Contract Pricing and Market Efficiency: Can Peer-to-Peer Internet Credit Markets Improve Allocative Efficiency? *

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Extended Abstract

In this paper I examine the effects of contract terms offered by a platform on the behavior of market participants. In many internet marketplaces, which facilitate the transactions between buyers and sellers, the terms of the transactions are often controlled by the platform. This directly restricts one of the fundamental functions of a free market: that a market is able to aggregate information which is then reflected in prices. When prices are set to maximize a platform's profits, it raises the question of whether the market is able to allocate the resources efficiently.

The platform I focus on is a peer-to-peer (P2P) internet credit platform which sets the prices of loans, assigns loan limits, and controls the information flow between borrowers and lenders. On this platform borrowers and lenders are both price takers.

To measure the responsiveness of market participants to such contract terms, I build a structural econometric model of borrower loan demand and repayment choices with a particular focus on the interdependencies of borrower choices. I also build an econometric model of lender supply of loanable funds. Then I estimate these models using granular data about decisions made by borrowers and lenders to get the elasticities of loan demand and repayment and elasticities of supply loanable funds.

Finally, I use these structural elasticities to conduct an important counterfactual experiment in which the prices are determined by the usual forces of supply and demand so they reflect available information in the market. The changes in borrower and lender surplus gives us a measure of the change in welfare when prices are set by profit maximizing platforms instead of being determined by the market forces of supply and demand. This finding should be of significant interest to academics, policy makers, and regulators since we know very little about how to regulate such marketplaces that make up the sharing economy. [1]

*JEL codes: D14, D47, G21, L8. Keywords: Peer-to-Peer Lending, Platform Marketplaces, Market Efficiency

[1]Preliminary results are provided in Table 2. Results of the counterfactual experiment are pending

Summary of Preliminary Findings

On the borrowers' side of the market I find that as loan interest rates or loan origination fees on the longer maturity contracts increase relative to the shorter maturity contract, the likelihood that borrowers will choose longer maturity contracts decreases and the borrowers will choose smaller loans. If borrower choose to take larger loans, it increases the liklihood that they will pick the longer maturity contract. Finally, if borrowers had chosen loan contracts with higher interest rates, larger amounts, or longer maturities, it increases their likelihood of default. On the lenders' side of the market, I find that as interest rates increase, loan maturity increases or credit scores increase, the lenders are willing to supply more credit to borrowers.

A Model of Loan Demand and Repayment

Each borrower makes three decisions on the platform:

- Which loan maturity contract to pick from 3 or 5 years of maturity?
- How much loan to take constrained by the assigned loan limit?
- How much loan to repay?

  Stage 1:

  Contract choice: A borrower j who picks k-year contract gets indirect utility given by

$$U_{jk}^* = \alpha_{Lk} L_j + W_{jk}' \alpha_W + X_{1j}' \alpha_{Xk} + \varepsilon_{Ujk}$$

  Loan size choice: The loan size choice of borrower j is given by

$$L_j^* = \beta_Q Q_j + W_j' \beta_W + X_{2j}' \beta_X + \varepsilon_{Lj}$$

  Stage 2:

  Default choice: The fraction of loan principal repaid by borrower j is given by

$$D_j^* = \gamma_Q Q_j + \gamma_L L_j + W_j' \gamma_W + X_{3j}' \gamma_X + \varepsilon_{Dj}$$

Where W_{jk} is a vector of interest rate and loan origination fee on a k-year loan contract for borrower j, D_j and D_j^* are the observed default and the true (latent) fraction of loan repaid, C_j is a loan censoring point for borrow j denoting the fraction of loan due by the end of sample period, L_j and L_j^* are the observed loan size and the true (latent) loan size choices. X_{1j}, X_{2j} and X_{3j} are borrower specific variables for equations 1, 2, and 3 respectively.

Due to the interdependencies in these choices, all three equations need to be estimated simultaneously. For that assume $(\varepsilon_U,\, \varepsilon_L,\, \varepsilon_D)$ are distributed jointly normal with the distribution given by $f\,(\varepsilon_U,\, \varepsilon_L,\, \varepsilon_D) = N\,(0,\, \Sigma)$, where Σ is the covariance matrix as given below

$$\Sigma = \begin{bmatrix} \sigma_Q^2 = 1 & \rho_{QL}\sigma_Q\sigma_L & \rho_{QD}\sigma_Q\sigma_D \\ \rho_{QL}\sigma_Q\sigma_L & \sigma_L^2 & \rho_{LD}\sigma_L\sigma_D \\ \rho_{QD}\sigma_Q\sigma_D & \rho_{LD}\sigma_L\sigma_D & \sigma_D^2 \end{bmatrix}$$

To derive the choice probabilities and the likelihood function, I first rewrite the joint density as the product of two conditional densities and on unconditional density:

$$f\,(\varepsilon_U,\, \varepsilon_L,\, \varepsilon_D) = f\,(\varepsilon_D \mid \varepsilon_L,\, \varepsilon_U)\, f\,(\varepsilon_L \mid \varepsilon_U)\, f\,(\varepsilon_U)$$

Next, I derive the individual choice probabilities. First consider the choice of loan contract. Define Q_j as

$$Q_j = \begin{cases} 1,\; if\, U_{j5}^* \geq U_{j3}^* \\ 0,\; if\, U_{j5}^* < U_{j3}^* \end{cases}$$

The probability that a borrower picks the 5-year loan contract is givenby

$$P_{Qj=1} = F_{\varepsilon_U}\left(\alpha_L L_j + \Delta W_j' \alpha_W + X_{1j}' \alpha_X\right)$$

and the probability that a borrower picks the 3-year contract is $P_{Qj=0} = 1 - P_{Qj=1}$, where $\alpha_L = \alpha_{L5} - \alpha_{L3}$, $\alpha_X = \alpha_{X5} - \alpha_{X3}$, and $\varepsilon_U = \varepsilon_{U5} - \varepsilon_{U3}$.

Next, conditional on the contract choice, I derive the probability of loan size choice. Define the observed loan size choice as

$$L_j = \begin{cases} L_j^* = \beta_Q Q_j + W_j' \beta_W + X_{2j}' \beta_X + \varepsilon_j^L, & if\, L_j^* < \bar{L}_j \\ \bar{L}_j, & if\, L_j^* \geq \bar{L}_j \end{cases}$$

Where $\bar{L}_j$ is the loan limit assigned to borrower j by the platform. If $L_j^* \geq \bar{L}_j$, the true loan demand of the borrower, L_j^*, is observed since the borrower's loan limit constrained was not binding. The probability of observing such a case is given by

$$\begin{aligned} P_{Lj=L_j^*|\varepsilon_{Uj}} &= Prob\left(L_j^* = \beta_Q Q_j + W_j' \beta_W + X_{2j}' \beta_X + \varepsilon_j^L\right) \\ &= f_{\varepsilon_L|\varepsilon_U}\left(L_j^* - \beta_Q Q_j - W_j' \beta_W - X_{2j}' \beta_X\right) \end{aligned}$$

On the other hand, if the loan limit constraint is binding for borrower j, i.e. $L_j^* \geq \bar{L}_j$, then the true loan demand of the borrower is not observed and thus the probability of observing a loan equal to the limit is given by

$$P_{Lj=\bar{L}_j|\varepsilon_j^Q} = Prob\left(L_j^* \geq \beta_Q Q_j + W_j'\beta_W + X_{2j}'\beta_X + \varepsilon_j^L\right)$$
$$F_{\varepsilon_L|\varepsilon_U}\left(-\bar{L}_j + \beta_Q Q_j + W_j'\beta_W + X_{2j}'\beta_X\right)$$

Next, conditional on the contract choice and loan size choice, I derive the probability of observing loan repayment outcome censored by full payments or end of sample. There are two possibilities: (i) default before full repayment, (ii) repayment censored due to full payment or the end of sample. Define a censoring point $C_j \in (0,1]$ as the fraction of loan observed before the end of our sample. The observed default indicator is then given by

$$D_j = \begin{cases} 1, \, if \; D_j^* < C_j \\ 0, \qquad\quad o.w \end{cases}$$

The probability of observing default is given by

$$P_{Dj=1|\varepsilon_j^U,\varepsilon_j^L} = F_{\varepsilon^D|\varepsilon^U,\varepsilon^L}\left(\gamma_Q Q_j + \gamma_L L_j + W_j'\gamma_W + X_{3j}'\gamma_X\right)$$

The probability of observing full or censored repayment is given by

$$P_{Dj=0|\varepsilon_j^U,\varepsilon_j^L} = 1 - P_{Dj=1|\varepsilon_j^Q,\varepsilon_j^L}$$

Now I can write the full likelihood function in terms of observables. For that, I first define 8 indicators for the 8 possible mutually exclusive outcomes observed in the data. for $k \in \{3,5\}$, j belongs to one of the following sets

- I_{k1}: Borrower picked contract k, loan less than limit, and defaulted at some point
- I_{k2}: Borrower picked contract k, loan less than limit, and loan is censored/repaid in full
- I_{k3}: Borrower picked contract k, loan equal to limit, and defaulted at some point
- I_{k4}: Borrower picked contract k, loan equal to limit, and loan is censored/repaid in full

The Log Likelihood function is given by

$$log\,L = \sum_{j\in I_{31}}\left\{log\left(P_{Qj=0}\right)+log\left(P_{Lj=L_j^*|\varepsilon_j^Q}\right)+log\left(P_{Dj=0|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{32}}\left\{log\left(P_{Qj=0}\right)+log\left(P_{Lj=L_j^*|\varepsilon_j^Q}\right)+log\left(P_{Dj=1|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{33}}\left\{log\left(P_{Qj=0}\right)+log\left(P_{Lj=\bar{L_j}|\varepsilon_j^Q}\right)+log\left(P_{Dj=0|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{34}}\left\{log\left(P_{Qj=0}\right)+log\left(P_{Lj=\bar{L_j}|\varepsilon_j^Q}\right)+log\left(P_{Dj=1|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{51}}\left\{log\left(P_{Qj=1}\right)+log\left(P_{Lj=L_j^*|\varepsilon_j^Q}\right)+log\left(P_{Dj=0|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{52}}\left\{log\left(P_{Qj=1}\right)+log\left(P_{Lj=L_j^*|\varepsilon_j^Q}\right)+log\left(P_{Dj=1|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{53}}\left\{log\left(P_{Qj=1}\right)+log\left(P_{Lj=\bar{L_j}|\varepsilon_j^Q}\right)+log\left(P_{Dj=0|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

$$+\sum_{j\in I_{54}}\left\{log\left(P_{Qj=1}\right)+log\left(P_{Lj=\bar{L_j}|\varepsilon_j^Q}\right)+log\left(P_{Dj=1|\varepsilon_j^Q,\varepsilon_j^L}\right)\right\}$$

Estimates of the parameters α, β, γ, and Σ maximize this log-likelihood function.

The Supply Curve

The lender supply curve for a loan by borrower j is given by

$$S_j = min\left\{S_j^* = \delta_Q Q_j + W_j'\delta_W + X_4'\delta_X + \varepsilon_j^S,\, L_j\right\}$$

$$S_j = \begin{cases} S_j^* = \delta_Q Q_j + W_j'\delta_W + X_4'\delta_X + \varepsilon_j^S, & if\; S_j^* < L_j \\ L_j & if\; S_j^* \geq L_j \end{cases}$$

Where S_j^* is the true loan amount supplied by the lenders to borrower j who requested a loan of size L_j, while S_j is the observed amount supplied by the lenders. If $S_j^* < L_j$, the true loan demand for borrower j is observed and the probability of observing such a case is given by

$$\begin{aligned} P_{S_j=S_j^*} &= Prob\left(S_j^* = \delta_Q Q_j + W_j'\delta_W + X_4'\delta_X + \varepsilon_j^S\right) \\ &= f_{\varepsilon S}\left(S_j - \delta_Q Q_j - W_j'\delta_W - X_4'\delta_X\right) \end{aligned}$$

If $S_j^* \geq L_j$, the true loan supply for borrower j is not observed and thus the probability of observing such a case is given by

$$
\begin{aligned}
P_{S_j=L_j} &= Prob\left(S_j^* \geq \delta_Q Q_j + W_j'\delta_W + X_4'\delta_X + \varepsilon_j^S\right) \\
&= F_{\varepsilon S}\left(-L_j + \delta_Q Q_j + W_j'\delta_W + X_4'\delta_X\right)
\end{aligned}
$$

Where $f_{eS} = N(0, \sigma_S^2)$. This can be estimated by a simple maximum likelihood estimator.

Data and Estimation Results

The data for estimation of the models come from the API of Prosper.com which is the second largest peer-to-peer internet credit platform in the U.S. The data contain all required loan variables for borrowers including a rich set of credit bureau variables, demographic information and loan repayment information. Time stamps for all loan issuance and repayment were also provided. I selected a random sample of 20,000 loans issued between May1st, 2013 to June 30th, 2014 and their repayment data was observed until Feb 29th, 2016. The time period was selected to ensure there were no fundamental changes to the borrowing, repayment and investing processes. Some summary statistics and preliminary results are provided below.

Table 1: Summary Statistics

Variable	Mean	Sd
Loan Maturity (1 = 5-years)	0.36	0.48
Interest Rate (%)	16.02	5.53
Loan Amount ($)	11,996.12	7,163.83
Default Rate (1 = Default)	0.13	0.33
Credit Score	708.85	54.24
Prosper Score (0-11)	6.11	2.49
Home Owner (1 = True)	0.53	0.50
MonthlyDebt ($)	1,119.79	960.55
Prior Prosper Loan (1 = Yes)	0.11	0.31
No. of Observations	20,000	

Table 2: Estimates of Borrower Demand and Repayment Model

Dep. Var	**Contract Term**	**Log(Loan Amount)**	**Default**
	Marginal Effect	Average Effect	Marginal Effect
Δ Interest Rate	-0.0284***	-	-
	(0.0053)		
Δ Loan. Orig. Fee	-0.4280***	-	-
	(0.0104)		
Interest Rate	-	-0.0220***	0.0056***
		(0.0015)	(0.0008)
Loan. Orig. Fee	-	0.0911***	0.0089
		(0.0070)	(0.0050)
Contract Term	-	0.2914***	0.0231***
		(0.0095)	(0.0055)
Log(Loan Amount)	0.1859***	-	0.0267***
	(0.0064)		(0.0042)
N		20,000	
Controls	Credit Scores, Seasonal Fixed Effects, Demographic vars.		