the platform. The adverse selection not only affects borrowers' propensity to default but also to make prepayments as well. Consequently, the analysis of adverse selection might be partial and inaccurate without considering the influence of adverse selection on prepayment.

Moreover, as far as we are concerned, our paper is the first to investigate the impact of interest on the peer-to-peer lending platform in the presence of borrower heterogeneity in both risk and sophistication. It has been well illustrated that borrowers in the peer-to-peer lending market have private information regarding their own risk of default, such that platforms cannot distinguish among borrowers with different risks. This asymmetric information raises the well-known adverse selection issue, meaning that high-risk borrowers are more likely to participate and turn crowdfunding platforms into lemon markets. However, the prevalent behavioral bias is usually abstracted away in the existing research despite its prevalence and critical role in loan markets. As pointed out by Green and LaCour-Little (1999), borrower prepayment behavior appears to be highly irrational, in the sense that many borrowers fail to prepay their mortgages when the prepayment option is substantially in the money. To fill the gap, our paper allows borrowers to be heterogeneous in not only default costs but also sophistication as well. Hence, the paper also contributes to the intersection of asymmetric information and behavioral bias.

Literature Review Our paper is mainly built upon the literature on asymmetric information and its derivative adverse selection issue in credit markets. In past decades, there is growing research focusing on proving the presence of adverse selection and further disentangling it from moral hazard (Akerlof, 1978; Diamond, 1989; Adams et al., 2009). Specifically, the existence of adverse selection in the credit market was first pointed out by Stiglitz and Weiss (1981), who provided a theoretical model to show why interest rate acts as a critical tool for loan market screening. When interest rates increase, borrowers with high default risks are more likely to accept new loans with higher prices. In other words, the adverse selection makes the mix of applicants worse after an increase in interest rates. To empirically confirm this prediction, Ausubel (1999) used pre-approved solicitations in the credit card market. He showed that customers who accept inferior offers, including higher interest rates and shorter duration, are significantly more likely to default based on reduced-form analysis. Karlan and Zinman (2009) also used credit mail offers as a natural experiment and distinguished adverse selection from moral hazard.

Additionally, our paper is also related to the growing studies on screening and market design (Einav et al., 2012; Adams et al., 2009), especially those aiming at estimating and alleviating the adverse selections in credit markets. For instance, Freedman and Jin (2011) analyzed a peer-to-peer lending platform and illustrated the reasons why learning by doing is critical in alleviating information asymmetry. The paper found that early lenders have systematically underestimated borrowing risks, but they are able to learn from their mistakes. Einav et al. (2013) built a two-period structural model for automobile finance, where borrowers arrive at the dealership and are offered a car with a specific down payment and interest, and then they decide whether to repay the loan in the second period. Through the model, they showed credit scoring effectively screens high-risk borrowers and performs better in targeting more generous loans with lower-risk borrowers. Erzo and Shue (2010) also analyzed the peer-to-peer lending market and examined how users collect and infer information from different sources. The paper investigated whether the interest rate at which lenders are willing to lend decreases with the credit score within a credit category. Since lenders only have access to borrowers' credit as categorical variables, the negative relationship between interest and specific Fico scores within the same category proved lenders' ability to infer information through the platform.

Other research focuses more on how to improve the welfare of peer-to-peer markets. Kawai et al.

(2015) developed an equilibrium model where a borrower may signal her default risk through reserve interest rates and greatly increase the welfare. Xin (2020) focused more on the role of reputation by examining borrowers who had two concurrent loans. The finite-horizon dynamic model in the paper allows borrowers and lenders to interact repeatedly over time and found that the welfare loss induced by asymmetric information is greatly alleviated by the reputation system of a peer-to-peer lending platform. Einav et al. (2013) exploited a contract model, showing credit scoring and different elements of loan contracts greatly affect the borrower pool and their performance in a large auto finance company.

Most of these studies, except a few (Mayer et al., 2009; Ernst, 2005; Mayer et al., 2013), focus solely on addressing the default in credit markets. However, default is not the only option for borrowers to terminate the loan early. Prepayment is also an important alternative that places concerns for both the platform and lenders. Although default generates losses of both the principal and interest to lenders while prepayment only reduces the paid interest amount, the percentage of prepayments being observed in online lending is much higher than the default rate (Li et al., 2016). Furthermore, Berger et al. (2021) revealed how the prepayments greatly determine the Fed's stimulation of the economy through interest rates. As a consequence, understanding prepayment is critical not only in lending markets but also the fiscal policy as well.

Lastly, our paper also fits into a broader literature on the borrowers' difficulties in managing mortgages. Guiso et al. (2017) and Andersen et al. (2015) pointed out that many borrowers lack the sophistication needed to make financial decisions and are thus susceptible to the bank's advice. Similar patterns are also claimed by Campbell (2016), who argued that financial ignorance is pervasive and unsurprising given the complexity of modern financial products. As estimated by Keys et al. (2016) studies, around 20% of US households failed to choose the optimal strategy during their mortgages. Among them, the optimal prepayment is especially challenging (Campbell and Cocco, 2003; Campbell, 2013). The majority of the research focuses on the housing market and a special form of prepayment, namely the refinance. We further extended borrowers' inattention to the more general prepayment option on peer-to-peer lending markets, where there is usually no prepayment penalty and the prepayment ratio is much higher than in the conventional banking industry.

The remainder of the paper is organized as follows. We first present the institution background and data in Section 2 and then provide reduced-form evidence in Section 3. A theoretical model is developed in Section 4, with comparative status in Section 5. Lastly, we summarize our findings and conclude in Section 6.

2 Institution Background and Data

With the rapid development of information technology, peer-to-peer lending has grown increasingly prevalent due to its convenience. Precisely, online peer-to-peer lending platforms match borrowers with lenders at much lower costs than traditional financial institutions, and borrowers can obtain loans without going through complicated processes. According to the latest survey,[1] the approximate value of the global peer-to-peer lending market achieved 68 billion dollars in 2019. Moreover, it is expected to grow by more than 30 % annually in the next seven years. Consequently, online peer-to-peer lending has already become a critical alternative to conventional banking services and has crucial effects on the economy.

While benefiting from the high returns, lenders also have to accept high risks. Most peer-to-peer lending platforms operate solely as intermediaries, meaning that the loans are unsecured and lenders incur default risks directly. As a consequence, interest plays a more prominent role in peer-to-peer lending than other market types, as it not only affects the number of users in two groups but also user composition as well. To provide a complete analysis of the interest's influence, we analyze a recent price adjustment on Prosper, The platform is ideal for the study. First, Prosper's reputation system is quite representative of the general peer-to-peer lending markets. Moreover, all the transactions on Prosper take place online, and thus we have access to almost all the information observed by lenders. Furthermore, the reputation system on Prosper is mainly based on external credit scores, such as Fico scores, and the internal risk evaluation which is based on similar users in its historical dataset. Consequently, its reputation system is more objective than those of marketplaces, where the feedback is mainly based on customer reviews and personal opinions.

2.1 Institution Background

Since its establishment in 2006, Prosper has attracted more than a million users and created more than $4 billion in loan volumes. Through the platform, both lenders and borrowers can finish their transactions in a much quicker and more convenient procedure than conventional banking institutions. Precisely, the funding process on Prosper.com is as follows. To borrow through Prosper, a potential borrower has to first register on the platform and provide relevant information, including but not limited to annual income, employment status, amount requested (between $2,000 and $35,000), and other related information. Based on such a profile, Prosper will decide whether to accept or reject the application.[2] If Prosper approves the application, it uses a soft credit inquiry that can be done instantly.

[1] https://www.marketwatch.com/press-release/peer-to-peer-lending-market–2027-with-cagr-30-industry-analysis-and-opportunity-assessment-2021-08-27

[2] Prosper.com may reject applications due to several reasons. According to its website *https://prosper.zendesk.com/hc/en-us/articles/210013963-What-are-the-minimum-criteria-to-borrow-on-Prosper-*, bor-

Once Prosper obtains the borrower's credit score, it will assess the required loan's potential risks. Prosper takes advantage of the borrower's external credit information (credit score, number of delinquencies in the last seven years, bankcard utilization, total inquiries, etc.) obtained from its credit reporting partner. In addition, the platform also uses the historical performance of borrowers with similar characteristics to further evaluate the borrower's risks. As pointed out by Prosper, all potential variables available at the time of listings were analyzed for potential inclusion in the algorithm, including the number of inquiries on the credit bureau, number of delinquent accounts, credit card utilization, and debt-to-income ratio. With the risk estimation, Prosper may make further adjustments based on several factors, such as the borrower's previous Prosper loan performance, and macroeconomic environment, and then assign a specific Prosper rating to the listing on its website. Precisely, Prosper ratings have seven grades: A.A, A, B, C, D, E, and H.R., with A.A. being the lowest risk and H.R. being the highest risk.[3] Lastly, Prosper assigns each listing an interest based on the Prosper rating as shown in Figure 1.

Figure 1: Determinant of Loan interest

Prosper provides 3-year and 5-year loan options for the borrowers to choose from, except that loans with amounts larger than 20,000 dollars or with a 5-year term are not eligible for H.R. borrowers.[4] The interest rate depends on the term, the amount, and the borrower's Prosper rating.[5] Once the borrower chooses the contract, a combination of the term and interest rate, Prosper will list such a contract for 14 days on its webpage with detailed information. In addition to the information provided by the borrower, Prosper also reveals additional information about the borrower from a third-party credit report agency, such as Fico score, number of credit lines, and delinquency information. Potential lenders observe all the information and decide whether to fund the loan or not. A lender can invest as little as $25 in each loan listing she selects. If the listing is funded over 70 percent before it expires, a loan is successfully originated. The borrower should pay back the loan every month after its origination till the loan is paid off. [6]

rowers must satisfy specific requirements including debt-to-income ratio, income amount, no bankruptcies last year, and so on, to be eligible for loan applications

[3]For the mapping between Prosper Rating and the estimated loss rate, please see Table A.1 in the Appendix.

[4]Before November 2011, Prosper only provided 3-year loans. Afterward, Prosper introduced both 1-year loans and 5-year loans to its platform. However, Prosper stopped providing the 1-year loan option in May 2013 as few people chose this option.

[5]Prosper used auctions to determine the interest rate before December 20, 2010. It switched to a posted price mechanism afterward.

[6]If a borrower is late in her loan payment, Prosper has its specific procedure to follow, including notifying borrowers,

2.2 Data Description

The data used in our study is publicly available and can be directly downloaded on Prosper's website. It covers all the borrowers' information accessible to potential lenders on the platform, such as credit background, homeownership, prior Prosper loan performance, income, occupation, and so on.

On February 15, 2016, Prosper announced an adjustment to its pricing rules. As indicated by Prosper, this adjustment aims to increase returns for its investors and to preserve the relative competitiveness of Prosper loans versus alternative traded assets. Specifically, Prosper expects this adjustment to move up its average interest rate from 13.5% to 14.9%. [7]

To examine the effect of this adjustment while limiting other disturbing factors, we restrict the data to only include the listings whose starting dates are within 8 months before and after the adjustment.[8] That is, our paper analyzes the listings whose origination dates are between July 2015 and September 2017, resulting in 392,429 listings. Among them, about 71.20% borrowers chose three-year loans. Overall, about 71.46% of those three-year listings received sufficient funding and successfully become loans, about 27.56% were canceled by Prosper,[9] about 0.65% were withdrawn by borrowers, and 0.34% did not reach the funding threshold by end of 14 days.

Specifically, our paper focuses on three-year loans as it is chosen by the majority of borrowers. Following the conventional literature (Freedman and Jin, 2011; Kawai et al., 2015), we also exclude observations that were either withdrawn by borrowers or canceled by Prosper a. As a consequence, our final sample consists of 200,609 listings. For those listing that successfully turned into loans, Prosper also records their loan performance, including the loan status, principal balance, interest paid, and so on.

2.3 Data Pattern

Since the borrowers' external credit is a critical source to evaluate Prosper's screening effectiveness, we first examine how the adjustment affects the Fico score distribution for those who decided to take up the loan on the platform. To investigate, we plot the Fico distribution before and after the adjustment in Figure 2. For ease of comparison, we follow the conventional industry practice[10] to define borrowers

hiring a collection agency, and possibly forbidding defaulted borrowers from using its website again in the future. The detailed information could found on its website: https://help.prosper.com/hc/en-us/articles/210013613-What-happens-if-a-borrower-misses-a-payment-

[7] See https://www.prosper.com/blog/2016/02/26/prosper-pricing-changes/.

[8] Prosper adjusted its interest rates again in October 2016, our study focuses on the listings whose origination dates are before that.

[9] Prosper may cancel listings due to the failure of information verification.

[10] For more information, please visit *https://www.experian.com/blogs/ask-experian/credit-education/score-basics/what-is-a-good-credit-score/*. Note that we use 680 instead of 670 as the cutoff for the fair group because Prosper categorizes

whose Fico scores below 680 as the poor group, those between 680 and 739 as the fair group, those between 740 and 779 as the good group, and those above 780 as the exceptional group. We observe a reduction in the proportion of borrowers classified as "poor" while an increase in all other groups. This indicates that the new screening by Prosper rating deters borrowers with high risks more and improves borrower composition on the platform.

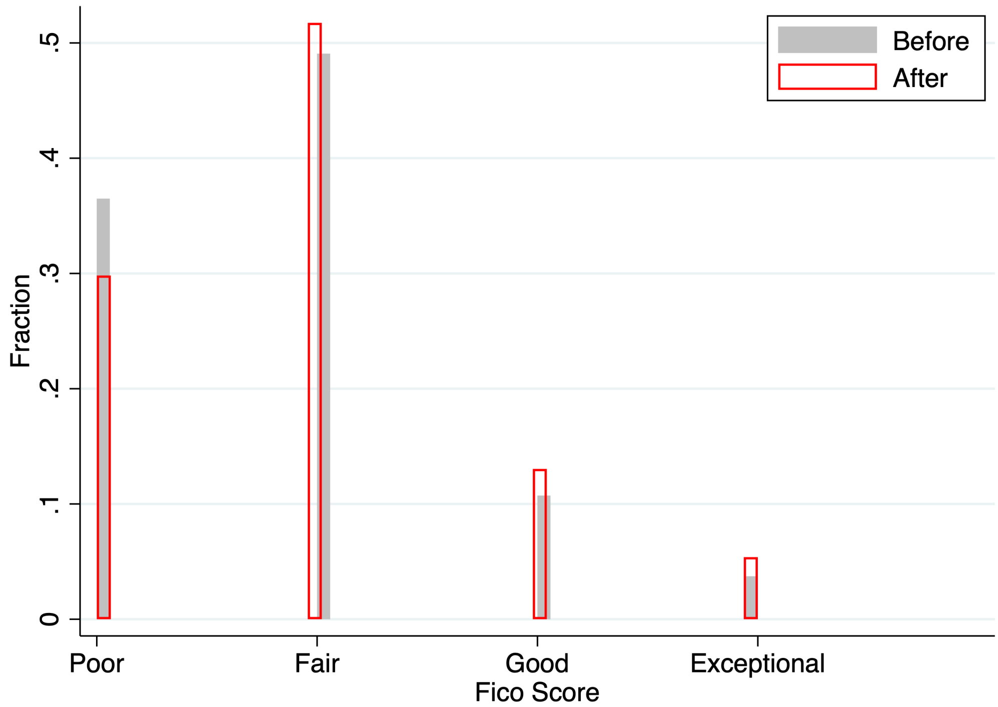


Figure 2: Fico Score Distribution

For all listings on the platform that successfully switch to loans, we continue checking their repayment performance. Specifically, we use the final principal received by the lenders to define whether a loan is defaulted or not. If the principal paid by a borrower is lower than its borrowed amount, we view this loan as defaulted.[11] Otherwise, it is completed. Note that completed loans could incur late payments, but it is always paid off at the end. There are about 82.04% of the loans are completed and about 17.96% have defaulted. Among those completed loans, we further check whether those loans are paid off before their maturity dates, i.e., making prepayments. Precisely, we calculate the paid ratio between the total amount (sum of paid principal and interest) a borrower actually paid at the end of the loan and

FICO score by every 20 difference.

[11]We derive similar results when we alternatively define defaulted loans using Prosper's information about loan status. Since the purpose of our study focuses more on the actual return of lenders, instead of the repayment timing, we adopt the default definition using the principal actually received.

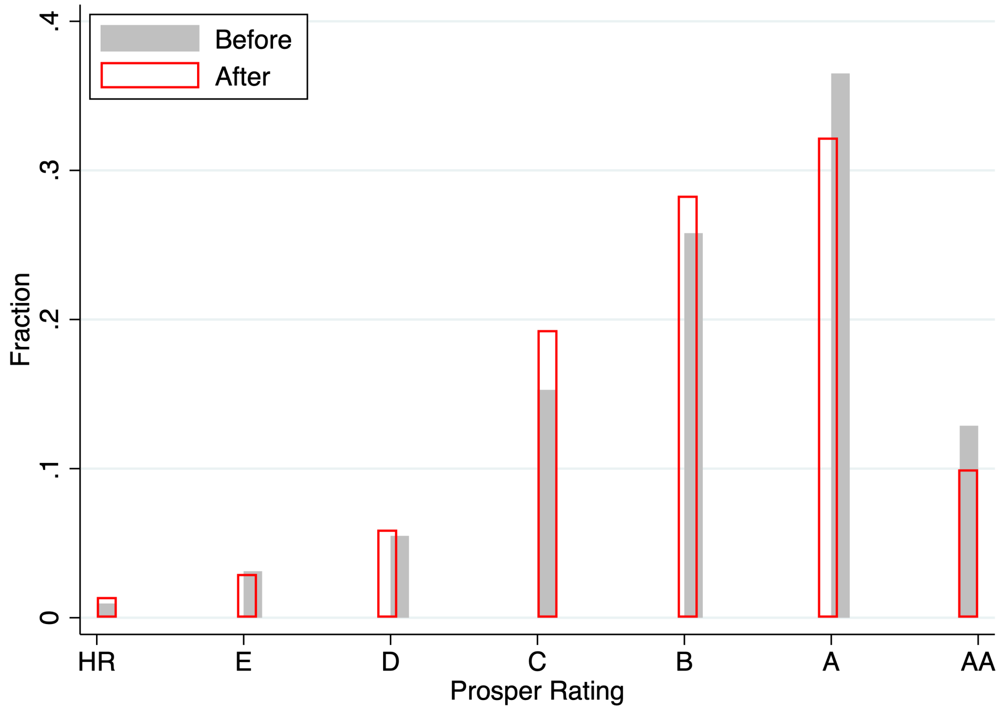


Figure 3: Prosper Rating Distribution for Fair Fico Group

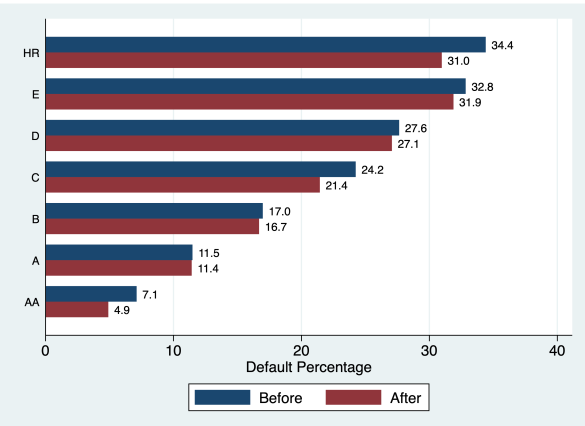
the loan amount a borrower was supposed to pay following regular monthly payments. We find there are 56.78% completed loans that have paid ratio lower than 100%, indicating they made prepayments and ended their loans earlier than the designated dates. Indeed, we find that there are only about 35.46% of borrowers who paid their loans without being defaulted or prepayments.

We then plot the Prosper rating distribution of a representative Fico group in Figure 3. We find that borrowers generally have a lower chance to be assigned with a high Prosper rating (A, AA) after the adjustment. Furthermore, we provide the statistic summary of the representative Fico group in Table 1. We observe that there is an increase in the interest rates in all Prosper rating groups. However, the magnitudes in the interest increments are heterogeneous, with the low Prosper ratings (HR, E, D, C) having significant increases in interest while high Prosper ratings (AA, A, B) having little changes. Responding to the increase in interest rates, the listing amount dropped dramatically after the adjustment in most groups. Also, we find the actual returns in most Prosper ratings increase. However, the relative magnitude of the low Prosper ratings is much larger than that of the high Prosper ratings. In the following reduced-form analysis, we also show that not every loan generates higher actual returns after controlling varied loan characteristics.

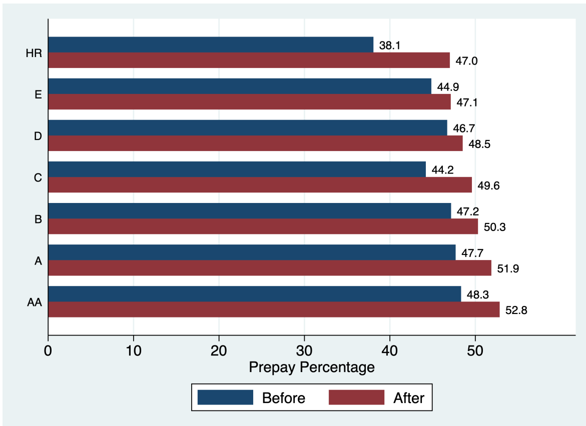
Table 1: Statistic Summary of Fair Fico Group

	Interest			Amount (thousand)			Actual Return		
	Before	After	% Change	Before	After	% Change	Before	After	% Change
HR	0.294	0.312	6.122	5.755	5.618	-2.381	0.097	0.124	27.835
E	0.25	0.274	9.600	9.619	8.841	-8.088	0.059	0.087	47.458
D	0.207	0.224	8.213	11.337	11.891	4.887	0.049	0.07	42.857
C	0.155	0.164	5.806	14.217	13.869	-2.448	0.041	0.064	56.098
B	0.119	0.121	1.681	15.197	15.17	-0.178	0.05	0.053	6.000
A	0.09	0.092	2.222	14.41	14.168	-1.679	0.053	0.053	0.000
AA	0.07	0.071	1.429	12.649	12.813	1.297	0.056	0.063	12.500
Total	0.118	0.128	8.475	13.956	13.849	-0.767	0.050	0.060	20.000

To investigate, we further study the borrowers' repayment behaviors. We surprisingly find the percentage of defaulted loans to be lower at higher interest rates in all Prosper ratings as shown in Figure 4. Furthermore, borrowers have stronger motivations in making prepayments and ending the loans much earlier than the maturity dates, but they are less likely in following regular payments. The influences on borrowers' repayment behaviors produce conflicting influences on loan returns. On the one hand, higher interest rates and lower default probability after the adjustment should raise the actual returns of loans on Prosper. However, the increase in prepayments decreases the actual interest paid by borrowers and thus reduces the return.



(a) Default Percentage



(b) Prepay Percentage

Figure 4: Repayment Outcomes by Prosper Ratings

3 Reduced-form Evidence

In this section, we investigate how the adjustment affects the peer-to-peer lending platform after controlling the observed heterogeneity across listings and borrowers' characteristics. Particularly, we are interested in the influences of the adjustment on the platform's screening system, i.e. interest rate assignments, borrowers' performance in repayments, and lenders' returns.

3.1 Interest Rate

We begin our study by checking how Prosper adjusts its rules in assigning borrowers interest rates. As indicated in section 2, a borrower i has to share her background information and requires a list to get a loan on Prosper. With the background information, Prosper checks the borrowers' outside credit and its internal dataset, and allocates a Prosper rating R_i to her listing. The platform then determines its pricing for each loan based on its Prosper rating. To investigate the adjustment, we model the pricing rule on Prosper using the following linear model.

$$p_{it} = \alpha_0 change_t + \sum_j \alpha_1^j I(R_i = j) + \sum_j \alpha_2^j I(R_i = j) \times change_t + \sum_k \alpha_3^k I(S_i = k) + X_i \alpha_4 + \epsilon_i^2.$$

where $change_t$ is the policy change indicator at the time of the listing t, Particularly, we control for the covariates of the listing amount, Prosper rating, and monthly fixed effect. Moreover, we allow the change in pricing rule to be heterogeneous for borrowers with different Prosper ratings as shown in Table A.2.

We observe an increase in interest rates for all Prosper ratings. However, the adjustments in price are heterogeneous among Prosper ratings. As indicated by the Prosper rating-specific intercept before and after the change in Figure A.1, the overall magnitudes in the interest increase are high for borrowers with low Prosper ratings while almost no changes for borrowers with high Prosper ratings.

3.2 Repayment Outcome

With higher interest rates, we are interested in how the borrowers' repayment behaviors change correspondingly. More precisely, our analysis mainly focuses on the following two aspects. First, whether the adjustment on Prosper successfully reduces the default ratio on the platform? In other words, whether more lenders receive full principals at the end of the loans after the adjustment? Second, for loans that pay full principals, how does the adjustment influences their repayment strategies?

Specifically, we model the probability of default in the following Logit regressions:

$$\begin{aligned}&\Pr(default_{it} = 1|X_{it}, S_i, Fico_{it})\\ = \quad &\frac{exp\left(\delta_0 change_t + \sum_j \delta_1^j I(R_i = j) + \sum_j \delta_2^j I(R_i = j) \times change_t + \sum_k \delta_3^k I(S_i = k) + X_i\delta_4\right)}{1 + exp\left(\delta_0 change_t + \sum_j \delta_1^j I(R_i = j) + \sum_j \delta_2^j I(R_i = j) \times change_t + \sum_k \delta_3^k I(S_i = k) + X_i\delta_4\right)},\end{aligned}$$

where $default_{it}$ is a dummy variable such that $default_{it} = 1$ when the borrower did not pay off all the principal at the end of the loan, and $default_{it} = 0$ otherwise. Our regression results are listed in Table A.3, where X_i includes the borrower's monthly payment amount, income, debt-income ratio, and so on.

In order to better reveal how the policy affects different Prosper ratings, we present the predicted default probability for each Prosper rating in Figure **??**. Surprisingly, we observe default probability can either increase or decrease, even after controlling the heterogeneity across borrowers. Higher default rates are straightforward. First, borrowers now face a higher monthly payment due to the higher interest, and thus it is harder to manage and more likely to default. Second, it has been well illustrated in the existing research about the adverse selection issue in loan markets. Borrowers with good credit usually have better outside options and are more likely to refuse the high interest. As a consequence, those good credit borrowers exit the market first, making the borrower composition worse, and increasing default rates. Combining these two aspects, our finding that the default probability reduces for some borrowers even with higher interest rates is counter-intuitive and interesting.

In addition to defaulted loans, we also aim to further understand the behaviors of borrowers who pay all principals off at the end. To investigate, we divide those loans into the following two types: prepayment and regular payment. Specifically, we distinguish those loans based on the actual interest paid by the borrowers. Prepayment refers to the loans that are paid off before the loan is mature, while regular payment indicates that the borrowers pay the monthly payment on time and pay off the loan as scheduled. We construct two dummy variables $prepay_{it}$ and $regular_{it}$, where $prepay_{it} = 1$ ($regular_{it} = 0$) when the borrower paid off the principal while its paid interest is less than the expected interest amount with regular monthly payments, and $regular_{it} = 1$ ($prepay_{it} = 0$) otherwise.

Similar to the default analysis, we then run the logit regression of prepayment and regular payment in Table A.4 and Table A.5 respectively. To better understand the results, we list the predicted probability for a borrower to make prepayments and regular payments before and after the adjustment in Figure A.3. We find that the increase in interest motivates all groups to make more prepayments and fewer regular payments.

3.3 Lender's Returns

Lastly, we analyze how the adjustment affects the return of lenders. As shown in the previous subsections, the adjustment generates conflicting effects on a lender's investment. On the one hand, we observe an increase in the interest rate and a reduction in default probability after adjustment, both of which raise a lender's expected return. On the other hand, we also find more borrowers tend to make prepayments and this diminished the actual return received by the lender. As a consequence, the influence of the adjustment on a lender's actual return on Prosper is uncertain.

To investigate, we model a lender's return on the platform as the following linear model

$$Actual_{it} = \gamma_0 change_t + \sum_j \gamma_1^j I(Fico_i = j) + \gamma_2^j amount + \sum_j \gamma_3^j amount \times I(change_t) + \sum_k \gamma_4^k I(S_i = k) + \epsilon_i^r$$

with the actual payment paid by borrowers being the dependent variable $Actual_{it}$, and controlling for the loan amount, prosper score, and Fico scores. In addition, we allow the effect of policy adjustment to have heterogeneous effects on the return of loans with different amounts.

Our regression results are listed in Table A.6, with the heterogeneity of adjustment in loans with different amounts. Specifically, we find that loans with low amounts tend to have higher returns after the adjustment. However, this return increase magnitude diminishes in the loan amounts. As a consequence, the adjustment even reduces the return for loans whose amounts exceed $14,100$ dollars.

4 A Borrower's Entry and Dynamic Repayment Model

This section first lays out the borrower's problem when he/she needs to borrow a loan from the peer-to-peer platform. We then characterize the borrower's optimal decision regarding taking up the loan and also the optimal repayment decision if the borrower indeed takes up the loan. For illustration purposes, we assume away any borrowers' observable and focus on the borrower's unobserved characteristics, which affect the borrower's optimal decisions.

4.1 Model Setup

A borrower needs to decide whether to borrow M_1 amount of money with a two-period repayment plan from the peer-to-peer platform. Both the amount and the term of the loan are exogenously given. Given the term of the contract, the platform determines the interest rate r based on the borrower's observed characteristics. The interest rate then determines the per-period regular payment amount $m(M_1, r)$, which can be calculated as $m = \frac{(1+r)^2 M_1}{2+r}$. The borrower has to decide whether to accept such a contract (M_1, r) or not. Specifically, the borrower decides between the loan and an outside option with a value of V_0. If the borrower decides not to borrow from the platform, the decision is over.

However, if the borrower does accept the loan, the borrower needs to repay the loan in two periods. Motivated by the empirical evidence in the existing literature, we assume that there are two types of borrowers in the market when it comes to repayment decisions. One type of borrower is sophisticated in the sense that in each period they consider all the possible amounts they can afford to pay back the loan. In other words, a sophisticated borrower considers the tradeoff between different courses of action such as default, regular payment, and prepayment after successfully borrowing a loan of (M_1, r). The other type of borrower is naive in the sense that they are not aware of the potential prepayment option and only consider making regular payments or choosing default. That is, the repayment decision is binary.

The dynamic repayment process can be described as follows. At the beginning of each period t, we assume that the borrower receives income z_t, which is a random variable with a cumulative distribution $F(z)$. Once the income flow is realized, the borrower faces the principal balance M_t and the disposable amount x_t ($t \in \{1, 2\}$), which the borrower can use to repay the loan. We further assume that the borrower does not have other resources besides this income in the first period, i.e., $x_1 = z_1$.

Sophisticated Borrowers For sophisticated borrowers, the decision is the amount to repay the loan, which is equivalent to choosing the saving balance in her bank account after making the loan payment, denoted as y_t. Note that $y_t \in [0, x_t]$ because negative payment is not allowed, and $x_t - y_t$ represents the amount that the borrower pays towards the loan in period t.

For ease of illustration, we assume that the loan defaults if the borrower's payment is less than the pre-determined payment amount. That is, the borrower has to pay at least the regular per-period payment m so that the loan is in good standing in the first period. Otherwise, the borrower defaults. Note that defaulting is a terminating action. Once the borrower defaults, the loan terminates, and there is no future action available to the borrower. That is, only if the borrower pays at least the regular amount in period 1, i.e., $m \leq x_1 - y_1$, the loan enters the next cycle, i.e. the second period. In period 1, the payment $x_1 - y_1$ made by the borrower is used first to pay towards the outstanding interest $r * M_t$ and the rest goes to the principal balance so that the principal balance in period 2 equals

$$M_2 = M_1 - (x_1 - y_1 - r * M_1). \tag{1}$$

As a consequence, the saving amount at the beginning of the 2nd period is

$$x_2 = y_1 + z_2. \tag{2}$$

We now introduce the borrower's flow utility. Let R denote the default cost for the borrower, and such a cost is the same regardless of the default timing or borrower characteristics. The default cost summarizes the penalty toward the borrower's credit rating, reputation, and so on. We abstract away consumption in this model and mainly focus on the decision regarding repayment. In each period, if the borrower pays the required amount, there is no penalty, so the flow utility from the loan is normalized to be zero, and it is $-R$ otherwise.

Besides caring about the loan outcome, the borrower also cares about the saving amount after the loan matures. In other words, if the borrower pays the required amount in the first period, then in the last period, i.e., $t = 2$, when the loan is matured, the borrower's overall utility, denoted as $w_2(x_2, y_2, M_2)$, consists of two parts - the saving and the utility from the loan outcome. Precisely, it can be represented as:

$$w_2(x_2, y_2, M_2) = \begin{cases} y_2 - R & (1+r)M_2 > x_2 - y_2 (\text{default}) \\ y_2 & (1+r)M_2 \leq x_2 - y_2 (\text{payoff}). \end{cases} \tag{3}$$

where y_2 is the saving the borrower keeps at the end of the loan and R is the default cost if any.

In the first period, the borrower's overall value, denoted as $V_1(x_1, y_1, M_1)$, consists of the loan outcome in the first period and the expected future payoff from the second period. Without loss of generality, we assume that there is no depreciation in the two periods. Specifically,

$$V_1(x_1, y_1, M_1) = \begin{cases} 0 + E[w_2(x_2, y_2, M_2)|x_1, y_1, M_1] & m \leq x_1 - y_1 (\text{regular payment or prepayment}) \\ -R + E[y_2|x_1, y_1, M_1] & m > x_1 - y_1 (\text{default}), \end{cases} \tag{4}$$

Note that if the borrower defaults in the first period, there is no action taken in the second period, so the expected payoff comes from the saving, i.e., $E[y_2|x_1, y_1, M_1]$.

Naive Borrowers For naive borrowers, the repayment decision is simple. That is, in each period, they have to decide whether to pay the regular per-period payment or not. If the naive borrowers default in the first period, the loan is terminated, and no further decision needs to make. Otherwise, a regular monthly payment m will be made in the first period and the principal balance in period 2 equals $M_2 = M_1 - (m - r * M_1)$, resulting in a remaining amount of m in the second period.

Same as the sophisticated borrower, the naive borrower also incurs a default cost R whenever she defaults. Also, her saving amount at the beginning of the period 2 is the sum of the saving balance and income shock at the end of period 1, namely, $x_2 = y_1 + z_2$. Therefore, the flow utility of a naive borrower equals

$$w_2(x_2, y_2, M_2) = \begin{cases} y_2 - R & m > x_2 - y_2 (\text{default}) \\ y_2 & m = x_2 - y_2 (\text{payoff}). \end{cases} \tag{5}$$

in the second period, and

$$V_1(x_1, y_1, M_1) = \begin{cases} 0 + E[w_2(x_2, y_2, M_2)|x_1, y_1, M_1] & m = x_1 - y_1 (\text{regular payment}) \\ -R + E[y_2|x_1, y_1, M_1] & m > x_1 - y_1 (\text{default}), \end{cases} \tag{6}$$

in the first period.

4.2 Optimal Decisions

This subsection characterizes the borrower's decision whether to take up the loan and the repayment decisions after they decide to take up the loan. We start by analyzing the naive borrowers and then the sophisticated borrowers. Note that when the default cost is sufficiently low, that is, $R \leq m$, the borrower always prefers default regardless of the ability to repay, which indicates that the borrower is going to default right away. Therefore, we only analyze the borrower's behavior when the default cost is reasonable. Our data also support this because there is very rare that borrowers default right away.

4.2.1 Naive Borrowers

We first characterize a naive borrower's optimal decision using backward induction. That is, we first characterize the optimal repayment decision assuming that the borrower takes up the loan; we then characterize the optimal decision regarding taking up the loan or not.

Period 2 repayment decision If the borrower does not default in the first period and has sufficient savings in the second period, that is, $x_2 \geq (1+r)m$, it is optimal for him to pay off the loan. Otherwise, he has to default and thus chooses to pay nothing. Consequently, the borrower's optimal strategy y_2^* in the second period could be described as

$$y_2^* = \begin{cases} x_2 & x_2 < (1+r)m \text{ (default)} \\ x_2 - (1+r)m & x_2 \geq (1+r)m \text{ (payoff)}. \end{cases} \tag{7}$$

Given the optimal strategy y_2^* in the second period, we can represent the optimal payoff in the last period given saving x_2 and principal balance m as follows:

$$w_2^*(x_2, m) \equiv \max_{0 \leq y_2 \leq x_2} w_2(x_2, y_2, m) = \begin{cases} x_2 - R & x_2 < (1+r)m \\ x_2 - (1+r)m & x_2 \geq (1+r)m, \end{cases}$$

where $x_2 = y_1 + z_2$ with z realized after the decision in the first period.

Period 1 repayment decision We then proceed to study the borrower's repayment behavior in the first period. If a borrower has insufficient savings in the first period, i.e., $x_1 < m$, he has no choice but to default immediately. Given that $x_1 \geq m$, the borrower faces disutility that comes from the default cost but gains benefit from a larger saving balance if defaulting. Since the naive borrower heavily relies on the platform's suggestion and never considers the possibility of making prepayments, she will pay regular payments m in the first period if avoid default. Note that when borrowers decide to pay the regular payments, she is forward-looking and evaluates the expected payoff from the second period's behavior. Specifically, she computes the expected payoff from the second period if she decides to avoid default, facing the uncertainty of the income and thus the probability of defaulting in the second period.

To investigate a naive borrower's strategy, we compare the payoff between regular payments and default. We first represent the borrower's payoff from defaulting in the first period. If the borrower does default in the first period, the borrower cannot choose regular payment in the second period and gets to save all his money automatically. If the borrower defaults, i.e., $y_1 = x_1$, the payoff correspondingly equals

$$V_1(x_1, x_1, M_1) = \frac{\bar{I}}{2} + x_1 - R. \tag{8}$$

where $\bar{I}/2 + x_1$ is the expected saving if the borrower default, and R is the default cost.

Since the borrower defaults in the second period if her saving is not sufficient, the probability of default in the second period, with a regular payment in the first period, could be calculated as $(2m - x_1)/\bar{I}$. This means that given the borrower does not default in the first period, the default probability in the second period decreases in the saving in the first period x_1. Once the first-period saving x_1 reaches $2m$, further increases in saving no longer benefit the borrowers in reducing default probability in the second period. Consequently, when $x_1 > 2m$, the payoff of the regular payment equals $x_1 + \bar{I}/2 - 2m$. In this case, we can easily derive that the naive borrower chooses to default in the first period when $R < 2m$ and make regular payments otherwise.

When $x_1 < 2m$, the payoff associated with regular payment can be represented as

$$V_1(x_1, x_1 - m, M_1) = \frac{\bar{I}}{2} - 2m - \frac{2m(R-m)}{\bar{I}} + (1 + \frac{R-m}{\bar{I}})x_1.$$

We then calculate the payoff difference between making regular payments and default:

$$\begin{aligned} \Delta V_1^b(x_1, M_1, R) &\equiv V_1(x_1, x_1 - m, M_1) - V_1(x_1, x_1, M_1) \\ &= -2m + R - \frac{2m(R-m)}{\bar{I}} + \frac{R-m}{\bar{I}} x_1. \end{aligned} \tag{9}$$

which is increasing in default cost R and initial saving x_1 because $R > m$. Intuitively, if the borrower's default cost or saving is higher, it is better to make payments than to default. However, the tradeoff between regular payment and default is not straightforward. It ultimately depends on the relationship between the saving amount and the default cost. Specifically, there is another cutoff for the saving

$$\bar{x}_1(R) \quad = \quad 2m - \bar{I} + \frac{m}{R-m}\bar{I} = 2m + \frac{2m-R}{R-m}\bar{I} \tag{10}$$

such that if $x_1 > \bar{x}_1(R)$, regular payment is better than the default; and the default is better, otherwise. Intuitively, between the selection of default and regular payment, the borrower prefers regular payment more if the default cost or initial saving is larger. However, when it comes to borrowers with different income caps, it becomes complex. This is due to the fact that an increase in income cap I has multiple effects on the payoff difference $\Delta V_1^b(x_1, M_1, R)$ between regular payments and default. On the one hand, an increase in income makes regular payments more attractive and reduces the cut-off $\bar{x}_1(R)$. On the other hand, an increase in income also reduces the weight of initial savings in the payoff. Consequently, the borrower requires a higher initial saving cut-off $\bar{x}_1(R)$ to make regular payments. The strength of these two conflicting effects is determined by the default cost R. Given the default cost is above $2m$, i.e., $R \geq 2m$, the borrowers prefer regular default more if the income cap becomes larger.

To summarize, a naive borrower will pay off the loan in the second period as long as she has sufficient savings. In the first period, she always defaults when her default cost is extremely low $R < 2m$ or she has no sufficient saving $x_2 < m$. Otherwise, her strategy depends on her saving x_1 and default cost R as shown in Figure 5. Precisely, she chooses to make a regular payment when the savings x_1 or default cost R are high and defaults otherwise.

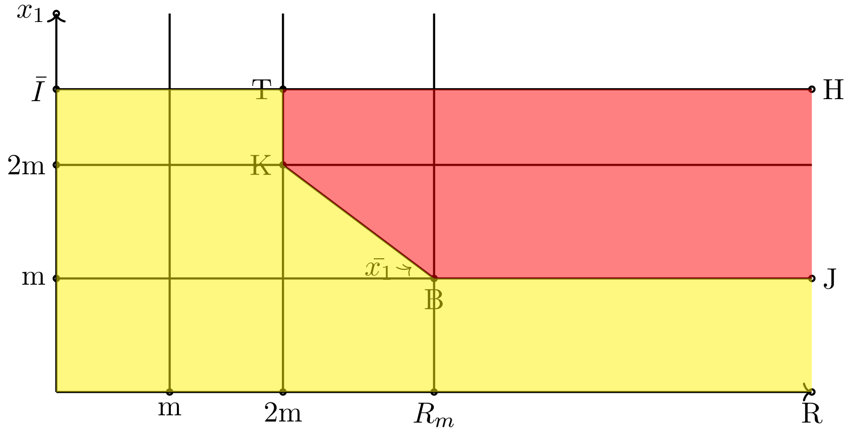


Figure 5: Naive Borrower repayment strategy

Loan or not? Once the borrower's optimal repayment strategies are established, the borrower will accept the loan if the expected value from the loan is greater than the value of the outside option. That is, if $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)] \geq V_0$, the borrower accepts the loan, and leaves the platform otherwise.

As shown in Appendix A.3, $E_{z_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in default cost R and interest rate r for given M_1 and r. Therefore, for any given borrow amount M_1 and interest rate r, there exists a default cost cutoff, denoted as $\bar{R}(M_1, r)$ such that any borrower whose default cost is higher than such a cutoff would choose not to take up the loan, and only those whose default cost is lower than the cutoff would take up the loan. Moreover, if the interest rate increases, such a cutoff becomes lower, indicating that a higher interest rate would deter more of the good borrowers out of the market, which is consistent with the finding in the seminar paper by (Stiglitz and Weiss, 1981).

Implicate of a rising interest rate As shown in Figure 5, naive borrowers with lower default costs are more likely to default rather than make payments. When there is an increase in interest rates, the loan becomes less attractive to borrowers with higher default costs, and thus seek outside options, but the riskier borrowers stay. Moreover, higher interest indicates that borrowers have to pay a higher amount of monthly payments. Both effects suggest naive borrowers have higher default probabilities on the peer-to-peer lending platform if the interest rate increases.

4.2.2 Sophisticated Borrowers

We then characterize a sophisticated borrower's optimal repayment and entry decision using backward induction. Same as the naive borrower, a sophisticated also prefers default regardless of the ability to repay when the default cost is sufficiently low $R \leq m$.

Period 2 repayment decision

Given $R > m$, a sophisticated borrower will also choose to pay off the loan if she has sufficient savings such that $x_2 \geq (1+r)M_2$. Otherwise, he has to default and thus chooses to pay nothing. Consequently, the borrower's optimal strategy y_2^* in the second period could be described as

$$y_2^* = \begin{cases} x_2 & x_2 < (1+r)M_2 \text{ (default)} \\ x_2 - (1+r)M_2 & x_2 \geq (1+r)M_2 \text{ (payoff)}. \end{cases} \tag{11}$$

With the optimal strategy y_2^* in the second period, we can represent the optimal payoff in the last period given saving x_2 and principal balance M_2 as follows:

$$w_2^*(x_2, M_2) \equiv \max_{0 \leq y_2 \leq x_2} w_2(x_2, y_2, M_2) = \begin{cases} x_2 - R & x_2 < (1+r)M_2 \\ x_2 - (1+r)M_2 & x_2 \geq (1+r)M_2, \end{cases}$$

where $x_2 = y_1 + z_2$ and $M_2 = (1+r)M_1 - x_1 + y_1$ with z realized after the decision in the first period.

Period 1 repayment decision

We then proceed to study the borrower's repayment behavior in the first period with a modest initial saving amount, i.e., $m \leq x_1 \leq (1+r)M_1$. With insufficient savings in the first period, i.e., $x_1 < m$, a borrower has no choice but to default immediately. While if the borrower's saving is too high such that he can pay off the loan immediately in the first period $x_1 > (1+r)M_1$, there is no trade-off between regular payment and prepayment. However, one goal of the model is to understand the trade-off between regular payment and prepayment, thus we study the scenario where $x_1 > (1+r)M_1$ in the later analysis.

Specifically, conditional on the current saving x_1, payment plan y_1 and balance M_1, the expected payoff from not defaulting can be presented as

$$\begin{aligned}
& V(x_1, y_1, M_1) = E[w_2^*(x_2, M_2)|x_1, y_1, M_1] \\
= \;& \int_0^{(1+r)M_2-y_1} \underbrace{(y_1 + z - R)}_{\text{default in period 2}} \, dF(z) + \int_{(1+r)M_2-y_1}^{\bar{I}} \underbrace{(y_1 + z - (1+r)M_2)}_{\text{payoff in period 2}} dF(z) \\
= \;& E(Z) - R + y_1 - \int_{(1+r)^2M_1-(1+r)x_1+ry_1}^{I} \left[(1+r)^2 M_1 - (1+r)x_1 + (1+r)y_1 - R\right] dF(z),
\end{aligned} \tag{12}$$

where $0 \leq y_1 \leq x_1 - m$. Such an expected payoff presents the trade-off payments at different amounts. If the borrower pays a larger amount, i.e., y_1 becoming smaller, she faces a lower principal balance in the second period, i.e., $M_2 = (1+r)M_1 - x_1 + y_1$ being smaller, so that the overall saving after paying off is higher if the borrower has enough income flows to pay off the loan. However, if the borrower gets unlucky and is forced to default due to insufficient savings, paying a higher amount in the first period will result in lower savings in this situation. Consequently, the borrower has to weigh the default probability when she makes the optimal repayment amount.

On the other hand, if the borrower defaults in the first period, there is no future action taken, so the expected payoff then can be represented as

$$V_1(x_1, y_1 = x_1, M_1) = -R + x_1 + E(Z). \tag{13}$$

To better understand the borrower's repayment plan, we first analyze the borrower's optimal payment amount when not defaulting and then study the decision over whether default or not. To analytically derive the optimal strategy, we assume that the income distribution follows a uniform distribution, i.e., $F(z) = \frac{z}{\bar{I}}$, where $z \in [0, \bar{I}]$ with $\bar{I}$ being the income cap.

Regular payment versus prepayment If the borrower does not default in the first period, that is, $m \leq x_1 - y_1$, the overall payoff comes from the expected utility of the second period, represented by Equation 12. With the assumption $F(z) = \frac{z}{\bar{I}}$, this overall payoff function is a convex function of y_1, so the suboptimal payment is either just paying the regular payment, i.e., $y_1 = x_1 - m$, or pay all current saving, i.e., $y_1 = 0$. To determine which plan is better, we compare the overall payoff associated with these two strategies. Specifically, we calculate the difference between the expected payoffs from paying the regular payment and all saving

$$\begin{aligned}\Delta V_1^a(x_1, M_1, R) &\equiv V_1(x_1, x_1 - m, M_1) - V_1(x_1, 0, M_1) \\ &= \frac{(x_1 - m)}{\bar{I}}\{-r(\bar{I} + R) - mr(1+r) + (1+r)^2(2r+1)M_1 - (1+r)^2 x_1\}, \quad (14)\end{aligned}$$

which is monotonically decreasing with the initial saving and default cost. Specifically, the larger the initial saving/default cost, the better off if the borrower pays all savings. Consequently, there exists a threshold for the initial saving depending on the default cost,

$$\hat{x}_1(R) = \frac{(1+r)^2(2r+1)M_1 - mr(1+r) - r(I+R)}{(1+r)^2} = m + \frac{(2r+1)m - r(I+R)}{(1+r)^2},$$

at which level the borrower is indifferent between regular payment and paying all savings, and the borrower prefers regular payment more than paying all savings if the initial saving is below this cutoff. In addition, this cutoff $\hat{x}_1(R)$ is decreasing in default cost R and income cap I, indicating the borrower prefers prepayment more when the income cap or default cost is larger. Intuitively, when the borrower has low initial savings, or the income distribution is low, his chance to default in the future increases. As a consequence, his motivation to make more payments in the first period reduces.

Now that this cutoff does not trivially hold meaningful only if it is greater than the regular monthly payment m and smaller than the income cap. If it is smaller than the initial saving, i.e., $\hat{x}_1(R) < m$, paying all savings is always preferred. If it is larger than the income cap, i.e., $\hat{x}_1(R) > \bar{I}$, regular payment is always preferred. Thus, we need to determine where this cutoff falls between m and $\bar{I}$. First of all, if the income cap is big enough, i.e., $\bar{I} \geq 2m$, which holds trivially in practice, this cutoff of indifference is always below the income cap, i.e., $\hat{x}_1 \leq I$. Secondly, the relationship between this cutoff and the regular payment depends on the borrowed amount M_1, the income cap $\bar{I}$, and the default cost R. Specifically, there is a cutoff default cost

$$\hat{R}(r) = \frac{(1+r)^2(1+2r)M_1}{r(2+r)} - \bar{I},$$

such that $\hat{x}_1 > m(r)$ if $R \leq \hat{R}(r)$; and $\hat{x}_1 \leq m(r)$ otherwise. To avoid the trivial market equilibrium that no one prefers regular payment, we also let $\bar{I} \leq I^* \equiv (1 + \frac{1}{r})m$ so that $\hat{R} > m$. Thus, we are able to summarize the decision over regular payment and all savings conditional on not defaulting in the following lemma.

Lemma 1. *Given that the income cap satisfies the following condition, i.e., $2m \leq \bar{I} \leq I^*$, borrowers who have moderate default costs, i.e., $m \leq R \leq \hat{R}(r)$, prefer regular payments other than paying all savings when the saving is smaller than the saving cutoff $\hat{x}_1(R)$; and prefer using up all saving to regular payment otherwise; for borrowers who have relatively high default costs, i.e., $R > \hat{R}(r)$, they always prefer using up all the saving. That is,*

$$y_1^*|no\ default = \begin{cases} x_1 - m & m \leq x_1 < \hat{x}_1(R) \& m \leq R \leq \hat{R}(r) \\ 0 & x_1 \geq \hat{x}_1(R) \& m \leq R \leq \hat{R}(r), or\ R > \hat{R}(r). \end{cases} \quad (15)$$

Intuitively, in the situation of not defaulting in the first period, if the borrower has a high default cost, the borrower is highly motivated to avoid default in the second period. Making as much as possible prepayment not only saves interest for the borrower but also reduces the borrower's default risks in the future. When the borrower's default cost is low, i.e., $R < \hat{R}$, the benefit of avoiding default in the second period decreases. On the other hand, if he defaults in the future, making prepayments in the first period will reduce his saving and make him even worse. Thus the borrower's payment strategy depends on his saving x_1. Precisely, the borrower chooses to only make the minimum payment m when his saving is relatively low. Otherwise, it is better for the borrower to make prepayments and use up all his savings.

Regular payment versus default From the previous analysis, we derive that, for borrowers who have moderate default costs, i.e., $m(r) \leq R \leq \hat{R}(r)$, they prefer regular payment more than paying all savings when the saving is smaller than the saving cutoff, i.e., $m(r) \leq x_1 < \hat{x}_1(R)$. Based on the previous analysis of naive borrowers, we find making regular payments is better than choosing default when $x_1 > \bar{x}_1(R)$; and the default option is better otherwise.

To determine the region that regular payment is the best among all three options, we need to sort out the overlapping between region $m \leq x_1 < \hat{x}_1(R)$ and $x_1 > \bar{x}_1(R)$, with $m \leq R \leq \hat{R}(r)$. That is, we have to figure out the relationship between $\hat{x}_1(R)$ and $\bar{x}_1(R)$ when $m \leq R \leq \hat{R}(r)$. As shown in Appendix, we find that the overlapping of the two conditions depends critically on the income cap. We summarize the result in the following lemma.

Lemma 2. *When a borrower has moderate default costs, i.e., $m(r) \leq R \leq \hat{R}(r)$, and low initial saving, i.e., $m(r) \leq x_1 < \hat{x}_1(R)$, the borrower's preference over default and regular payment is determined by his income distribution. More precisely, there exists some cutoff for the income cap defined as*

$$\bar{I}_1 = \frac{m(1+r) + m\sqrt{1-2r-3r^2}}{2r}, \tag{16}$$

such that

- *If the income cap is low, i.e., $2m < \bar{I} < \bar{I}_1$, there exists a cutoff for default $\bar{R} \in [m, \hat{R}]$ such that $\hat{x}_1(\bar{R}) = \bar{x}_1(\bar{R})$. Thus, the optimal repayment strategy can be characterized as*

$$y_1^* = \begin{cases} x_1 - m \textit{(regular payment)} & \bar{x}_1(R) < x_1 < \hat{x}_1(R) \\ x_1 \textit{(default)} & m \leq x_1 \leq \bar{x}_1(R), \end{cases} \tag{17}$$

  where the default cost is not too large, i.e., $m(r) \leq R \leq \hat{R}(r)$.

- *If the income cap is modest, i.e., $I^* \geq \bar{I} \geq \bar{I}_1$, then $\bar{x}_1(R)$ is always higher than $\hat{x}_1(R)$ for any R that $m(r) \leq R \leq \hat{R}(r)$. Thus, the optimal repayment strategy can be characterized as*

$$y_1^* = x_1 \textit{(default)}, \quad x_1 \leq \hat{x}_1(R) \quad \& \quad m \leq R \leq \hat{R}. \tag{18}$$

Prepayment versus default From the comparison between regular payment and prepayment, we know that borrowers prefer paying all savings to regular payment in the following two regions: 1) moderate default costs jointly with relatively high savings, i.e., $(1+r)M_1 > x_1 \geq \hat{x}_1(R)$ where $m(r) \leq R \leq \hat{R}(r)$, and 2) high default cost, i.e., $R > \hat{R}(r)$ but $m(r) < x_1 < (1+r)M_1$.

To determine the borrower's optimal strategy in these two regions, we need to compare the payoff between paying all savings and default. We first represent the payoff from paying all savings in the following:

$$V_1(x_1, 0, M_1) = \frac{\bar{I}}{2} - \frac{R[(2+r)m - (1+r)x_1]}{\bar{I}} - \frac{[(2+r)m - (1+r)x_1][\bar{I} - (2+r)m + (1+r)x_1]}{\bar{I}}$$

We then simplify the payoff difference between prepayment and default as

$$\begin{aligned} & \Delta V_1^c(x_1, M_1, R) \equiv V_1(x_1, 0, M_1) - V_1(x_1, x_1, M_1) \\ = \; & \frac{(1+r)^2}{\bar{I}} x_1^2 + \left(r - \frac{2m(1+r)(2+r)}{\bar{I}} + \frac{(1+r)}{r} R \right) x_1 + R + \frac{m(2+r)[(2+r)m - \bar{I} - R]}{\bar{I}}, \end{aligned} \tag{19}$$

which again depends on the initial saving x_1 and default cost R. Specifically, the comparison between prepayment and default is monotonically increasing with the default cost. With a higher default cost, prepayment is more attractive. Such a difference is a concave function of the initial saving x_1. Furthermore, we find that the concave function is effective in our analysis in the region where x_1 is increasing. That is, when the initial saving becomes larger, the borrower prefers prepayment to default.

Similar to the previous analysis, there is a saving cutoff

$$\tilde{x}_1(R) = \frac{2m(2+3r+r^2) - \bar{I}r - (1+r)R + \sqrt{\bar{I}^2 r^2 + 2\bar{I}(2+3r+r^2)(2m-R) + R^2(1+r)^2}}{2(1+r)^2},$$

such that if $x_1 > \tilde{x}_1(R)$, the payoff difference $V_i^c(x_1, M_1, R)$ is positive; and is negative, otherwise.

Since the borrower only prefers prepayment over regular payment in specific areas, we then have to analyze the position of $\tilde{x}_1$ in the two regions respectively. In the first region where borrowers have moderate default costs jointly with relatively high savings, i.e., $(1+r)M_1 > x_1 \geq \hat{x}_1(R)$ and $m(r) \leq R \leq \hat{R}(r)$, two crucial overlappings determine the portion of borrowers preferring default over prepayments. Firstly, it is critical to sort out the relationship between $\hat{x}_1(R)$ and $\tilde{x}_1(R)$ when $m \leq R \leq \hat{R}(r)$. In other words, we are interested in knowing if there is an intersection between $\hat{x}_1(R)$ and $\tilde{x}_1(R)$ when $m \leq R \leq \hat{R}(r)$. Second, we have to check the relationship between $\tilde{x}_1(R)$ at $R = \hat{R}$ and the maximum saving $(1+r)M_1$ beyond which borrowers can pay off the loan immediately in the first period. If $\tilde{x}_1(\hat{R}) \geq (1+r)M_1$, the cutoff $\tilde{x}_1$ has no intersection with the first region, and thus all the borrowers in the first region prefer default over prepayments. In the second region where borrowers have high default cost, i.e., $R > \hat{R}$, we have to compare the relationship between the saving cutoff $\tilde{x}_1$ and the boundary m.

In order to focus on the critical aspects without losing generality, our paper mainly discusses the scenario where the income cap is moderate $(2+r)m < \bar{I} < \bar{I}_1$, and thus borrowers have positive possibilities in choosing all three strategies: default, regular payments, and prepayments.[12] In particular, we find that the borrower's strategy over default and prepayment could be summarized as follows.

Lemma 3. *Given that a borrower's income cap is moderate, i.e., $(2+r)m < \bar{I} < \bar{I}_1$, the borrower's strategy of paying all savings and default is determined by his default cost and initial savings. Specifically, there exists a combination of the default cost and initial saving, i.e., $R = \bar{R}$ and $x_1 = (\tilde{x}_1(\bar{R}) = \hat{x}_1(\bar{R}) = \bar{x}_1(\bar{R}))$, with which the borrower is indifferent among default, prepayment, and regular payment. More precisely, the optimal repayment strategy can be characterized as*

- *When the borrower's default cost is low, her optimal repayment strategy can be characterized as*

$$y_1^* = \begin{cases} 0\,\textit{(pay all saving)} & x_1 > \tilde{x}_1(R), \textit{where } m < R \le \bar{R} \\ x_1\,\textit{(default)} & \hat{x}_1 \le x_1 \le \tilde{x}_1(R), \textit{where } m < R \le \bar{R} \end{cases} \tag{20}$$

- *The borrower's optimal repayment strategy is always to pay all savings when the borrower's default cost is moderate, i.e., $\hat{R} > R > \bar{R}$, together with the saving is relatively larger, i.e., $x_1 \ge \hat{x}_1(R)$, or the default cost is very big, $R \ge \hat{R}$. That is,*

$$y_1^* = 0. \quad R \ge \hat{R}, \quad \textit{or } x_1 > \hat{x}_1(R), \textit{where } \hat{R} > R > \bar{R} \tag{21}$$

Pay off versus Default In the previous investigation, we assume that the borrower's initial saving is not sufficient to pay off the loan immediately in the first period, i.e. $x_1 < (1+r)M_1$. In this section, we study the borrower's choice of prepayment and default. If a borrower's initial saving is high such that $x_1 \ge (1+r)M_1$, we may imagine him as if dividing the saving into the following two parts. The first part consists of $(1+r)M_1$ amount and is used to pay off the loan in the first period. Corresponding, his payoff equals the utility of paying all his savings at $x_1 = (1+r)M_1$. According to Equation 19, his utility equals $V_1((1+r)M_1, 0, M_1)$ and can be simplified as $\bar{I}/2$. The second part consists of the rest of the savings and brings a utility of $x_1 - (1+r)M_1$. As a consequence, the borrower's utility for paying off the loan in the first period is

$$V_1(x_1, x_1 - (1+r)M1, M_1) = x_1 + \frac{\bar{I}}{2} - \frac{2+r}{1+r}m$$

Based on this, we further calculate the payoff difference between paying off the loan and default and derive:

$$\Delta V_1^d = V_1(x_1, x_1 - (1+r)M1, M_1) - V_1(x_1, x_1, M_1) = R - \frac{2+r}{1+r}m$$

[12]The analysis of other cases is provided in the Appendix and indicates similar conclusions.

The result indicates that the borrowers prefer paying off the loan in the first period when their saving and default costs are both larger than $(1+r)M_1$. In addition, we also find that $\tilde{x}_1(R)$ equals $(1+r)M_1$ at $R=(1+r)M_1$.

Given that the income cap is not too high, i.e., $\bar{I} < \bar{I}_1$, the optimal repayment strategy in period 1 could be any of the three strategies: default, regular payment, and making prepayments as shown in Figure 6, depending on the realization of the income flow and the default cost. Specifically, a borrower's optimal repayment strategy could be characterized as follows. First, the borrower will always default when his default cost is low, i.e., $R < (1+r)M_1$, or the initial income realization is low, i.e., $x_1 < m$. Given that the borrower's default cost is median, i.e., $R \geq (1+r)M_1$, and his initial income realization x_1 is sufficient to pay off the loan, i.e., $x_1 > (1+r)M_1$, he will pay off the loan immediately in the first period. Otherwise, the optimal repayment depends on three cutoffs: $\bar{x}_1$, $\hat{x}_1$, and $\tilde{x}_1$, which crosses at R^*. When the borrower's default cost is low $R < R^*$, he will default when his initial income x_1 is lower than $\tilde{x}_1$ and pay all his savings otherwise. When the borrower's default cost is moderate such that $R^* \leq R \leq \hat{R}$, the borrower chooses to default if his saving is extremely low $x_1 < \bar{x}_1$, make regular payment when his saving is moderate $\bar{x}_1 \leq x_1 \leq \hat{x}_1$, and pay all the savings when his saving is high $x_1 > \hat{x}_1$. Once the borrower's default cost exceeds $\hat{R}$, he always tries to avoid default. As a consequence, his optimal strategy is to use up all his savings to pay off the loan as soon as possible.

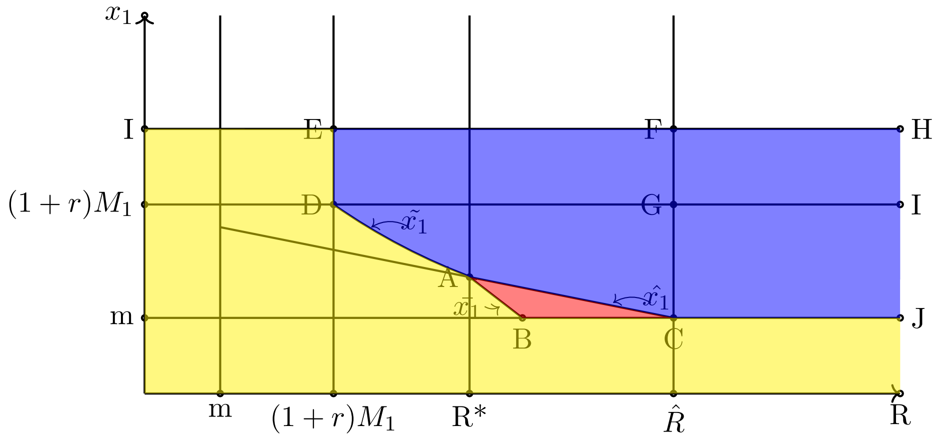


Figure 6: Sophisticated borrower repayment strategy ($\bar{I} < \bar{I}_1$)

Intuitively, if a borrower has an extremely low default cost, he always prefers to default as soon as possible and derives all the savings. When a borrower's default cost is extremely high, he always prefers avoiding being defaulted. As a consequence, his best deal is to use his savings and pay off his loan as soon as possible. If a borrower's default cost is moderate, his strategy depends on how much savings he has in the first period. If his saving is low, his default risk in the future is correspondingly high. As a consequence, the borrower chooses to default in the first period to receive all the utility from savings. While if the borrower's saving in the first period is high, he will be better off making as much prepayment as possible. In this way, he is able to save interest and reduce his default risk in the future at the same time. When the borrower's saving is moderate, his strategy is between those two radical strategies. More precisely, the borrower chooses to pay the minimum amount to avoid being default in the first period.

Loan or not

For sophisticated borrowers, the repayment strategies are more complicated. Once a sophisticated borrower takes up the loan, the lower the default cost, the borrower is more likely to default and less likely to make prepayments (see Figure 6), i.e., two dimensions of loan risks that a lender would like to avoid. Given a specific default cost and an assigned interest, a borrower forms an expected utility for using Prosper based on her repayment strategy. If this expected utility $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is no less than the outside option V_0, the borrower will accept the interest assigned by Prosper and join the platform. Otherwise, she leaves the market.

Same as the naive borrowers, a sophisticated borrower's utility on Prosper $E_{z_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in default cost R and interest rate r for given M_1 and r, meaning that there exists a default cost cutoff such that only borrowers whose default cost lower than this cutoff will join the platform. Moreover, an increase in interest decreases this default cost cutoff and diminishes the number of borrowers on the platform.

Implication if interest rate increases

As shown in Figure 6, sophisticated borrowers with lower default costs are more likely to default, while less likely to make prepayments. With higher interest rates, borrowers whose default costs are high leave the market first, resulting in a riskier borrower composition. Therefore, the percentage of borrowers with low default costs increases and we should expect to see the fraction of default increase while prepayment decreases. Besides the adverse selection in borrowers, higher interest rates also generate larger monthly payments, which is the minimum amount for borrowers to avoid default. Intuitively, this also indicates borrowers should find it more difficult to avoid default or make prepayments. In summary, both effects increase the default probability but decrease the prepayment probability of sophisticated borrowers.

5 Simulations

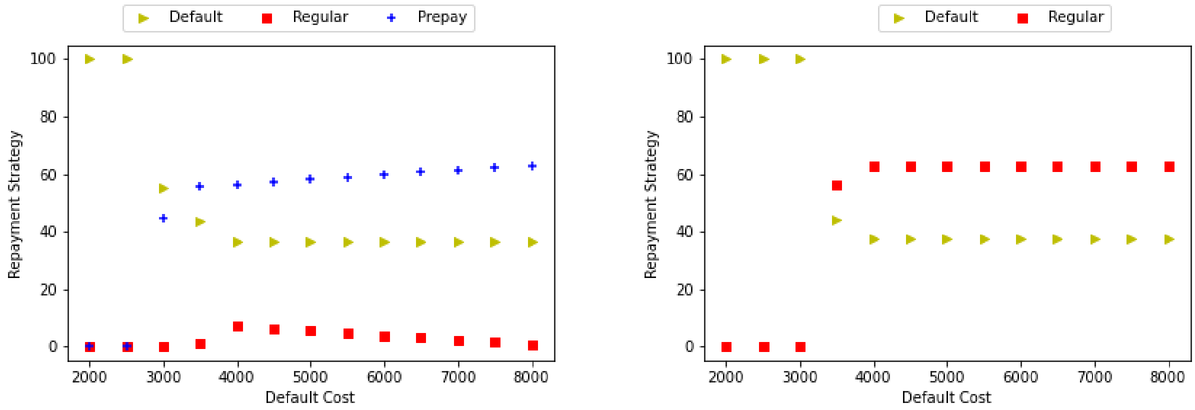
In this section, we simulate borrowers' behaviors in a simple environment, mimicking Prosper's practice, to rationalize the observed counter-intuitive pattern: when there is an interest increase on a peer-to-peer lending platform, the platform's overall prepayment ratio increases, the regular payment ratio decreases, while the default ratio may either increase or decrease.

5.1 Borrowers' optimal response

We are interested in how default costs and interest rates impact the entry and repayment behaviors of sophisticated borrowers and naive borrowers on the platform.

As a starting point, we first investigate the optimal entry strategies of sophisticated and naive borrowers respectively. In Figure A.4, we plot the expected utility of borrowers with different default costs for joining Prosper. To simplify, we assume all borrowers are from the same Fico score, with the same loan amount $M = \$2500$, face the same interest rate $r = 15\%$, and draw income shocks from the same uniform distribution in $U[0, 5000]$. The figure shows that both sophisticated borrowers and naive borrowers derive lower expected utility for joining Prosper when they have higher default costs. Moreover, given the same default cost, the utility of a naive borrower is always lower than that of a sophisticated borrower. This is because sophisticated borrowers have a wider set of strategies than naive borrowers.

The monotone relationship between utility and default cost indicates that, given an interest rate, there must exist a default cutoff c such that only borrowers whose default cost is lower than c will join the platform. Also, at the same interest rate, the cutoff of naive borrowers must be always lower than that of sophisticated borrowers. To confirm, we estimate borrowers' default cost cutoffs with increasing interest rates in Figure A.5. As expected, naive borrowers have lower default cost cutoffs for using the platform than sophisticated borrowers. Furthermore, higher interest rates reduce all borrowers' default cost cutoffs for using Prosper. In other words, an increase in interest rate makes it more expensive to use Prosper and hence decreases the number of borrowers joining the platform.



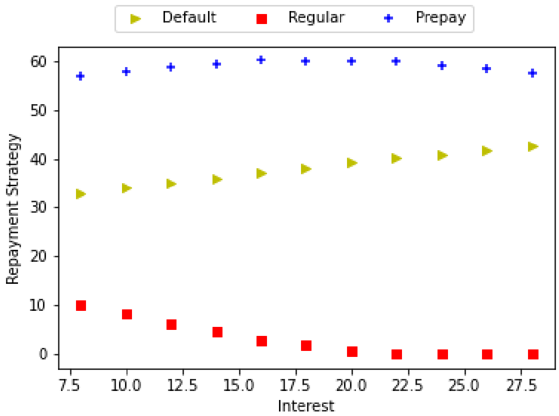
(a) Repayment Strategy (Sophisticated)

(b) Repayment Strategy (Naive)

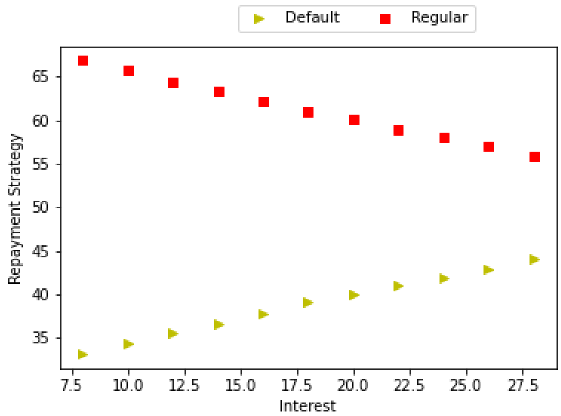
Figure 7: Repayment Strategy at Different Default Costs

We next extend our study to the borrowers' repayment behavior after joining Prosper. In Particular, we first investigate the impact of default costs on the repayment behaviors of sophisticated borrowers and naive borrowers respectively, and then extend to the impact of interest rates. Following the previous analysis, we continue assuming that all borrowers have the same loan amount $M = 2500$, the same interest rate $r = 15\%$, and the same uniform income shock in $U[0, 5000]$. In Figure 7, we plot the repayment strategies for borrowers with different default costs. For naive borrowers, the probability of default decreases when the default cost increases, while the probability of regular payments increases. For sophisticated borrowers, the default probability also decreases in default cost, the prepayment probability increases, and the regular payment probability may move in either direction but with quite small magnitudes.

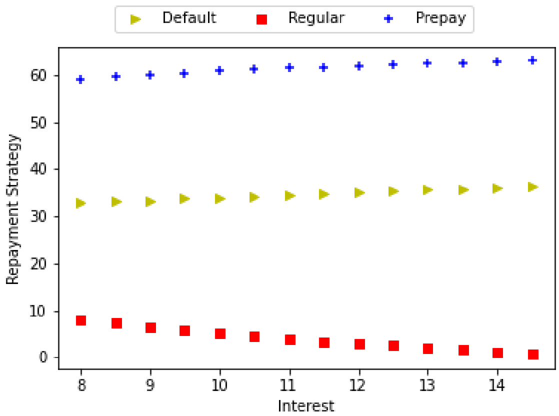
We then simulate borrowers' repayment strategies at different interest rates. In figure 8, we plot the probability of each repayment strategy with increasing interest rates of sophisticated borrowers and naive borrowers respectively. Without loss of generality, we focus on borrowers at two default cost levels $R = 6000$ and $R = 8200$.



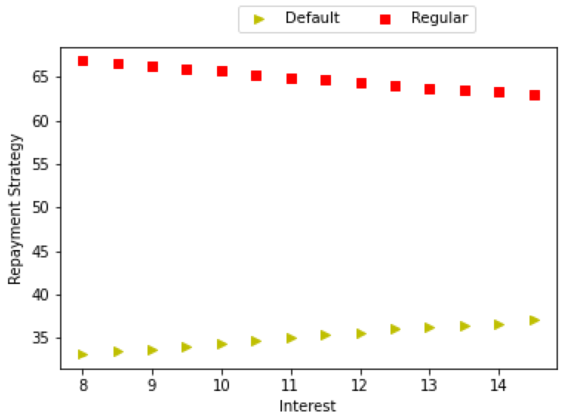
(a) Sophisticated Borrowers ($R = 6000$)



(b) Naive Borrowers ($R = 6000$)



(c) Sophisticated Borrowers ($R = 8200$)



(d) Naive Borrowers ($R = 8200$)

Figure 8: Repayment Strategies at Different Interests

Notes: The largest interest rates for borrowers with $R = 8200$ is set to be 15% in the figure, because naive borrowers with $R = 8200$ will all exist Prosper with higher interest rates.

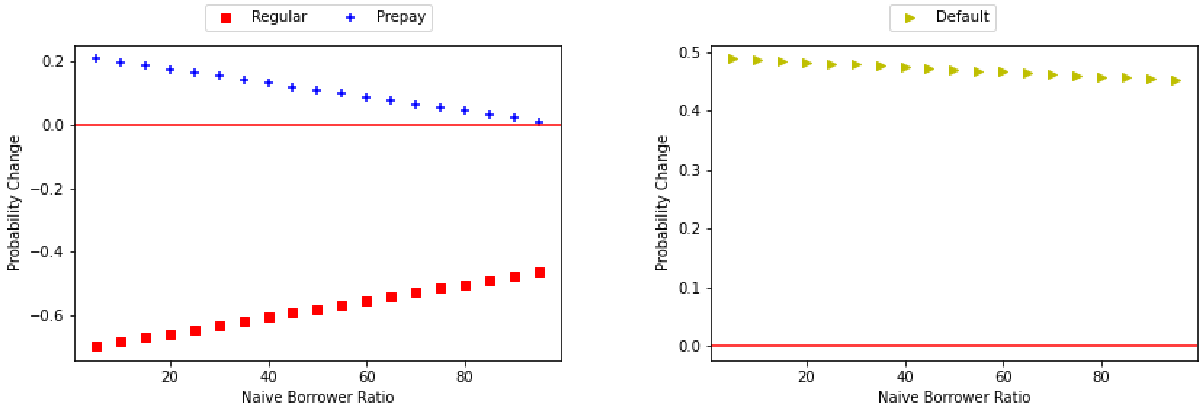
We find that a higher interest rate always increases the default probability while decreasing the regular payment probability for both sophisticated borrowers and naive borrowers. As for the prepayment strategy, its overall probability can either increase or decrease in interest rates. When interest rates are higher, borrowers have to pay more to reach the regular payment and avoid default. Therefore, the default probability increases but the regular payment probability decreases for all borrowers. For sophisticated borrowers, a higher interest rate increases the monthly payment amount and thus raises the threshold for prepayments. However, the increase in interest rates also makes the future payment more expensive and the prepayment option more profitable for borrowers. When interest rates are low, the impact on prepayment profitability is more dominant, and thus the prepayment probability increases in interest rate. But when interest rates are sufficiently high, the impact on the prepayment threshold becomes stronger, and the prepayment probability becomes decreasing in interest rate.

5.2 Prosper's Practice

Based on the findings concerning how interest and default costs affect sophisticated borrowers and naive borrowers, we now proceed to the more complicated scenario where two types of borrowers are mixed. If there is an increase in the interest rate on Prosper, there are two potential impacts imposed on borrowers. First, given a default cost level, some naive borrowers may leave the platform and thus the borrower composition can change after an interest increase. Second, with a higher interest rate, borrowers on Prosper may choose different repayment strategies even if they continue using the platform.

Considering the fact that given an interest rate, the naive borrowers' default cost cutoffs for joining Prosper are always lower than that of sophisticated borrowers, we can typically classify borrowers into two categories, depending on whether borrower composition changes after interest increase. The first category covers borrowers with low default costs such that they all continue staying on Prosper after the interest increase. The second category covers borrowers with higher default costs such that all naive borrowers leave the market after the interest increase. Based on the default cost cutoffs listed in Figure A.5, we study the scenario when interest increases from 15% to 16% and focus on the two representative default cost levels $R = 6000$ and $R = 8200$. In Particular, borrowers whose default cost equals 6000 all continue using Prosper after the interest increase, while borrowers whose default cost equals 8200 continue using Prosper after the interest increase only if they are sophisticated.

We first investigate the change of overall repayment strategy for borrowers whose default costs equal 6000. When the interest increases from 15% to 16%, we calculate the probability change of each repayment strategy with different percentages of sophisticated borrowers on the platform. As shown in Figure 9, higher interest rates always increase both the default and prepayment probability, while decreasing the probability of regular payment. Since there is no change in borrower combination after the interest increase, the result is not surprising given the impact of interest on sophisticated borrowers' and naive borrowers' repayment strategies as shown in Figure 8. Moreover, we also find the magnitude of the repayment strategy's absolute change tends to be smaller when the percentage of naive borrowers is high. This is due to the fact the change of repayment strategy of sophisticated borrowers is larger than naive borrowers when interest increases from 15% to 16%. Hence, when the percentage of naive borrowers increases, the magnitude of overall repayment change becomes smaller.

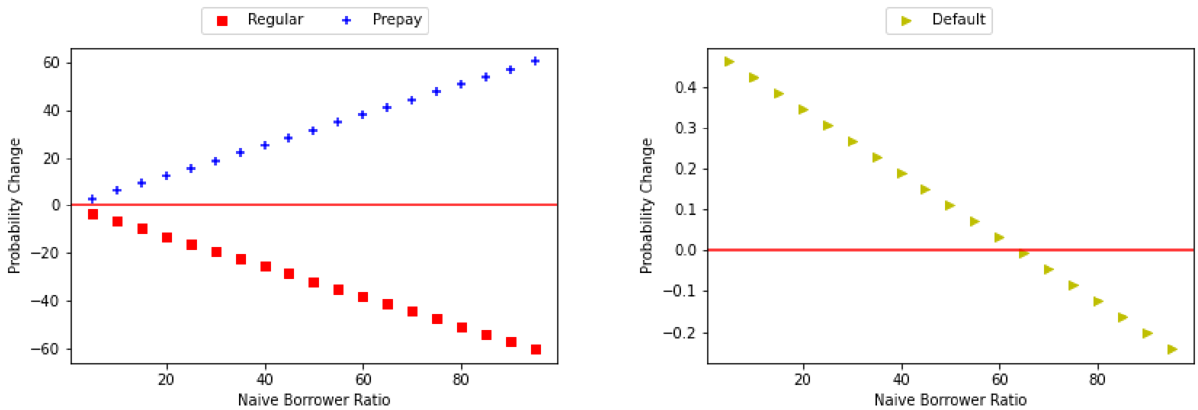


(a) Repayment Strategy Change ($R = 6000$) (b) Default Probability Change ($R = 6000$)

Figure 9: Repayment Strategy Change ($R = 6000$)

We then study the change of overall repayment strategy for borrowers whose default cost equal 8200. When the interest increases from 15% to 16%, naive borrowers exit the market. Therefore, the market incurs two simultaneous impacts. On the one hand, an increase in interest rate motivates borrowers to default more and prepay more, but less likely to make regular payments. On the other hand, an increase in interest rate expel naive borrowers from the market. Hence, the overall default and regular payment probability decrease while the prepayment probability increases. Furthermore, the composition of borrowers determines the magnitudes of two effects.

Figure 10: Repayment Strategy Change



(a) Repayment Strategy Change ($R = 8200$) (b) Default Probability Change ($R = 8200$)

In Figure 10, we calculate the probability change of each repayment strategy when the interest increases from 15% to 16%. We find that although higher interest rates always increase the prepayment probability and decrease the regular payment probability, their impact on the default probability is not always the same. When the percentage of naive borrowers is low, the overall default probability on the platform increases. When the percentage of naive borrowers is high, it is the opposite. Given the same interest rate, the default probability of a sophisticated borrower is always lower than that of a naive borrower with the same default cost. Thus, when the percentage of naive borrowers is high, the overall default probability before the interest increase is high. After the interest rate increases, all naive borrowers leave the market. Although higher interest rates increase the default probability of sophisticated borrowers, their default probability can still be lower than the overall default probability before the change.

Our results show that the overall impact of interest on the peer-to-peer lending platform depends on both the borrowers' default cost and their sophistication composition. When the borrowers' default costs are low, an increase in interest always increases the default ratio and prepayment ratio on the platform, while decreasing the regular payment ratio. When the borrowers' default costs are high, the non-default strategies change in the same direction. However, the overall impact of interest on the platform's default ratio is determined by the borrower's composition. When the ratio of naive borrowers is low, the default probability on the platform increases in interest rate. However, when the ratio of naive borrowers is sufficiently high, we observe the opposite pattern. In summary, an increase in interest rates generates exact patterns as observed on Prosper: the overall prepayment ratio increases, the regular payment ratio decreases, while the default ratio may change in either direction.

6 Conclusion

This paper aims to understand how interest changes affect the market outcome and users' welfare in the peer-to-peer lending market in the presence of adverse selection and heterogeneous borrower sophistication. To investigate, we analyze a recent price adjustment on Prosper, the largest crowdfunding platform in the US. Specifically, the platform raises the interest rate of all borrowers. Surprisingly, we notice that this new screening system significantly moves down the default ratio on the platform. In addition, lenders are not necessarily better off within the new mechanism. These finding challenges past research which indicates higher interests generate a riskier market due to adverse selection.

To investigate the underlying mechanism, we provide a complete evaluation of how adverse selection affects borrowers' repayment strategies. Distinguished from existing studies, we do not limit our research to borrowers' motivation in whether to default or not. Instead, we establish a full framework to structurally understand a borrower's tradeoff in all three possible strategies: default, regular payment, and prepayment. Furthermore, we allow borrowers to have heterogeneous intellects in making repayment decisions, such that a portion of borrowers find the prepayment option challenging and never consider it. As a consequence, our model incorporation more flexibility and explains the counterintuitive observations on Prosper.

We point out that although a higher interest makes each borrower more likely to default, it also changes borrower composition. Compared with sophisticated borrowers, naive borrowers have a narrower set of strategies. As a consequence, they are more likely to default and derive a lower surplus from using the platform. When interest rate increases, naive borrowers leave the market earlier than sophisticated borrowers. In other words, the borrower composition moves towards a higher ratio of sophisticated borrowers. This can potentially decrease the overall default ratio and regular payment ratio, while increasing the ratio of prepayments. Combining the impact of interest on borrower composition and its impact on borrowers' repayment strategy, we find that an increase in interest always reduces the regular payment probability and increases the prepayment probability, while can either increase or decrease default probability on peer-to-peer lending platforms.

The main contribution of this paper is to investigate how adverse selection affects both default and prepayment in the peer-to-peer lending market in the presence of heterogeneity of borrower sophistication. It is the first to provide a general and complete framework to investigate a borrower's problem in making repayments. Based on our model, we point out why an increase in interest does not necessarily always move up the default rate or lenders' return in loan markets. We show why the overall impacts depend on the borrower's default cost distribution, the magnificence of interest adjustments, and the composition of borrowers in sophistication. The framework could be extended in many promising directions and applies to other implications, including the regulation and screening in financial markets. We leave the structural estimation of the model primitives for future research, here we mainly focus to rationalize the counterintuitive phenomenon as a way to test our theoretical model.

A Appendix

A.1 Tables

Table A.1: Prosper Rating and Estimated Loss Rate Correspondence

Dependent Variable: Estimated Loss Rate	
Prosper Rating	Estimated Loss Rate
AA	$0.00 - 1.99\%$
A	2.00–3.99%
B	4.00–5.99%
C	6.00–8.99%
D	9.00–11.99%
E	12.00–14.99%
HR	$\geq 15.00\%$

Note: the table is based on the information published by Prosper. For more information, please visit $https://www.prosper.com/invest/how-to-invest/prosper-ratings/?mod=article_inline$

Table A.2: Interest OLS Regression

	(1) Interest	(2) Interest	(3) Interest	(4) Interest	(5) Interest
Change=1	0.434***	0.569***	0.569***	0.131***	0.318***
	(0.031)	(0.006)	(0.006)	(0.015)	(0.020)
Change X HR				1.179***	1.123***
				(0.033)	(0.033)
Change X E				2.208***	2.206***
				(0.029)	(0.029)
Change X D				1.694***	1.673***
				(0.024)	(0.024)
Change X C				0.666***	0.655***
				(0.019)	(0.019)
Change X B				0.043**	0.032*
				(0.019)	(0.019)
Change X A				0.008	0.004
				(0.018)	(0.018)
Prosper Rating			Yes	Yes	Yes
Amount Log			Yes	Yes	Yes
Time FE					Yes
R2	0.001	0.967	0.967	0.969	0.969
Observations	199877	199877	199877	199877	199877

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Default Logit Regression

	(1) Default	(2) Default	(3) Default	(4) Default	(5) Default
Default					
Change=1	-0.027	-0.104***	-0.065*	-0.065*	-0.464***
	(0.034)	(0.034)	(0.035)	(0.035)	(0.176)
Monthly Payment Log		0.163***	0.174***	0.174***	0.175***
		(0.023)	(0.030)	(0.030)	(0.030)
Change X HR					0.327
					(0.338)
Change X E					0.558**
					(0.237)
Change X D					0.490**
					(0.205)
Change X C					0.313*
					(0.189)
Change X B					0.406**
					(0.188)
Change X A					0.494***
					(0.191)
Prosper Rating		Yes	Yes	Yes	Yes
Borrower Variables			Yes	Yes	Yes
Observations	27978	27978	27978	27978	27978

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All the regressions are based on the logit model. The last three columns control for prosper rating and borrower characteristics, including income range, house payment, debt income ratio, employment length, and past late fees.

Table A.4: Prepay Logit Regression (Fico Fair)

	(1) Prepay	(2) Prepay	(3) Prepay	(4) Prepay	(5) Prepay
Prepay					
Change=1	0.175***	0.164***	0.172***	0.172***	0.253***
	(0.024)	(0.020)	(0.025)	(0.025)	(0.077)
Monthly Payment Log		-0.056***	-0.016	-0.016	-0.016
		(0.013)	(0.020)	(0.020)	(0.020)
Change X HR					0.077
					(0.277)
Change X E					-0.116
					(0.165)
Change X D					-0.236*
					(0.121)
Change X C					0.012
					(0.095)
Change X B					-0.082
					(0.090)
Change X A					-0.131
					(0.088)
Prosper Rating		Yes	Yes	Yes	Yes
Borrower Variables			Yes	Yes	Yes
Observations	27978	43577	27978	27978	27978

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All the regressions are based on the logit model. The last three columns control for prosper rating and borrower characteristics, including income range, house payment, debt income ratio, employment length, and past late fees.

Table A.5: Regular Logit Regression (Fico Fair)

	(1) Regular	(2) Regular	(3) Regular	(4) Regular	(5) Regular
Regular					
Change=1	-0.180***	-0.151***	-0.151***	-0.151***	-0.167**
	(0.026)	(0.026)	(0.026)	(0.026)	(0.077)
Monthly Payment Log		-0.004	-0.050**	-0.050**	-0.050**
		(0.017)	(0.021)	(0.021)	(0.021)
Change X HR					-0.084
					(0.310)
Change X E					-0.081
					(0.192)
Change X D					0.121
					(0.132)
Change X C					-0.013
					(0.098)
Change X B					0.021
					(0.092)
Change X A					0.024
					(0.089)
Prosper Rating		Yes	Yes	Yes	Yes
Borrower Variables			Yes	Yes	Yes
Observations	27978	27978	27978	27978	27978

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All the regressions are based on the logit model. The last three columns control for prosper rating and borrower characteristics, including income range, house payment, debt income ratio, employment length, and past late fees.

Table A.6: Return Amount Regression

	(1) Actual Payment	(2) Actual Payment	(3) Actual Payment	(4) Actual Payment
Change=1	787.900***	149.465***	145.050***	131.698***
	(64.714)	(47.384)	(47.483)	(47.663)
Amount Funded		1044.874***	1045.011***	1044.123***
		(2.067)	(2.104)	(2.126)
Change=1 × Amount Funded		-8.802***	-8.818***	-9.342***
		(3.286)	(3.287)	(3.289)
Constant	12018.971***	84.086***	87.536***	93.648
	(41.026)	(29.144)	(32.217)	(61.140)
Prosper Score				Yes
Fico Score			Yes	Yes
R2	0.002	0.827	0.827	0.827
Observations	88134	88134	88134	88041

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All the regressions are based on the OLS model.

A.2 Figures

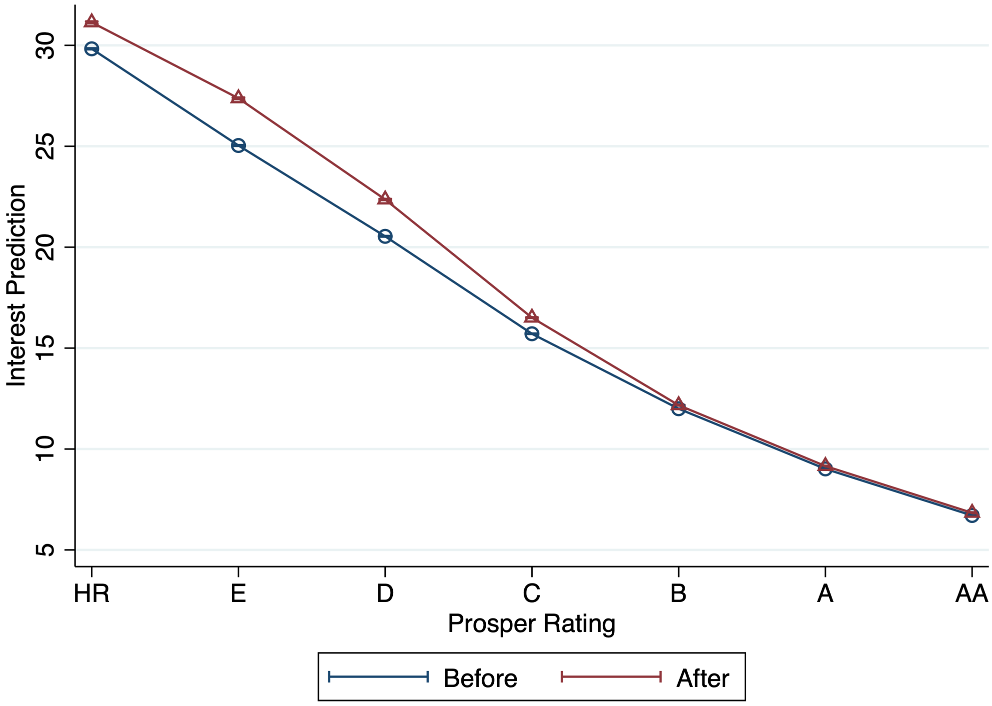
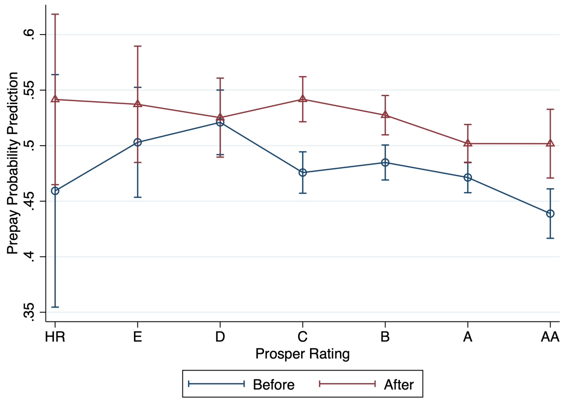
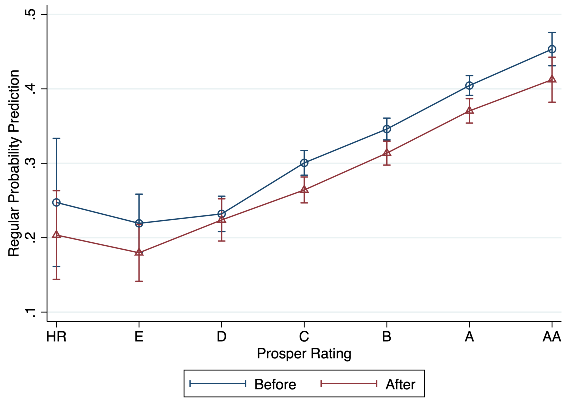


Figure A.1: Interest Prediction



(a) Prepay Prediction



(b) Regular Prediction

Figure A.3: Non-Defaulted Loan Predictions

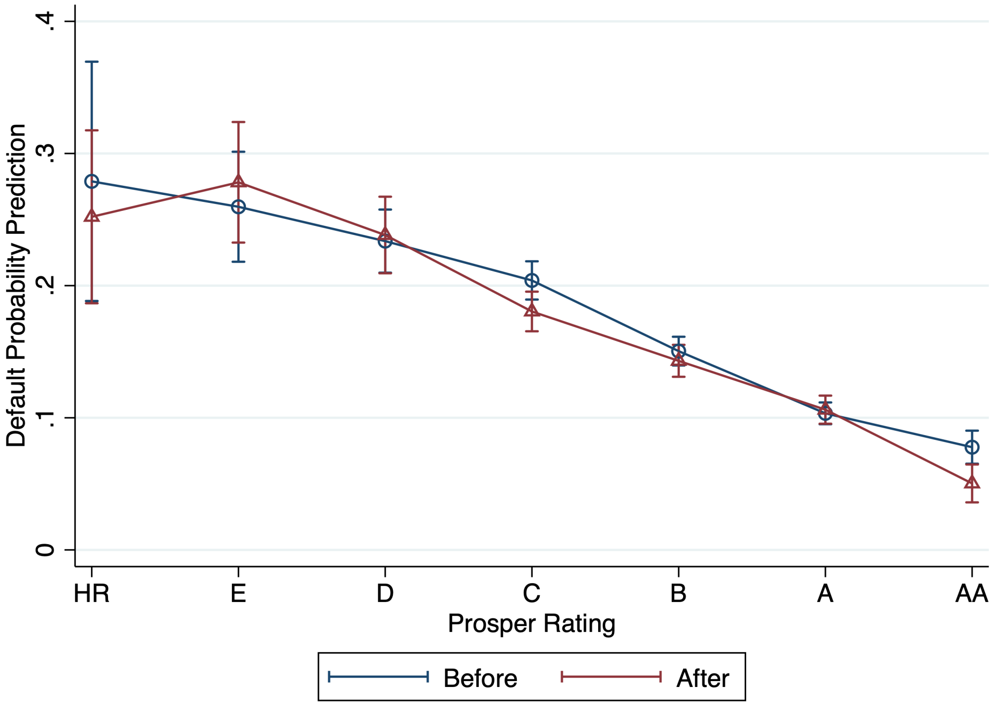


Figure A.2: Default Prediction

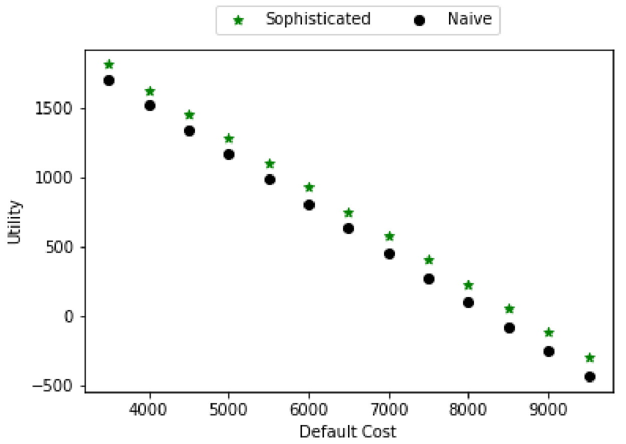


Figure A.4: Expected Utility of Prosper Loans

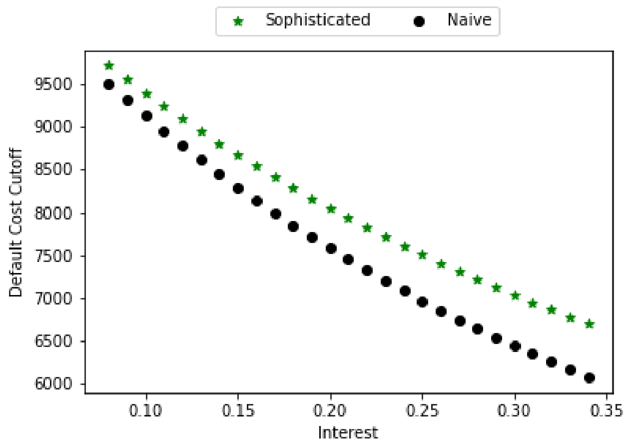


Figure A.5: Default Cost Cutoff for Using Prosper

A.3 Model Proofs

Proof of Lemma 2 In order to analyze the overlaps between $\hat{x}_1(R)$ and $\bar{x}_1(R)$ when $m \leq R \leq \hat{R}(r)$, we define the difference as

$$\Delta x_1^a(R) \equiv \hat{x}_1(R) - \bar{x}_1(R) = \frac{m^2r^2 - \bar{I}m(2+3r+2r^2) + (mr - mr^2 + \bar{I}(1+r+r^2))R - rR^2}{(1+r)^2(R-m)}.$$

We are interested in investigating the sign of Δx_1^a in the interval $R \in [m, \hat{R}]$. Specifically, the denominator of $\Delta x_1^a(R)$ is always positive since $m \leq R \leq \hat{R}(r)$. As a result, the sign of $\Delta x_1^a(R)$ is determined solely by the numerator denoted as $Num[\Delta x_1^a(R)]$, which is a concave function of R. To figure out the sign of this numerator, the values at the two endings are essential. A couple features regarding this numerator are worth noticing. First of all, it is always negative at $R = m$. Secondly, the derivative with respect to R of this numerator first increases and then decreases in R for $R > m$ because

$$\frac{\partial Num[\Delta x_1^a(R)]}{\partial R} \quad = \quad (mr - mr^2 + \bar{I}(1 + r + r^2)) - 2rR. \tag{22}$$

Thirdly, the value of $Num[\Delta x_1^a(R)]$ at $R = \hat{R}$ can be simplified as $-I^2 r + \bar{I}m(1+1/r) - m^2(1+1/r)$ and it depends on the income cap.

Since the borrower's annual interest rate on Prosper is between 5.32% and 31.90%, we assume the interest rate $0.05 < r < 0.32$. Given that $r < 1/3$ and $\bar{I} > 2m$, there exists some cutoff for the income cap defined as

$$\bar{I}_1 = \frac{m(1+r) + m\sqrt{1 - 2r - 3r^2}}{2r},$$

such that $Num[\Delta x_1^a(R)] > 0$ if $\bar{I} < \bar{I}_1$, and $Num[\Delta x_1^a(R)] \leq 0$ otherwise.

We now evaluate the property of the numerator in these two situations separately. When $\bar{I} < \bar{I}_1$, since $Num[\Delta x_1^a(m)] < 0$ and $Num[\Delta x_1^a(\hat{R})] > 0$, there exists one value of R denoted as $\bar{R}(r)$, where $m < \bar{R} < \hat{R}$, such that $Num[\Delta x_1^a(\bar{R})] = 0$ by the intermediate value theorem. If the default cost is at this value, the borrower is indifferent among default, prepayment, and regular payment when the saving level satisfies the following condition $\hat{x}_1(\bar{R}) = \bar{x}_1(\bar{R})$. Consequently, the borrower's optimal plan in region $x_1 \leq \hat{x}_1(R)$ where $m \leq R \leq \hat{R}(r)$ and $\bar{I} < \bar{I}_1$ is to default if $x_1 \leq \bar{x}_1(R)$ and to pay regular payment if $\hat{x}_1(R) \geq x_1 > \bar{x}_1(R)$.

When $\bar{I} \geq \bar{I}_1$, $Num[\Delta x_1^a(\hat{R})] \leq 0$. According the derivative in Equation 22, the numerator $Num[\Delta x_1^a(R)]$ is strictly increasing in R from m up to $\hat{R}(r)$. As a consequence, $Num[\Delta x_1^a(R)]$ is always negative in region $m(r) \leq R \leq \hat{R}(r)$. In other words, the borrower always prefers default to the regular payment in region $x_1 \leq \hat{x}_1(R)$ where $m \leq R \leq \hat{R}$ when $\bar{I} \geq \bar{I}_1$.

Proof of Lemma 3 To investigate the borrower's decision regarding prepayment and default, we first represent the payoff difference between these two options:

$$\Delta V_1^c(x_1, M_1, R) = \frac{(1+r)^2}{\bar{I}} x_1^2 + \left(r - \frac{2m(1+r)(2+r)}{\bar{I}} + \frac{(1+r)}{r} R \right) x_1 + R + \frac{m(2+r)[(2+r)m - \bar{I} - R]}{\bar{I}}.$$

Intuitively the probability of default in the future is strictly smaller than 1 with prepayment, the increases in default cost makes the prepayment option more attractive compared with the default option. That is, the value difference is strictly increasing in R. In addition, the value difference is a convex function of the initial saving, and the change in the initial saving affects the relative value between prepayment and default can be explicitly represented as the follows.

$$\frac{\partial \Delta V_1^c}{\partial x_1} = \frac{2(1+r)^2}{I} x_1 + \left(r - \frac{2m(1+r)(2+r)}{I} + \frac{(1+r)}{r} R \right),$$

which is symmetric around $x_{mid} = -(Ir - 2m(2+3r+r^2) + R + rR)/(2(1+r)^2)$. Thus, this derivative is positive when $x_1 > x_{mid}$, and negative otherwise. We analyze the comparison in the two regions separately.

Comparison in region $\{\hat{x}_1(R) \le x_1$, where $m \le R \le \hat{R}\}$ In this specific region, the payoff difference ΔV_1^c always increases in x_1 because $\hat{x}_1(R) > x_{mid}$ when $\bar{I} > 2m$ and $R > m$. Like the analysis regarding the borrower's choice between regular payment and default, we are searching for a saving cutoff $\tilde{x}_1(R)$, the bigger root of the convex value difference function, expressed as

$$\tilde{x}_1(R) = \frac{2m(2+3r+r^2) - Ir - (1+r)R + \sqrt{I^2r^2 + 2I(2+3r+r^2)(2m-R) + R^2(1+r)^2}}{2(1+r)^2}, \qquad (23)$$

such that $\Delta V_1^c(\tilde{x}_1(R), M_1, R) = 0$.

From the previous analysis, if the income cap is moderate, i.e., $2m < \bar{I} < \bar{I}_1$, there exists a unique cutoff for default cost $\bar{R} \in [m, \hat{R}]$ such that $\hat{x}_1(\bar{R}) = \bar{x}_1(\bar{R})$, indicating that the borrower is indifferent between prepayment, regular payment, and default for the combination of $(\bar{R}, x_1 = \hat{x}_1(\bar{R}) = \bar{x}_1(\bar{R}))$. This also implies that $\Delta V_1^c(\hat{x}_1(\bar{R}), M_1, \bar{R})$=0. Consequently, when $m \le R \le \bar{R}$, if $x_1 > \tilde{x}_1(R)$, prepayment is the optimal option; if $\hat{x}_1(R) < x_1 < \tilde{x}_1(R)$, default is preferred. For $\hat{R} \ge R > \bar{R}$, we know $\Delta V_1^c(\hat{x}_1(R), M_1, R)$ is always positive, so that prepayment is always preferred for all $x_1 \ge \hat{x}_1(R)$.

Additionally, if the income cap is relatively large, $\bar{I} \ge \bar{I}_1$, the saving cutoff $\hat{x}_1(R)$ and $\bar{x}_1(R)$ does not have an intersect, indicating that there is not a combination of saving and default cost such that the borrower is indifferent between all three options. That is, $\tilde{x}_1(R)$ is always larger than $\hat{x}_1(R)$. Consequently, if $x_1 \ge \tilde{x}_1(R)$, where $m < R \le \hat{R}$, the borrower prefers prepayment; for $\hat{x}_1(R) \le x_1 \le min\{(1+r)M_1, \tilde{x}_1(R)\}$, where $m < R \le \hat{R}$, the borrower prefers default.

Comparison in region $\{R \ge \hat{R}, m \le x_1 \le (1+r)M_1\}$ Since the value difference is a convex function symmetric at

$$x_{mid} = m + \left(m - \frac{I}{2(1+r)} - \frac{R}{2}\right)\frac{1}{1+r},$$

and $x_{mid}(\hat{R}) < m$ in the region $R \ge \hat{R}$, we only need to investigate the value difference in the segment that it is increasing with the initial saving x_1. That is, there always exists a unique cutoff for initial saving, expressed as Equation 23, such that the borrower is indifferent between prepayment and default.

Note that the initial saving amount should be within m and $(1+r)M_1$ to be meaningful in this scenario. To double check whether the cutoff is too low or too large compared to these two extreme values, we first derive the derivative of $\tilde{x}_1(R)$ with respect to default cost R:

$$\frac{\partial \tilde{x}_1(R)}{\partial R} = \frac{-1 - r - \frac{[(1+r)(I(2+r)-(1+r)R)]}{\sqrt{I^2r^2+2I(2+3r+r^2)(2m-R)+(1+r)^2R^2}}}{2(1+r)^2},$$

which is negative at $R = m$. Furthermore, the second order derivative

$$\frac{\partial^2 \tilde{x}_1(R)}{\partial R^2} = \frac{-2I(1+r)(I - m(2+r))}{(I^2r^2 + 2I(2+3r+r^2)(2m - R) + (1+r)^2R^2)^{(3/2)}},$$

is positive, when $I < (2+r)m$, indicating that $\frac{\partial \tilde{x}_1(R)}{\partial R}$ is increasing with R; this second order derivative is negative when $I \geq (2+r)m$, indicating that $\frac{\partial \tilde{x}_1(R)}{\partial R}$ is decreasing with R. Combining the fact that $\frac{\partial \tilde{x}_1(R)}{\partial R}|R = m$ is negative, when $I \geq (2+r)m$, $\tilde{x}_1(R)$ is decreasing in R; when $I < (2+r)m$, it is decreasing up to some value and then increasing afterwards.

Combining the result in the region of $x_1 \geq \hat{x}_1(R)$, where $R \leq \hat{R}$, we know if $I_1 \geq I \geq (2+r)m$, $\tilde{x}_1(R)$ is decreasing in R and only intercepts with $\hat{x}_1(R)$ once at $\bar{R} < \hat{R}$. Thus, $\tilde{x}_1(R) < \tilde{x}_1(\hat{R}) < \hat{x}_1(\hat{R}) = m$, indicating that the borrower always prefer prepayment to default in region $\{R \geq \hat{R}, (1+r)M_1 \geq x_1 \geq m\}$ as shown in Figure A.6.

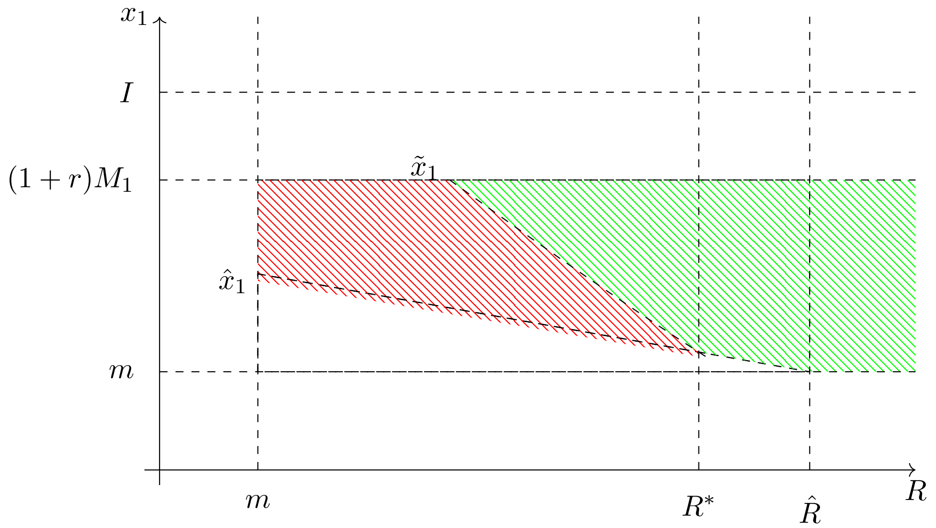


Figure A.6: Case $I < I_1$

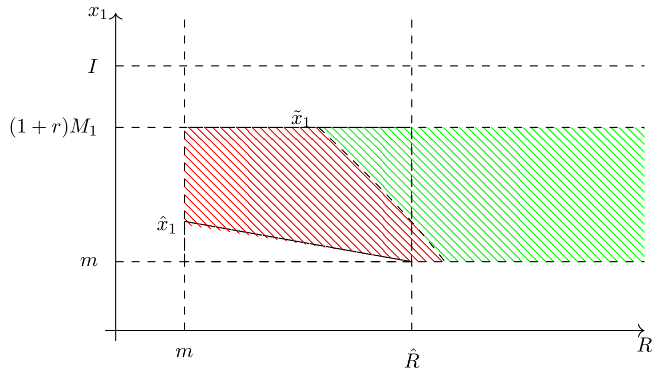
Moreover, when $I > I_1$, $\tilde{x}_1(R)$ is still decreasing in R but it is always larger than $\hat{x}_1(R)$ for any $R < \hat{R}$, that is, $\tilde{x}_1(R) > \hat{x}_1(R)$ and $\tilde{x}_1(\hat{R}) > \hat{x}_1(\hat{R}) = m$. To understand the location of $\tilde{x}_1(R)$ relative to $(1+r)M_1$, we first check the location of $\tilde{x}_1(R)$ at $R = \hat{R}$, which equals

$$\frac{m(-1+r+4r^2+2r^3) + r(I + \sqrt{(m^2(1+3r+2r^2)^2)/r^2 + I^2(5+8r+4r^2) - (2Im(3+7r+6r^2+2r^3))/r})}{2r(1+r)^2}.$$

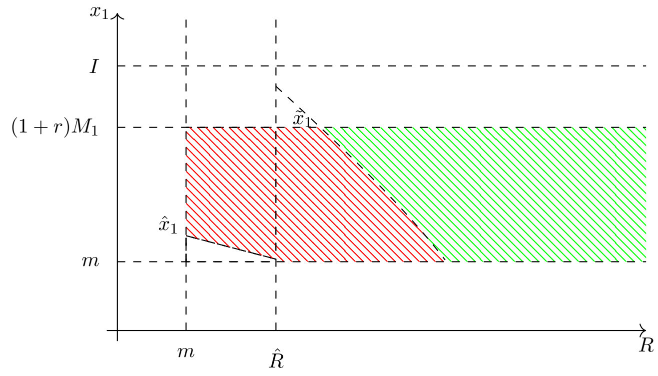
Such a value depends on the income cap. Specifically, for income cap smaller than the cutoff constructed as

$$\bar{I}_2 = \frac{m(1+r+r^2)}{r(1+r)},$$

$\tilde{x}_1(\hat{R}) < (1+r)M_1$ if $I < I_2$, and $x_1(\hat{R}) \geq (1+r)M_1$ otherwise as shown in Figure A.7.



(a) Case $I_1 \leq I < I_2$



(b) Case $I \geq I_2$

Figure A.7: Case $I \geq I_1$

Lastly, note that when $2m < I < (2+r)m$, $\tilde{x}_1(R)$ is decreasing up to some value and then increasing afterwards. Combining the result in the region of $x_1 \geq \hat{x}_1(R)$, $\tilde{x}_1(R)$ only intercepts with $\hat{x}_1(R)$ once at $\bar{R} < \hat{R}$. Thus, $\tilde{x}_1(R) > \hat{x}_1(R)$, when $R \leq \bar{R}$, and $\tilde{x}_1(R) < \hat{x}_1(R)$, when $\bar{R} < R \leq \hat{R}$. We also know that $\tilde{x}_1(\hat{R}) < \hat{x}_1(\hat{R}) = m$. Consequently, there exists another cutoff for the default cost $R_2 > \hat{R}$ such that $\tilde{x}_1(R_2) = m$. With the cutoff, we also know that $\tilde{x}_1(R)$ is increasing with R for $R \geq R_2$. Consequently, for $max\{m, \tilde{x}_1(R)\} < x_1 \leq (1+r)M_1$, where $R \geq \hat{R}$, the borrower's optimal repayment strategy is to pay all her initial saving; for $x_1 < \tilde{x}_1(R)$, where $R \geq R_2$, the borrower's optimal repayment strategy is to default.

Expected Utility Monotonicity in Default Cost We now prove that a borrower's expected utility for entering the platform is decreasing in default cost R. We focus on the sophisticated borrowers as naive borrower is much simplier and can be easily proved following the same steps. As shown in the previous analysis, a borrower's utility when it defaults in the first period equals

$$V_1(x_1, x_1, M_1) = \frac{\bar{I}}{2} + x_1 - R.$$

Otherwise, conditional on the current saving x_1, payment plan y_1 and balance M_1, the expected payoff from not defaulting equals

$$V_1(x_1, y_1, M_1) \quad = \quad E(Z) - R + y_1 - \int_{(1+r)^2 M_1 - (1+r)x_1 + ry_1}^{I} \left[(1+r)^2 M_1 - (1+r)x_1 + (1+r)y_1 - R\right] dF(z)$$

As a consequence, a borrower's utility following every strategy $V_1(x_1, y_1^*, M_1)$ (default, regular payment, and prepayment) is always decreasing in default cost R. In other words, we can easily derive $\frac{\partial V_1(x_1,x_1,M_1)}{\partial R} < 0$, $\frac{\partial V_1(x_1,x_1-m,M_1)}{\partial R} < 0$, and $\frac{\partial_1(x_1,0,M_1)}{\partial R} < 0$ respectively. Note that borrowers will payoff in the first period if $x_1 > (1+r)M_1$ and $R > (1+r)M_1$, then its utility $V_1(x_1, x_1 - (1+r)M_1, M_1)$ does not depend on default cost. Thus we do not consider $x_1 > (1+r)M_1$ when $R > (1+r)M_1$ for simplicity.

According to Figure 6, a borrower's expected utility for joining the platform with given borrowed amount M_1 and interest rate r depends on default cost R. When $R \leq (1+r)M_1$,

$$E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)] = \int_0^{\bar{I}} V_1(x_1, x_1, M_1) dF(x_1) = \int_0^{\bar{I}} (\frac{\bar{I}}{2} + x_1 - R) dF(x_1)$$

where $F(x_1) = F(z)$ is the income distribution in the first period. Thus, $E[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in default cost if $R \leq (1+r)M_1$. When $(1+r)M_1 \leq R \leq R^*$, a borrower's utility for joining the platform equals

$$E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)] = \int_0^{\tilde{x_1}} V_1(x_1, x_1, M_1) dF(x_1) + \int_{\tilde{x_1}}^{(1+r)M_1} V_1(x_1, 0, M_1) dF(x_1)$$

Consequently, we are able to calculate the derivative as

$$\begin{aligned}\frac{\partial E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]}{\partial R} \quad &= \quad \int_0^{\tilde{x_1}} \frac{\partial V_1(x_1, x_1, M_1) dF(x_1)}{R} + V_1(\tilde{x_1}, \tilde{x_1}, M_1) f(\hat{x_1}) \frac{\partial \tilde{x_1}}{R} \\ &+ \int_{\tilde{x_1}}^{(1+r)M_1} \frac{\partial V_1(x_1, 0, M_1) dF(x_1)}{R} - V_1(\tilde{x_1}, 0, M_1) f(\tilde{x_1}) \frac{\partial \tilde{x_1}}{R}\end{aligned}$$

Given $V_1(\tilde{x_1}, 0, M_1) = V_1(\tilde{x_1}, \tilde{x_1}, M_1)$, the derivative could be simplied as

$$\frac{\partial E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]}{\partial R} \quad = \quad \int_0^{\tilde{x_1}} \frac{\partial V_1(x_1, x_1, M_1) dF(x_1)}{R} + \int_{\tilde{x_1}}^{(1+r)M_1} \frac{\partial V_1(x_1, 0, M_1) dF(x_1)}{R}$$

Since $\frac{\partial V_1(x_1,x_1,M_1)}{R} < 0$ and $\frac{\partial V_1(x_1,0,M_1)}{R} < 0$, we show that a borrower's expected utility for joining the platform $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in default cost if $(1+r)M_1 \leq R \leq R^*$. Following the same steps, we can also prove that $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in default cost if $R^* \leq R \leq \hat{R}$ or $R \geq \hat{R}$.

Note that the utility is always continuous in R, combining our results implies that a borrower's expected utility for joining the platform is always decreasing in default cost.

Expected Utility Monotonicity in Interest The expected utility for a borrower to join the platform is decreasing in interest rate as shown in the following proof. We focus on the sophisticated borrowers as naive borrower is much simplier and can be easily proved following the same steps. According to the previous analysis, a borrower's utility when it defaults in the first period equals

$$V_1(x_1, x_1, M_1) = \frac{\bar{I}}{2} + x_1 - R.$$

which is not affected by interest rates r

As for the utility when the borrower does not default, it equals

$$V_1(x_1, y_1, M_1) = \int_0^{(1+r)M_2 - y_1} (y_1 + z - R)\, dF(z) + \int_{(1+r)M_2 - y_1}^{\bar{I}} (y_1 + z - (1+r)M_2)\, dF(z)$$

conditional on the current saving x_1, payment plan y_1 and balance M_1. Following Leibniz rule, the derivative of a borrower's utility with respect to the interest rates could be simplified as

$$\frac{\partial V_1(x_1, y, M_1)}{\partial r} = 2(1+r)^2 M_1 - 2(1+r)x_1 + (1+2r)y_1 - R - I$$

When the borrower does not default, we must have $y_1 \leq x_1 - m$. Furthermore, we also have $R \geq m$, $x_1 \geq m$, and $I > m$. Otherwise, borrowers always default and thus the expected utility equals $V_1(x_1, x_1, M_1) = \frac{\bar{I}}{2} + x_1 - R$ and is not affected by interest rate r. Under the above conditions, the derivative of $\frac{\partial V_1(x_1, y, M_1)}{\partial r} < 2(1+r)^2 M_1 - (4+2r)m = 0$

When the borrower pays off its loan in the first period, its utility equals $V_1(x_1, x_1 - (1+r)M1, M_1) = x_1 + \frac{\bar{I}}{2} - \frac{2+r}{1+r}m$ and is also always decreasing in interest rates. Thus, a borrower's utility in all strategies are all decreasing in interest rates, except choosing to default.

According to Figure 6, a borrower's expected utility for joining the platform with given borrowed amount M_1 and interest rate r depends on default cost R. When $R \leq (1+r)M_1$, the borrower always chooses to default and its expected utility for joining the platform is not influenced by interest. When $(1+r)M_1 \leq R \leq R^*$, a borrower's utility for joining the platform equals

$$E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)] = \int_0^{\tilde{x_1}} V_1(x_1, x_1, M_1) dF(x_1) + \int_{\tilde{x_1}}^{(1+r)M_1} V_1(x_1, 0, M_1) dF(x_1) + \int_{(1+r)M_1}^{I} V_1(x_1, x_1 - (1+r)M1, M_1) dF(x_1)$$

Consequently, we are able to calculate the derivative as

$$\begin{aligned}
\frac{\partial E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]}{\partial r} &= \int_0^{\tilde{x_1}} \frac{\partial V_1(x_1, x_1, M_1) dF(x_1)}{r} + V_1(\tilde{x_1}, \tilde{x_1}, M_1) f(\tilde{x_1}) \frac{\partial \tilde{x_1}}{r} \\
&+ \int_{\tilde{x_1}}^{(1+r)M_1} \frac{\partial V_1(x_1, 0, M_1) dF(x_1)}{r} - V_1(\tilde{x_1}, 0, M_1) f(\tilde{x_1}) \frac{\partial \tilde{x_1}}{r} + V_1((1+r)M_1, 0, M_1) f((1+r)M_1) \frac{\partial (1+r)M_1}{r} \\
&+ \int_{(1+r)M_1}^{I} \frac{\partial V_1(x_1, x_1 - (1+r)M1, M_1) dF(x_1)}{r} - V_1((1+r)M_1, 0, M_1) f((1+r)M_1) \frac{(1+r)M_1}{r}
\end{aligned}$$

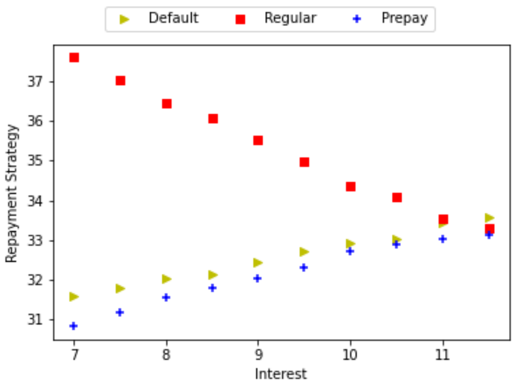
Given $V_1(\tilde{x_1}, 0, M_1) = V_1(\tilde{x_1}, \tilde{x_1}, M_1)$, the derivative could be simplied as

$$\frac{\partial E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]}{\partial r} = \int_0^{\tilde{x_1}} \frac{\partial V_1(x_1, x_1, M_1) dF(x_1)}{r} + \int_{\tilde{x_1}}^{(1+r)M_1} \frac{\partial V_1(x_1, 0, M_1) dF(x_1)}{r} + \int_{(1+r)M_1}^{I} \frac{\partial V_1(x_1, x_1 - (1+r)M_1, M_1) dF(x_1)}{r}$$

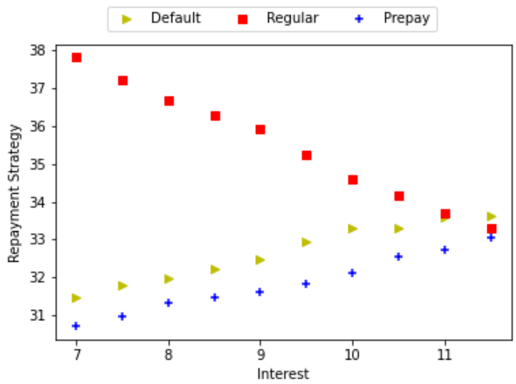
Thus, we show that a borrower's expected utility for joining the platform $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in interest if $(1+r)M_1 \leq R \leq R^*$. Following the same steps, we can also prove that $E_{x_1}[V_1(x_1, y_1^*(M_1, x_1), M_1)]$ is decreasing in interest if $R^* \leq R \leq \hat{R}$ or $R \geq \hat{R}$.

A.4 Interest Change with Varied Magnitudes

To investigate the robustness of our conclusion about the impacts of interest on borrowers' repayment behavior, we plot in Figure A.8 the borrower's repayment strategy corresponding to Figure **??**. We observe the same pattern such that both default and prepayment probabilities increase in interest while regular payment probability decreases. Through the analysis, we show that our findings about the impacts of interest rates are quite consistent and robust over different magnitudes in interest increase.



(a) Repayment Strategy (Prosper Rating G)



(b) Repayment Strategy (Prosper Rating B)

Figure A.8: Repayment Strategy

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