

P2P Lending and Screening Incentives

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Abstract

This paper provides an analysis of the peer-to-peer (P2P) lending market. We lay out key features of this quickly developing sector, explore the economic determinants at play that can explain its participation in the credit market and develop a model with asymmetric screening costs to analyze its impact on loan supply. To do this, we first present the model for a monopolistic industry in which only a bank participates and then illustrate a duopolistic industry with a platform active in the lending market. The theoretical results show that lower screening costs, a better economic outlook and higher profits from good projects incentivizes the platform and the bank to screen more. Additionally, participation in the market of the platform increases the amount of loans granted, supplying the product to a new part of the population and improving financial inclusion.

It is also shown that as long as the platform has lower screening costs and better screening quality, it will grant more loans than the bank. A lower quality in screening leads to a reduction in the screening incentives of both agents, which simultaneously contracts the credit supply. It is important noting that the gap between the optimal amounts of screening under imperfect and perfect screening conditions reduces as the economic outlook improves.

JEL-Classification: L13, D62, G20

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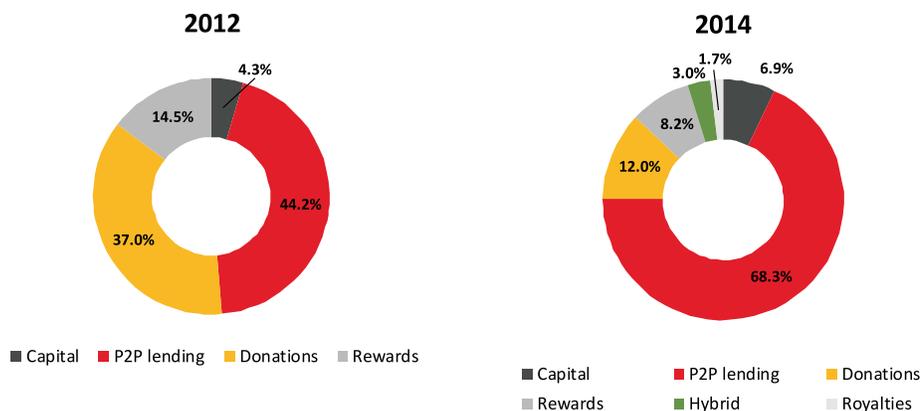
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1 Introduction

P2P lending is defined as a process of debt financing that directly relates lenders and borrowers through an electronic platform on the internet. Over the last years, with the advancement of technology, this business has rapidly developed as an alternative mechanism that provides financial services and improves supply and demand conditions for resources. Companies that have implemented these services have helped to enhance financial inclusion through different products, which have emerged outside of the traditional financial system and are characterized by their flexibility and low cost, given the use of innovative technological tools in these businesses.

This innovation, P2P lending, is one of the forms of crowdfunding, which is defined as a mechanism of financial disintermediation that relates the funding needs of individuals, companies and projects with investors or providers of resources seeking a return and/or reward or pursuing to contribute to a social good. According to the World Bank, in the last ten years crowdfunding has mobilized nearly USD 16 billion, with an average annual growth of 300%, concentrated mainly in North America, Europe and Asia.

Figure 1: **Composition of Crowdfunding by category**



Source: Company Data, Morgan Stanley Research estimates.

P2P lending is the most important category of crowdfunding and the one with the highest growth. In 2014, this funding method accounted for 68.3% of the crowdfunding market globally, followed by donations (12.0%), rewards (8.2%) and equity (6.9%). Donations are defined as contributions where those that disburse resources receive nothing in return. The reward is a form of investment where resource con-

tributors do not receive a financial return, but a compensation such as a product or a service. Finally, in the Equity Based Crowdfunding mode, equity shares are issued and investors obtain participation in a company or project. Compared to 2012, P2P lending gained 24.1 participation percentage points (pp), while donations lost representation in nearly 25 pp (Figure 1).

The purpose of this paper is to explain the main features of P2P lending and discuss its advantages, risks and impact on the credit market. To illustrate the effects of its entry in the lending market, we develop a simple model based on Mukminov (2015) and incorporate asymmetric screening costs between a traditional bank and a P2P lending platform. The most relevant component in the model is that platforms face lower costs and possess better screening quality than a conventional bank.

We study the factors that determine their screening standards to shed light on the analysis of loan supply. The model states that lower screening costs and better quality in underwriting borrowers, encourages loan suppliers to screen more and therefore raise loan supply, while having bad economic outlook and higher expected losses from high-risk projects undermines screening incentives.

The paper is organized as follows: Section 2 describes P2P lending, how it works and its development. Section 3 discusses the advantages of having P2P financial services available in the market. Section 4 defines the adverse selection problem in the credit market, which is useful as an introduction to the analysis of trust and reputation mechanisms explained in Section 5. Section 6 presents the model and Section 7 elucidates some insights about the impact of having a platform on welfare gains. Section 8 contains a description of the risks associated with P2P loans that might erode their cost advantages. Section 9 summarizes the regulatory measures that have been taken in developed countries like the United States, the United Kingdom, France, among others, and in the final section of this paper, we provide our conclusions.

2 P2P lending

As mentioned above, P2P lending is a credit mechanism that directly matches lenders and borrowers through an electronic platform on the internet. This platform organizes the entire process from the time the credit application arrives; it carries out the assessment of the borrowers' risk profile, provides information to investors and supervises the disbursement of funds and loan payments. Hence, the platform allows faster transactions at lower cost by eliminating operating expenses such as salaries, rent on banking buildings, maintenance charges, among others, which are

incurred by traditional banks in financial intermediation activities.

In the business of P2P lending, the traditional intermediation process performed by banks is avoided. The platform neither has to deal with the challenges of mismatches in terms of assets and liabilities nor has to use guarantees to mitigate the effects of the possible materialization of the credit risk. Therefore, it is worth noting that unlike banks, platforms are not directly responsible for defaulting debtors in credit operations. The money that investors place on the platform is considered an investment rather than a deposit, so the default risk is borne directly by them.

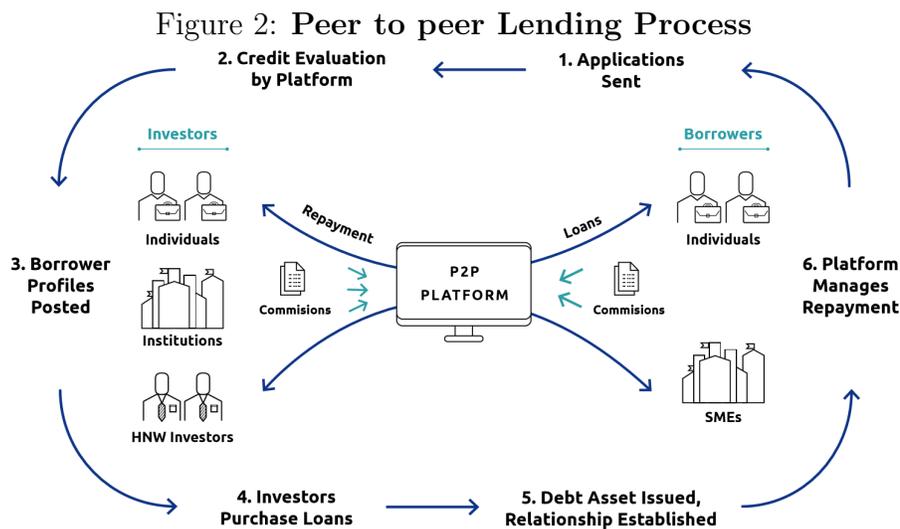
Moreover, P2P lending is a mechanism that includes both the advantages of informal loans (family, friends, etc.) and traditional banking. On the one hand, it presents gains in the credit granting time similar to the immediacy of informal loans disbursement, and on the other hand, it records gains in activities of risk profile detection, using a broader set of information. Consequently, this investment alternative complements the other two to the extent that borrowers can obtain financing in a quicker way compared to traditional banking, and costs are not as high as those offered in the informal credit market.

The international financial crisis of 2007-2009 has been a big boost for the business of P2P, because it has increased requirements for traditional banks, given the changes to the regulatory system, reducing their competitiveness in terms of costs. Under these circumstances, P2P platforms have recorded a high growth rate because they are not affected directly by these regulatory changes.

According to [Aveni \(2015\)](#), there is currently a large number of investors, including institutional and investment funds, companies and others, that are willing to invest in P2P business. There have been more bottlenecks on the side of prospective debtors, which means that platforms must invest resources in attracting them and there must be policies that encourage the applicants of resources to use the instrument massively. This, in order to have a decrease in costs by the P2P platforms, and thus contribute to have an imperfect substitute of traditional banking in the market.

2.1 How does it work?

In general, the process is carried out as follows (Figure 2):



1. Credit application is submitted online by a prospective borrower (individuals, groups or Small Medium Enterprises), including personal and financial information.
2. The platform makes the credit risk assessment of the application. During this phase the platform, taking into account the information provided by the debtor and additional information that can be obtained from other sources available online, generates a credit score, decides whether the loan can be granted and determines the interest rate. This rate, besides reflecting the risk of the debtor, includes the commission charged by the platform.¹
3. If the debtor accepts the credit conditions set by the platform, then the demand for credit is published on the platform’s website and the loan request can be viewed as a loan profile. In general, the information published corresponds to the credit score, interest rate, credit purpose, among others.
4. Investors (Individuals, Institutions or High Net Wealth Individuals), according to their risk preferences (risk versus return), select the loans in which they want to invest their resources. Usually a loan is funded by multiple investors,

¹Unlike a bank, P2P platforms charge commissions rather than make profit of a “spread” (difference in the rates offered to savers or investors and borrowers).

which means that they participate in several loans to diversify their investment portfolio and mitigate credit risk. The interest rate offered to investors also includes the fee charged by the platform.

5. Once the investment has been done, the lender receives a document issued by the platform, which certifies the investment, the term and its profitability. This implies the existence of a contractual relationship between the investor and the debtor.
6. The platform receives payments from loans, pays investors, and charges a fee for the administration of payments until maturity of the credit or until the debtor defaults. It is worth noting that the platform does not guarantee the payment of resources to the investors.

2.2 Development²

In the US, P2P loan approvals have doubled every year since 2010, reaching USD 12 billion in 2014 (Figure 3). Additionally, the trend is growing especially in Australia, China and the UK. As shown in Figure 3, there are already many P2P platforms around the world, mainly in the US, Europe and Asia, where the business has grown significantly.

In European countries the market of P2P platforms has become a fairly strong financing option. Between 2012 and 2014, more than 255 platforms have emerged in 27 countries by providing financing to consumers, entrepreneurs, artists, SMEs, social enterprises, renewable energy projects, among others. The UK is the leader in the development of platforms in the European market. Between 2012 and 2014 this business went from managing USD 642.2 millions to USD 3595.2 millions, with an average annual growth rate of 146%. Meanwhile, in continental European countries, this alternative is also flourishing, with France, Germany, the Netherlands, Spain and the Nordic countries with the highest growth rates. In particular, in these countries P2P lending grew at an average annual rate of 115% between 2012 and 2014, reaching a value of USD 753.8 millions.

In terms of the use of credits generated by P2P lending platforms, in Europe (excluding the UK) most of them are used for consumption (74.7%) (Figure 4, Panel A) and the opposite happens in the UK (Figure 4, Panel B), where most of these loans are granted to companies (62.1%). Within this group, 40.9% of loans are for companies in the real estate sector.

²The data presented in this section differ from the introduction as different sources are used.

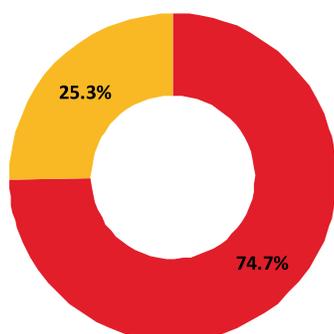
Figure 3: Main Suppliers of P2P Lending

Type of Credit	Provider (country, year of origination)			
	America		Europe	Asia
Consumer Loans	Prosper (USA, 2006)	Zopa (UK, 2005)	Abrate (UK, 2010)	CreditEase (China, 2006)
	Lending Club (USA, 2007)	RateSetter (UK, 2010)	Assetz Capital (UK, 2010)	PPDai (China, 2007)
	Peerform (USA, 2012)	Yes Secure (UK, 2012)	Crowdproperty (UK, 2010)	Renrendai (China, 2007)
	Wikiloan (USA, 2012)	Smava (Germany, 2007)	Folk2Folk (UK, 2010)	
		Auxmoney (Germany, 2007)	Funding Circle (UK, 2010)	MoneyAuction (South Korea, 2007)
	Fairplace (Brazil, 2010)	Kokos (Poland, 2008)	Funding Secure (UK, 2010)	Popfunding (South Korea, 2007)
		Finansowo (Poland, 2008)	Funding Knight (UK, 2010)	Donjoy (South Korea, n/a)
	KuboFinanciero (México, 2013)	Kokos (Poland)	Landbay (UK, 2010)	Capital Match (Singapore, 2014)
	Prestadero (México, 2014)	Finansowo (Poland)	Investly (UK, 2010)	
	Doopla (México, 2014)	Smartika (Italy)	Lendingworks (UK, 2010)	Maneo (Japan, 2008)
	Pitchbull (México, 2014)	Prestiamoci (Italy, 2007)	Lendinvest (UK, 2010)	Aqush (Japan, 2009)
		Boober (Italy, 2007)	MoneyThing (UK, 2010)	SBI Social Lending (Japan, 2008)
	Afluenta (Argentina, 2011)	Friendsclear (France, 2008)	Proplend (UK, 2010)	
		Pret d'Union (France, 2011)	Wellesley (UK, 2010)	iGrin (Australia, 2007)
		Lendix (France)	Archover (UK, 2010)	Lending Hub (Australia, 2009)
		Unilend (France)	Saving Stream (UK, 2010)	
		Cashare (Switzerland, 2008)		Nexx (New Zealand, n/a)
		Fixura (Finland, 2010)		Lendit (New Zealand, n/a)
		Fellow Finance (Finland, 2013)		Harmony (New Zealand)
		Fixura (Finland)		
		Toborrow (Sweden, 2010)		ThinCats (Australia, 2010)
		isePankur (Estonia, 2009)		
		Comunitae (Spain, 2009)		
		Bondora (Spain, 2008)		
		Growly (Spain, 2014)		
		LoanBook (Spain, 2012)		
		Lendland (Russia)		
		Frooble (Netherlands, 2007)		
		Lendahand (Netherlands, 2013)		
		Geldvoorelkaar (Netherlands)		
		Twino (Denmark)		
		FriendCredit (Romania, 2012)		
		Noba (Hungary, 2010)		
		Finbee (Lithuania)		
		Mintos (Lithuania)		
	Savy (Lithuania)			
	Viventor (Latvia, 2010)			
	Trustbuddy (Norway, 2010)			
	The Lending Well (UK, 2012)			
Daily Pay Loans	YadYap (USA, 2010) Kudols (USA, 2012)			Qifang (China, 2008)
Student's Loans	People2Capital (USA, 2010) Social Finance (USA, 2011)	Relendex (UK, 2010) Estateguru (Estonia, 2015)		
Mortgage and Commercial Loans	Money360 (USA, 2010) Briq (México, 2013)	Fundingcircle (UK, 2010) ThinCats (UK, 2010)		
Business	Rebirth Financial (USA, 2011) SoMoLend (USA, 2012)	Massow's Angels (UK, 2012)		
Leasing		Leasing Squirrl.com (UK, 2012)		
Factoring		Factoring MarketInvoice (UK, 2010)		

Source: Moenninghoff (2012)

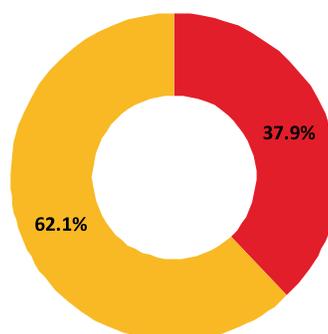
Figure 4: Loan Distribution Originated by P2P platform

Panel A. Europe (Without UK) in 2014



■ Consumer Loans ■ Commercial Loans

Panel B. UK in 2015



■ Consumer Loans ■ Commercial Loans

Source: Company Data, Morgan Stanley Research estimates.

3 Advantages

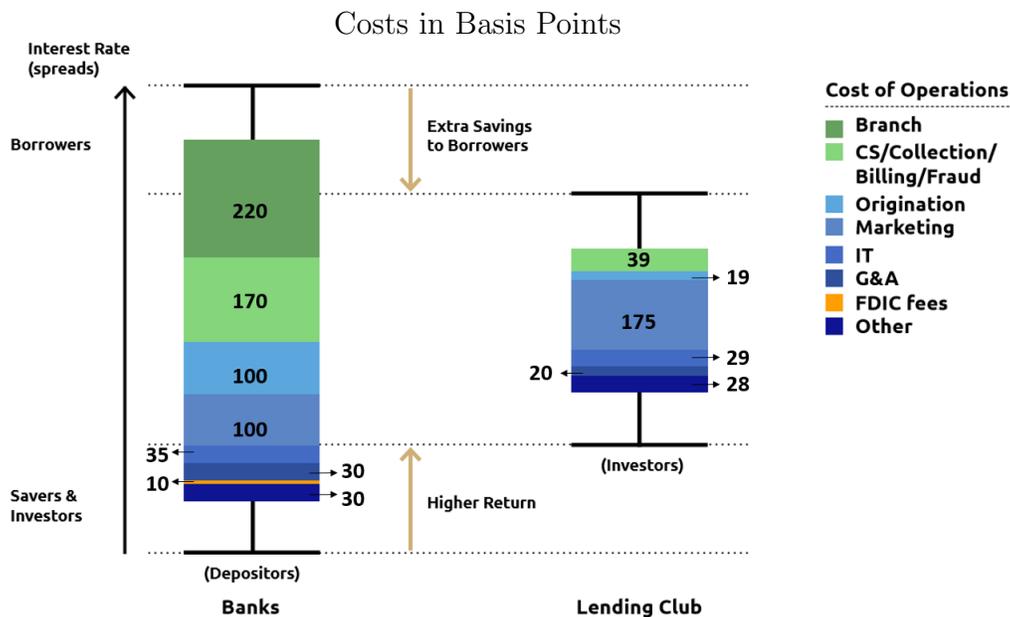
Several aspects make P2P lending activities an attractive instrument for disintermediation of the lending process:

1. Investors take part in the screening process and are free to decide who receives the resources. On the other hand, borrowers can negotiate the terms of the loan and do not incur in prepayment penalties.
2. P2P companies have broader access to information, given their potential in the internet network. They increase financial innovation by using alternative technological tools in the credit rating process of prospective borrowers based on sources of information that banks do not frequently use. For example, they create algorithms using information from mobile applications, social networks, websites, purchase history, among others³.

³All this analysis is performed under the concept of Big Data Analytics, which refers to the study of large amounts of information in order to uncover hidden patterns, correlations, trends or any other behavior in the information to improve business' efficiency.

- In figure 5 it is shown that platforms have lower costs compared to the intermediation operations of banks. The former do not have to include provisions for credit losses or deposit guarantees, since resources in the platform come from an investment operation and not a deposit transaction. Also, this online lending model requires less labour and does not have to deal with infrastructure maintenance. This operational efficiency allows faster processes and may translate into improved client services and better interest rates for investors and debtors.

Figure 5: Costs and Interest Spreads for Banks and Lending Club



- They improve financial inclusion by considering customers who are being sidelined from the formal credit system. The platforms use information sources and alternative methodologies (Big Data Analytics) as activities of screening that reduce adverse selection problems. Besides, more borrowers can afford the lower interest rates offered by the platforms.
- A traditional firm has fixed capacity that prevents it from having a supply elastic enough to adjust quickly to new market conditions, so that changes in demand cannot be compensated directly by supply modifications, making the price more volatile. Meanwhile, low adjustment costs allow platforms to adapt

more rapidly to abrupt shocks in the economy, avoiding large alterations in price and undesirable effects on users' welfare (Einav et al., 2015).

4 Adverse Selection and Screening

As pointed out previously, the severe global financial crisis of 2007-2009 and the lack of a regulatory structure cleared the path for the rise of P2P lending. Many questions about what were the regulatory failures that allowed this situation to happen remain open, and several answers have been related to the screening incentives that financial institutions had to grant loans. Multiple empirical studies have found evidence that before the crisis, banks had been gradually relaxing their screening standards in the lending market (Dell et al., 2012) and that securitization induced them to screen less (Keys et al. (2010) and Mian & Sufi (2009)).

Screening incentives are related to the adverse selection problem, which is characterized by the asymmetric information present *before* the loan is granted. Asymmetric information in the lending market occurs when the financial institution is less informed than its borrowers about the quality and riskiness of their projects. To mitigate this problem and obtain useful information to distinguish the projects that have positive expected return (good projects) from the ones that have negative expected return (bad projects), it undertakes a screening process.

This process is complex and costly, considering that the financial institution needs loan officers that contact credit agencies and previous creditors, suppliers and customers to collect information in order to evaluate the borrower's ability of repayment and guarantee successful loans (Ruckes, 2004). The advantage in costs that the platform has over a conventional bank in evaluating its borrowers has been exposed, but it has also been noted that it targets people who are not usually seen as credible by conventional loan suppliers, which explains why a precise underwriting process is decisive.

According to Aveni (2015), in 2010, Lending Club was screening out 87% of the applications. We use our model to learn about how the economic outlook, the screening costs and the expected returns from the projects may induce the loan suppliers, a bank and a platform, to screen more or less and how this impacts the loan supply.

In the model presented in this paper, the main focus is on the screening incentives and will not consider the effect that operational efficiency has on market power. Therefore, the interest rate offered by the bank and the platform to borrowers is exactly the same. In this model only the supply side is analyzed.

5 Trust and Reputation

These P2P lending platforms generally fall within the concept of “two-sided markets”, defined as markets in which one or several platforms enable interactions between end-users, court the two sides and try to keep them active in the market. In this case, the volume of transactions between end-users depends on both the structure and the overall level of fees charged by the platform (Rochet & Tirole, 2006).

The agility of the system, customer satisfaction, the success of the platform and its growth depend directly on the number of agents willing to participate in the market on both sides. Therefore, one of the biggest challenges of these platforms is to maintain users’ confidence in the system in order to have them in the market and willing to engage in convenient transactions.

In general, there are three mechanisms to build and maintain confidence in a market: initial inspection, external regulation and reputation. The first is connected to the problem of adverse selection, derived from the information asymmetry existent in the market, the second is related to the monitoring that is done given the presence of moral hazard⁴ and the third is a form of signaling and a key determinant of the demand and the platform’s success (Einav et al., 2015). We have already noted some important aspects about screening and its relevance to cope with the adverse selection problem. In this section we focus on reputation and we mention in Section 9 important advancements in regulation and some remaining challenges.

It is crucial for the platform to build a solid performance history to generate credibility, attracting participants willing to be involved in this kind of long-term financial commitment and capable to adapt to online financial services. A robust reputation gives users an information set to make decisions; without it, the financial institution has to incur in high marketing costs to advertise their services to users, be recognized and afterwards make loans. This means that if there is a traditional incumbent seller with an advantage in terms of reputation, a platform that has incentives to enter should make a greater effort to achieve it. It is noteworthy that this barrier to entry can be alleviated by the low cost of advertising on the Internet, a dreadful reputation of banks, or a certification process that facilitates the platform’s entry to the market.

On the other hand, due that investors assume directly the credit risk, platforms are highly interested in enforcing strict lender and borrower requirements to guar-

⁴“The term “moral hazard” describes the danger that, in the face of insurance (loan has been granted), an agent will increase her exposure to risk”. (Hale, 2009)

antee quality in the transactions, increase reputation and guard against misbehavior and fraud.

6 The Model

First we construct a theoretical screening model in which a bank, acting as a monopolist, receives a pool of loan applications and decides the amount of them to be screened in order to grant loans. Then we assume that the bank's optimal number of loans granted is small relative to market demand⁵ and its scale economies are sufficiently limited to justify a competitive lending market, enabling entry of a platform. We have discussed elements that lower entry costs for P2P lending platforms and allow them to compete with traditional financial institutions. We investigate how the economic outlook, the screening costs and the quality of screening affect the screening incentives of the bank and the platform and the resulting impact on loan supply in the market.

One of the purposes of P2P lending is to extend formal financial services to borrowers who are creditworthy but are dissatisfied with the services or interest rates that banks offer, or to borrowers who do not receive credit, because they do not meet banks' lending criteria. P2P lending creates new mechanisms for borrowers to prove creditworthiness and a new alternative to increase financial inclusion.

6.1 Perfect Screening

6.1.1 Monopoly Case

We base our models on [Mukminov \(2015\)](#) to analyze the effect that the economic outlook, the screening accuracy and the screening costs have on the bank's incentives to screen potential borrowers. To address this, we construct a simple theoretical model in which a bank faces a pool of loan applications and decides what percentage of them to screen and how many loans to grant. We first assume perfect screening, which means that the bank can detect with certainty whether a loan application is of good or bad quality and therefore the probability of classifying a high-risk project as a low-risk one is zero. We obtain the optimal level of loans approved, assuming that the deposit interest rate is an exogenous parameter, since the bank views itself as a price taker and demands deposits at prevailing market rates, given

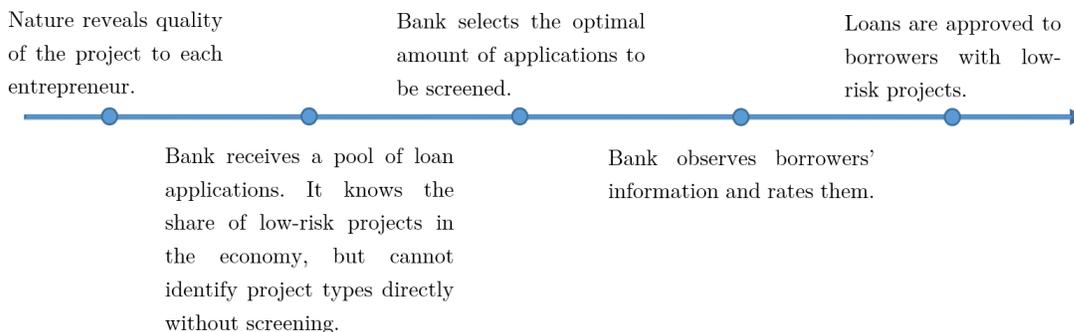
⁵In fact, this assumption does not set apart from what currently happens in emerging economies, where the markets still have low levels of banking penetration ([McKinsey, 2015](#)).

perfect competition in this market. In addition, we set the number of loans that the bank grants (L) equal to the amount of deposits required to finance the projects, considering that deposits are costly and it is not optimal for the bank to raise more deposits than it grants loans.

Additionally, we assume that each project requires one unit of funding, the entrepreneurs are protected by limited liability and cannot finance any part of it nor can they post collateral. The bank cannot identify directly the type of project without screening, but it knows the share of good (low-risk) projects in the economy, denoted by $\lambda \in (0, 1)$, which is a quality measure of the pool of loan applications and can be related to the conditions of the economy. The expected revenue from financing a low-risk project is strictly positive, $\pi^L = p_L R_L - 1 > 0$, the lending interest rate is given by $(R_L - 1)$, p_i is the probability of success of the project and it yields $R_i > 1$ if it is successful, where i is L for a low-risk project and H for a high-risk project. We assume that $p_L > p_H, p_L R_L > 1 > p_H R_H$, and $R_H > R_L > 1$. To streamline the model, we abstract from moral hazard and assume that entrepreneurs cannot affect the success probability of their projects.

Given the fact that entrepreneurs do not have collateral and cannot credibly signal their type to the bank, we assume that there is no possibility to obtain a credit without being subject to screening. Then, L , the number of loans supplied is directly related to k , the proportion of applications that the bank decides to screen. The timing of the problem is summarized in Figure 6.

Figure 6: **Timing of the Bank’s problem with Perfect Screening**



We assume a cost function of screening, $k^2 z$, with diseconomies of scale (per-project costs of screening increase in the number of loan applications screened), where $z \in (0, 1)$ is a parameter that affects the costs of screening. [Mukminov \(2015\)](#) justifies this form of screening costs on the fact that financial institutions gain expertise in evaluating certain type of loans and expanding the lending market to new borrowers might need an extra effort to underwrite the projects. Then, the

profit function is as follows:

$$\Pi_{Bank}^{ps}(k) = k\lambda\pi^L - rL - k^2z \quad (6.1)$$

The amount of loans that the bank grants, L , is given by $L = k\lambda$. The probability or fraction of low-risk loan applicants is represented by λ and multiplying it by k gives the number of loan applications that pass the screening process and are classified as low-risk.

$$\Pi_{Bank}^{ps}(k) = k\lambda\pi^L - rk\lambda - k^2z \quad (6.2)$$

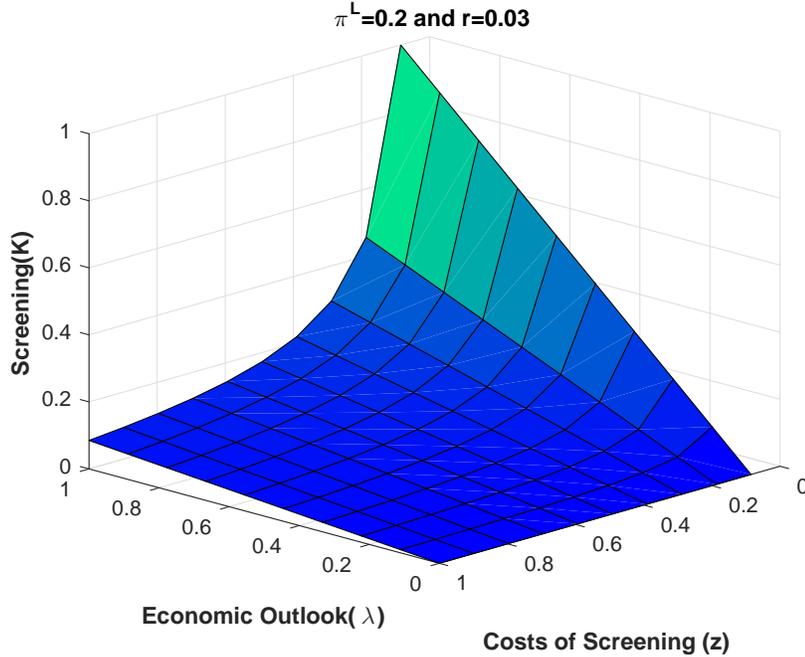
The first order condition, with respect to k , is⁶:

$$k_M^{ps} = \frac{\lambda\pi^L - r\lambda}{2z} \quad (6.3)$$

Then, the optimal amount of loans granted by the bank is:

$$L_M^{ps} = \frac{\lambda^2\pi^L - r\lambda^2}{2z} \quad (6.4)$$

Figure 7: Amount of loan applications screened by the bank



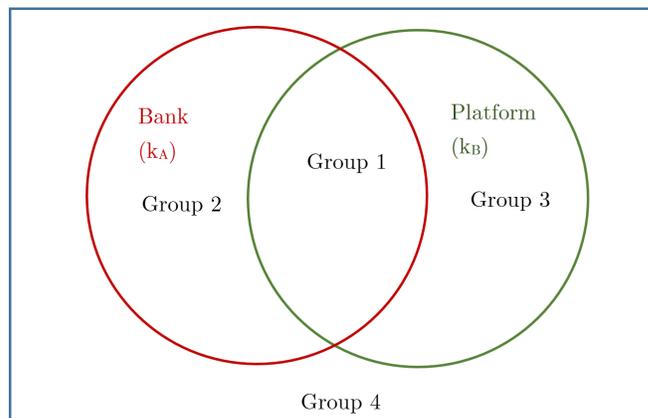
⁶“M” denotes monopoly and “ps” means perfect screening. Note that the bank enters the lending market when $\pi^L > r$ and λ is positive.

As it is shown in Figure 7, as the economic outlook improves, the incentives of the bank for screening increase and it decides to grant more loans. It can also be noted that lower screening costs have the same effect. Additionally, higher expected profits from low-risk projects incentivizes the bank to screen more, while having higher costs for deposits decreases the loan applications the bank screens and the amount of loans it grants.

6.1.2 Duopoly Case

Now we consider the case in which we have both a bank and a platform in the credit market that randomly and independently choose which loan applications to assess. Hence, we can find four groups of loan applications shown in Figure 8:

Figure 8: **Groups of loan applications**

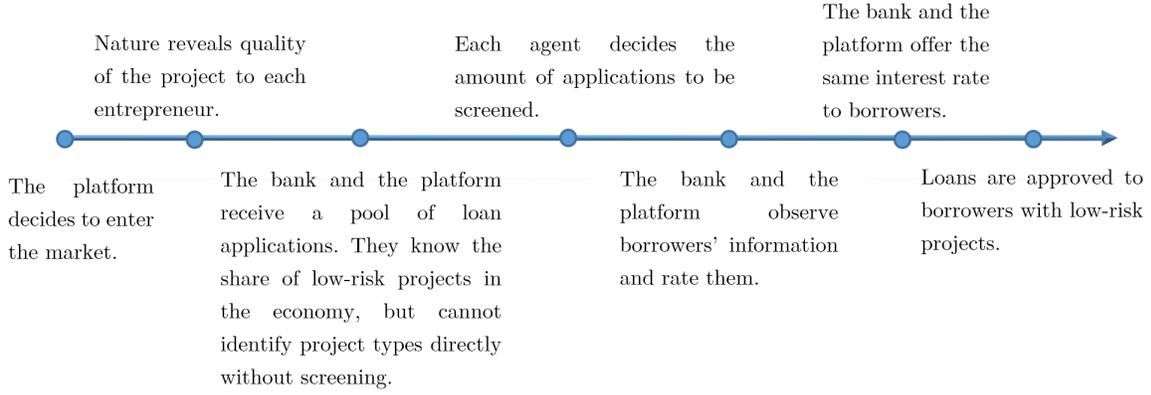


- Group 1: Loan applications screened by the bank (A) and the platform (B). Given the perfect screening activities, this group only contains projects classified as low-risk by both agents.
- Group 2: Loan applications checked only by the bank and not the platform.
- Group 3: Loan applications assessed only by the platform and not the bank.
- Group 4: Loan applications that have not been subject to screening.

To ensure the supply of credit and the presence of both agents in the market, there must be enough demand for credit and sufficient deposits to meet this demand.

It is important to note again that in this case, intermediaries just give funding to the projects that have been screened and classified as low-risk. The timing of this duopoly lending industry is shown in Figure 9.

Figure 9: **Sequence of decisions in a Duopoly lending industry with Perfect Screening**



The profit function for the bank in the industry will be:

$$\Pi_A^{ps}(k_A, k_B) = k_A k_B \frac{\lambda}{2} \pi^L + k_A (1 - k_B) \lambda \pi^L - r L_A - k_A^2 z_A \quad (6.5)$$

The first term represents the profit the bank obtains from financing loan applications from the first group, in which it competes with the platform and only gets to finance half of the group. It is important to mention that borrowers are indifferent between obtaining funds from the bank or the platform, given that both agents offer the same lending interest rate. The second term captures the bank's profit from financing loan applications from the second group, where it does not compete with the platform. Third and fourth terms are the deposit costs and the screening costs, respectively.

Similarly, this would be the profit function for the platform:

$$\Pi_B^{ps}(k_A, k_B) = k_A k_B \frac{\lambda}{2} \pi^L + k_B (1 - k_A) \lambda \pi^L - r L_B - k_B^2 z_B \quad (6.6)$$

We assume that $z_A > z_B$, considering that the platform as a lender expends less time and resources on screening a loan application compared to a bank. The number of loan applications that the bank and the platform decide to finance are:

$$L_A^{ps} = k_A k_B \frac{\lambda}{2} + k_A(1 - k_B)\lambda \quad (6.7)$$

$$L_B^{ps} = k_A k_B \frac{\lambda}{2} + k_B(1 - k_A)\lambda \quad (6.8)$$

Therefore, the total number of loans granted in the economy with a bank and a platform participating in the lending market is: $L_D^{ps} = L_A^{ps} + L_B^{ps}$.

The solution to the bank's optimization problem is given by the following first order condition:

$$-\frac{\lambda}{2}k_B\pi^L + \lambda\pi^L + rk_B\frac{\lambda}{2} - r\lambda - 2k_A z_A = 0 \quad (6.9)$$

And for the platform:

$$-\frac{\lambda}{2}k_A\pi^L + \lambda\pi^L + rk_A\frac{\lambda}{2} - r\lambda - 2k_B z_B = 0 \quad (6.10)$$

Solving the above first order conditions as a system of equations, equation 6.11 shows that in equilibrium, the amount of loan applications that the bank decides to screen, k_A , is always lower than the number of loan applications that the platform screens, k_B . Therefore, as long as $z_A > z_B$, L_B^{ps} is going to be bigger than L_A^{ps} and the platform will always grant more loans than the bank⁷.

$$k_B^{ps8} = k_A^{ps} \left[\frac{\frac{\lambda}{2}(r - \pi^L) + 2z_A}{\frac{\lambda}{2}(r - \pi^L) + 2z_B} \right] \quad (6.11)$$

We then find the optimal values of k_A and k_B expressed through the exogenous parameters (For details, see Appendix 1):

$$k_A^{ps} = \frac{\frac{\lambda^2}{2}(r - \pi^L)^2 + 2\lambda(r - \pi^L)z_B}{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B} \quad (6.12)$$

$$k_B^{ps} = \frac{\frac{\lambda^2}{2}(r - \pi^L)^2 + 2\lambda(r - \pi^L)z_A}{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B} \quad (6.13)$$

⁷ $L_B^{ps} > L_A^{ps}$
 $k_B\lambda - k_A k_B \lambda > k_A \lambda - k_A k_B \lambda$
 $k_B > k_A$

⁸ In order to have $k_B^{ps} > 0$, then the following conditions must be met: $2z_A > 2z_B > |\frac{\lambda}{2}(r - \pi^L)|$

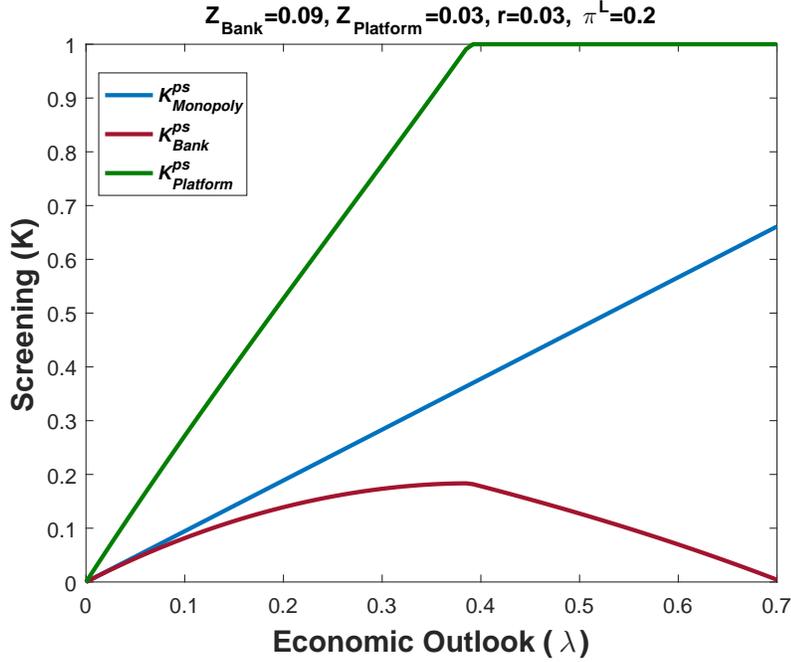
In order to investigate how a change in the parameter values affects the amount of loans screened by the agents, we start with the comparative statistics analysis and then proceed to the numerical analysis. First, we are interested in the effect that an increase in the costs of screening of the bank, z_A , has on the equilibrium value of k_A ⁹.

$$\frac{\partial k_A^{ps}}{\partial z_A} = \frac{\left[\frac{\lambda^2}{2}(r - \pi^L)^2 + 2\lambda(r - \pi^L)z_B \right] 4z_B}{\left[\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B \right]^2} < 0 \quad (6.14)$$

The mathematical result is intuitive. An increase in the costs of screening of the bank lowers its incentives to screen and encourages the platform to screen more intensively and grant more loans.

Now we provide a numerical illustration to see how the economic outlook affects the screening incentives of the bank and the platform (Figure 10):

Figure 10: **Screening and Economic Outlook**



⁹ $\lambda \in (0, 1)$, the revenue from financing a low-risk project is positive ($\pi^L > 0$) and bigger than r , and k_A and k_B are positive. Then, the partial derivative of k_A with respect to z_A is negative.

As the economic outlook improves, the bank and the platform are encouraged to screen more loan applications. However, the difference in screening costs allows the platform to screen more applications and get a bigger share of the market as the proportion of low-risk project increases, while the bank cannot take further advantage of the economic improvement.

When we compare the screening and loan provision in a duopoly banking industry with the case of a monopoly banking industry, we conclude that having the platform competing in the credit market is efficient in the sense that it provides more loans.

Given that $k \in (0, 1)$, the platform screens all the loan applications it receives, once the low-risk projects reach a proportion of nearly 0,4 of the total projects in the economy, while the bank barely screens 20% of its loan applications at this point.

6.2 Imperfect Screening

6.2.1 Monopoly Case

We continue assuming that screening is costly ($z > 0$), but now it is also imperfect, $\beta \in [0, 1]$, which is more realistic as banks do make mistakes. β is an exogenous parameter that represents the probability with which a high-risk project is misclassified as a low-risk one. Then, the risk that the bank or the platform approves unqualified loan applications rises as β increases. Mistakes in screening can be related to the expertise or willingness of the workers in charge of carrying out these tasks, the bank's or platform's technology and their efficiency, the lack of information about the potential borrowers, the ability of the bad entrepreneurs to present high-risk projects as low-risk ones, among others.

The bad projects that are mistakenly approved by the bank have an strictly negative expected revenue for the bank, ($\pi^H < 0$), where $\pi^H = p_H R_L - 1 < 0$.

The profit function for the bank is then as follows:

$$\Pi_{Bank}^{is}(k) = k[\lambda\pi^L + (1 - \lambda)\beta\pi^H] - rL - k^2z \quad (6.15)$$

Compared to equation 6.1, the first term in this equation changes, as it accounts for the losses from the high-risk projects that are mistakenly classified as low-risk ones.

The number of loans funded also changes, given the misclassification of projects:

$$L_M^{is} = k[\lambda + (1 - \lambda)\beta] \quad (6.16)$$

Replacing this expression in the profit function:

$$\Pi_{Bank}^{is}(k) = k[\lambda\pi^L + (1 - \lambda)\beta\pi^L] - rk[\lambda + (1 - \lambda)\beta] - k^2z \quad (6.17)$$

The optimal number of loan applications that the bank should screen to maximize profits is:

$$k_M^{is} = \frac{\lambda\pi^L + (1 - \lambda)\beta\pi^H - r[\lambda + (1 - \lambda)\beta]}{2z} \quad (6.18)$$

There are two ways in which k equals the value of perfect screening (equation 6.3): either λ equals one or β is zero. In this case we assume that a perfect classification can only be achieved at an unreasonably high cost and there is always a share of high-risk projects in the economy. Then, the level of screening under imperfect screening conditions, k_M^{is} , is always lower than the k_M^{ps} obtained in the perfect screening case.

In order to have $k_M^{is} > 0$, λ must satisfy the following condition:

$$\lambda > \frac{-\beta(\pi^H - r)}{\pi^L - r - \beta(\pi^H - r)} \quad (6.19)$$

The bank's decision to become active in the lending market depends on the loan pool quality, the screening accuracy, the deposit rate and the expected losses from misclassifying bad projects as good ones. It is worth highlighting that the decision to enter the market is not influenced by the screening costs.

If the probability of misclassification increases, the bank will require a greater λ to have incentives to enter the loan market¹⁰. When screening is perfect, the bank is always active in the market, independently of the economic outlook. An important hypothesis we pretend to test through numerical examples is that imperfect screening tightens the credit restriction in the economy, leading to greater welfare losses.

These welfare losses could be compensated by the entry of a platform with better screening standards, which would require a lower λ to enter the credit market, relaxing the credit restriction and supplying loans to a part of the population that would be excluded otherwise.

6.2.2 Duopoly Case

In this theoretical model we assume that screening is costly, imperfect and independent, and what differs among the bank and the platform are both the screening costs, z , and the probability β . We have again the four groups presented in the duopoly case of perfect screening, but now these groups also include high-risk projects, given

¹⁰ $\frac{\partial \lambda}{\partial \beta} = -\frac{(\pi^H - r)(\pi^L - r)}{[\pi^L - r - \beta(\pi^H - r)]^2} > 0$, since $\pi^H - r < 0$ and $\pi^L - r > 0$

the probability of misclassification. We assume that the platform has a better technology to screen ($\beta_B < \beta_A$) and it is also more efficient in the screening process ($z_B < z_A$).

According to these new conditions, the profit functions will be for the bank and the platform, respectively:

$$\begin{aligned} \Pi_A^{is}(k_A, k_B) = & \frac{k_A[\lambda\pi^L + (1-\lambda)\beta_A\pi^H]k_B[\lambda\pi^L + (1-\lambda)\beta_B\pi^H]}{2} & (6.20) \\ & + k_A(1-k_B)[\lambda\pi^L + (1-\lambda)\beta_A\pi^H] - rL_A - k_A^2z_A \end{aligned}$$

$$\begin{aligned} \Pi_B^{is}(k_A, k_B) = & \frac{k_A[\lambda\pi^L + (1-\lambda)\beta_A\pi^H]k_B[\lambda\pi^L + (1-\lambda)\beta_B\pi^H]}{2} & (6.21) \\ & + k_B(1-k_A)[\lambda\pi^L + (1-\lambda)\beta_B\pi^H] - rL_B - k_B^2z_B \end{aligned}$$

The first term, for both the bank and the platform, represents the profits that the agent obtains from funding loans from the first group, in which it competes with the other agent and therefore gets to finance half of the group. This group has good and bad projects, since both the bank and the platform make classification mistakes.

The amount of loans that the bank and the platform grant is given by the following expressions, respectively:

$$L_A^{is} = \frac{k_A[\lambda + (1-\lambda)\beta_A]k_B[\lambda + (1-\lambda)\beta_B]}{2} + k_A(1-k_B)[\lambda + (1-\lambda)\beta_A] \quad (6.22)$$

$$L_B^{is} = \frac{k_A[\lambda + (1-\lambda)\beta_A]k_B[\lambda + (1-\lambda)\beta_B]}{2} + k_B(1-k_A)[\lambda + (1-\lambda)\beta_B] \quad (6.23)$$

The solution of the optimization problem requires a lot of algebra, considering that we cannot assume a symmetric equilibrium, given the different costs that each agent faces. The first order conditions will be¹¹:

$$\frac{\partial \Pi_A^{is}}{\partial k_A} = k_B X + B - D - 2k_A z_A = 0 \quad (6.24)$$

$$\frac{\partial \Pi_B^{is}}{\partial k_B} = k_A Y + E - F - 2k_B z_B = 0 \quad (6.25)$$

¹¹For details, see Appendix 2

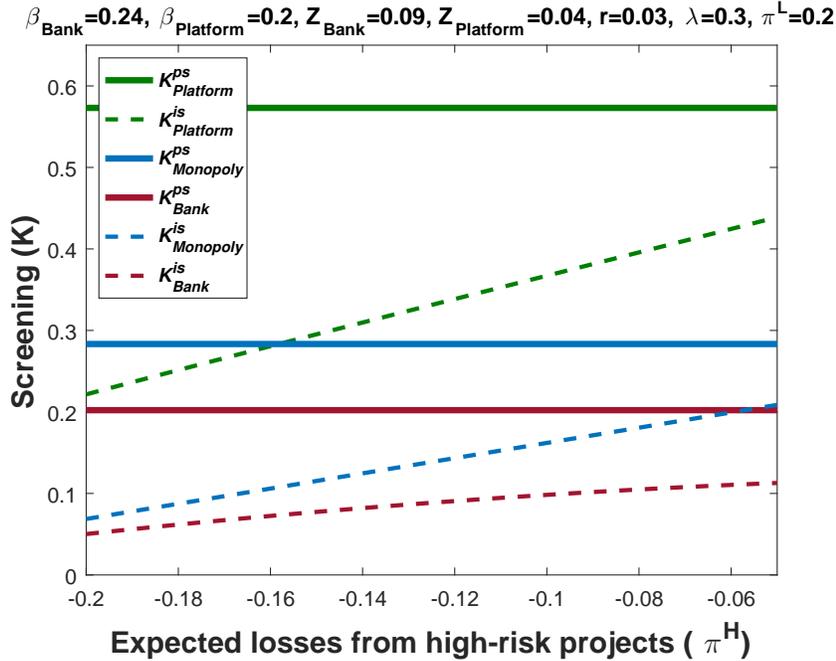
The optimal values for k_A and k_B , under imperfect screening conditions will be:

$$k_A^{is} = \frac{[F - E][X + 2z_B] + 2z_B[E - F + D - B]}{XY - 4z_a z_b} \quad (6.26)$$

$$k_B^{is} = \frac{k_A[Y + 2z_A] + E - F + D - B}{X + 2z_B} \quad (6.27)$$

Now we focus on the numerical analysis to explore how the screening incentives of the platform and the bank are affected by changes in the expected losses from financing high-risk projects, the economic outlook and the screening costs.

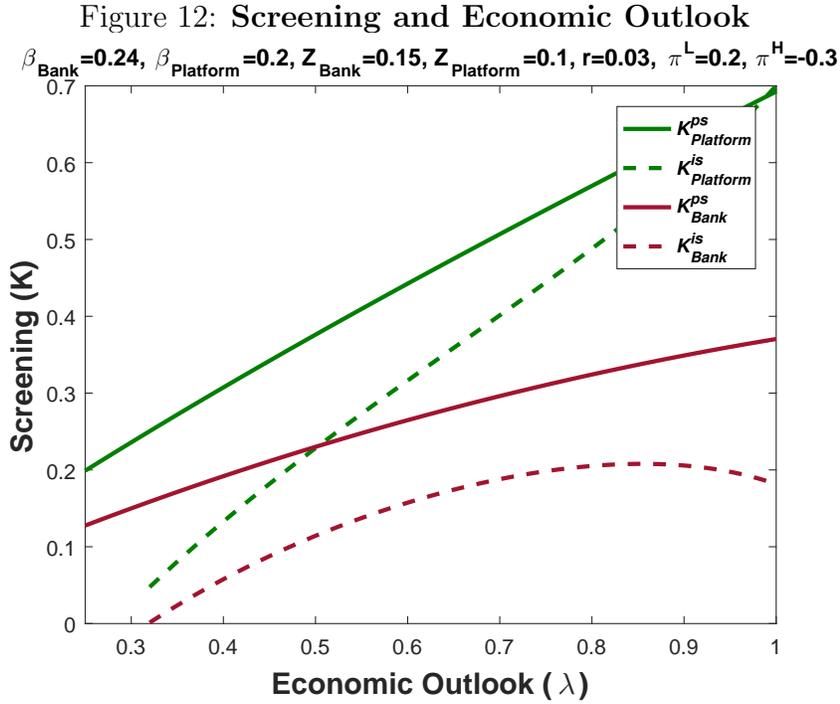
Figure 11: Screening and Expected Losses



From Figure 11, we can conclude that the agents decide to screen less and grant a lower amount of loans when the losses from high-risk projects increase. The results also show that imperfect screening discourage the agents to screen loan applications (compare for example “ K_{Bank}^{ps} ”, which is the proportion of loan applications screened by the bank when screening is perfect, to “ K_{Bank}^{is} ”, which is the fraction of loan

applications that the bank screens when screening is imperfect)¹². It can also be seen in Figure 11, that the amount of applications screened by the platform is always superior than the amount of screening that the bank carries out.

In the exercise presented in Figure 12, we analyze the effect of an increase in the amount of good projects in the economy. The results show that an improvement in the economic outlook has a positive effect on the amount of screening that the agents want to make. It is important noting that if the economic outlook is good enough, the platform always provides more loans than the bank, even if the bank has perfect accuracy of screening and the platform does not have it ($K_{Platform}^{is} > K_{Bank}^{ps}$).



In the following numerical analysis, we study the effect of the economic outlook when there are symmetric screening costs, but the platform is still better than the bank at detecting which are the low-risk projects ($\beta_A > \beta_B$)¹³.

¹² “ K^{is} ” denotes the amount of loan applications screened under imperfect screening conditions and “ K^{ps} ” means “perfect screening”.

¹³ Given that $z_A = z_B$, then we denote $k_A^{ps} = k_B^{ps} = K^{ps}$

Figure 13: Screening and Economic Outlook

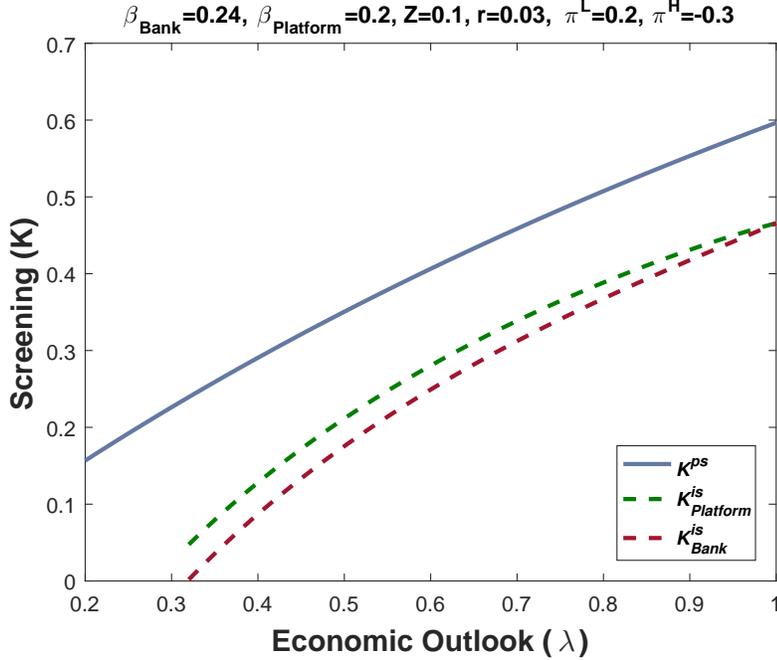


Figure 13 shows that low screening standards decrease the incentives of the platform and the bank to screen ($K^{ps} > K^{is}_{Platform} > K^{is}_{Bank}$). Since we assumed that there is no possibility to grant a loan without screening, lower screening directly decreases the amount of loans granted, affecting the welfare of potential borrowers that are restricted from the credit market. Figure 13 represents a situation in which both the bank and the platform face almost the same conditions and the only parameter that causes the differences in screening is β . Note that a better economic outlook decreases the gap between the amount of loan applications screened by the bank and the platform.

7 The Welfare Analysis

From the social welfare perspective it is important to analyze what is the impact of having a monopoly or a duopoly in the industry. Additionally, the welfare analysis allows us to have insights about the effects of imperfect screening on the socially optimal fraction of loan applications.

7.1 Perfect Screening

The welfare analysis takes into account the profits of the bank, as well as the welfare of good entrepreneurs. Since there is perfect screening, high-risk projects do not obtain funding and therefore their welfare is zero. The society will maximize the following social welfare function:

$$W^{ps}(k) = k\lambda\pi^L - k^2z \quad (7.1)$$

Here we assume that the marginal utility of consumption is the same across all individuals. The first term accounts for the social benefit from the loans that are granted by the bank after screening. Since we assume that the monopoly charges the interest rate, $R_L - 1$, to the entrepreneurs to provide them with one unit of funding, then the bank appropriates all the expected return of a good entrepreneur from making a loan application. The second term captures the screening costs.

It is important noting that the costs of deposits in which the bank incurs are completely compensated by the revenue of the depositors, rL . Then, the socially optimal fraction of loan applications that should be screened (k_M^{ps*}) is as follows:

$$k_M^{ps*} = \frac{\lambda\pi^L}{2z} > k_M^{ps} = \frac{\lambda\pi^L - r\lambda}{2z} \quad (7.2)$$

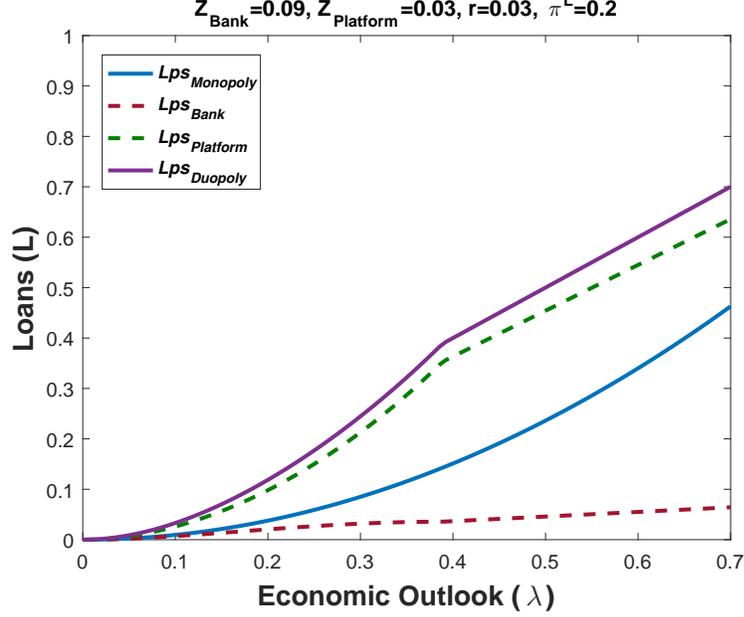
which is greater than the fraction of loan applications that the bank screens (k_M^{ps}).

Using the same data of Figure 10, then we can verify that the amount of loans granted in duopoly, when the platform and the bank are both active in the market, is bigger than the amount of loans granted by the bank when it is the only provider of this product (Figure 14).

Under this scheme with perfect screening, only good projects will get loans either from the bank or the platform. Then, P2P lending increases loan supply and seems to be a good alternative for those who deserve credit, but do not have access to financial services provided by regulated financial institutions. This would be an important innovation in developing economies, where many people depend on informal mechanisms that have forced them to pay high interest rates and pawn or sell assets.

Financial inclusion makes capital available to households, which allows them to manage risks, make investments in durable goods or realize business opportunities, bringing positive effects on welfare.

Figure 14: Loans and Economic Outlook



7.2 Imperfect Screening

Under imperfect screening conditions, the welfare analysis also considers the bank's losses from financing high-risk projects and the surplus of the high-risk entrepreneurs that receive funding for their projects. Then, the social welfare function is as follows:

$$W^{is}(k) = k[\lambda\pi^L + (1 - \lambda)\beta\pi^H] + k(1 - \lambda)\beta p_H(R_H - R_L) - k^2 z \quad (7.3)$$

where $p_H(R_H - R_L)$ is the expected return of an entrepreneur that applies to a loan with a high-risk project and it is strictly positive.

The first term is the fraction of loan applications that could pass the screening test and it is multiplied by the term in brackets that gives the profits and losses that the bank receives from good and bad projects, respectively. The second term captures the surplus of the high-risk entrepreneurs that get funds from the bank. The third term accounts for the screening costs.

The socially optimal screening when there is only a bank in the economy and $\beta > 0$, is:

$$k_M^{is*} > k_M^{is} \left(\frac{\lambda\pi^L + (1 - \lambda)\beta\pi^H + (1 - \lambda)\beta p_H(R_H - R_L)}{2z} \right) > \left(\frac{\lambda\pi^L + (1 - \lambda)\beta\pi^H - r[\lambda + (1 - \lambda)\beta]}{2z} \right)$$

When this result is compared to the optimal decision for a bank under imperfect screening conditions, the socially optimal screening is always greater than the screening of the bank.

The welfare gain obtained from having a platform active in the market under imperfect screening conditions is presented using a numerical example (Figure 15).

Figure 15: Loans and Economic Outlook

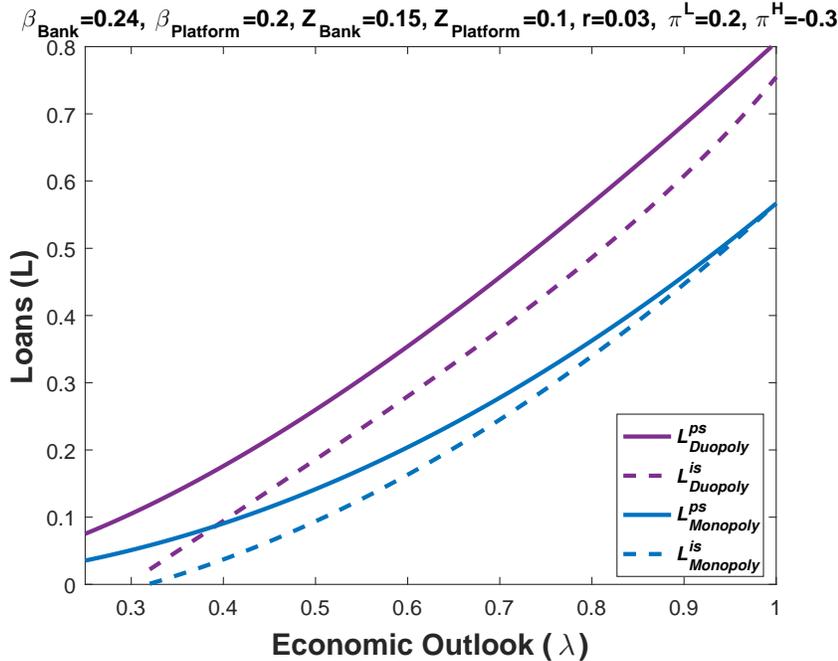


Figure 15 represents our main result: when the platform is active, there is always a greater provision of credit. This result should be analyzed carefully, taking into account that some high-risk projects, under imperfect screening conditions, also receive credit. Then, the welfare gain for the borrowers might not be enough to compensate the bank's welfare loss.

Figure 15 also shows that an increase in the number of good projects in the economy reduces the gap between the amount of loans granted under perfect and imperfect screening conditions. This means that having imperfect screening losses relevance as the economic outlook improves.

One of the most important lessons is that a rigorous underwriting process is imperative and by incorporating better analytical instruments for credit evaluation, banks and especially platforms can further improve financial inclusion, while increasing returns for investors and lowering interest rates for borrowers.

8 Risks

We have already described the advantages that the entry of P2P lending might bring to the credit market, but we must highlight that these attractive returns also come along with risks. In this section we characterize some of the concerns about P2P lending and what has been done to mitigate the risks.

1. P2P platforms have created a new asset class for investors, allowing them to diversify risk through a wider range of investment options. However, it should be clear that this kind of investment turns out to be an imperfect substitute for deposits, since these have protection through the deposit insurance, and for those that are not fully insured, credit risk is associated with the bankruptcy of the bank; while assets generated on P2P platforms are directly exposed to borrowers' credit risk
2. With respect to credit risk, unlike traditional banks that make loan loss reserves to cover estimated losses on loans due to defaults and nonpayment, generally in P2P lending, there is no such provisioning and investors assume directly the risk of default. In the event that there are fraudulent transactions on credit applications, this risk increases significantly. However, in recent years some platforms have begun to create provisions or a reserve fund, in order to have credit risk coverage of their operations. This fund collects resources through a fee paid by borrowers according to their risk profile and are used to pay investors in the event that operations are breached. It is also complemented with collection actions by hiring a third party; in case that the resources are recovered, they are returned to the fund.

There are some platforms that try to minimize the risk by imposing limits on the amounts that can be invested in certain projects, looking for a better risk diversification for investors, noting though, that investment decisions are made by investors directly, and therefore they assume all the risk of the credit operations and not the platform.

3. Contrary to deposits, investments made on P2P platforms are not a liquid asset in the sense that such resources cannot be refunded immediately to address an investor liquidity problem. A possible solution to this issue is the sale of loans in secondary market operations, for example using securitization processes. In recent years, these mechanisms have had a great development, mainly in the United States.

4. Unlike traditional banks subject to different rules that require them to have a system for operational risk management, not all P2P lending platforms have contingency plans that allow them to perform administration of payments between investors and debtors if any problem occurs or the platform goes into liquidation.
5. Regulators must be aware that platforms are now constrained by the amount of borrowers and in the execution of their growth strategy they might be attracting riskier borrowers. Therefore regulators should require them to have accurate screening standards.
6. There is also a risk that confidentiality of the customers' data or investors' data is violated. This information is directly managed by the P2P platforms, which should ensure data security of those involved and provide appropriate mechanisms to guarantee that borrowers and investors do not engage in fraudulent transactions such as money laundering, financing of illegal activities, etc. P2P lending has raised concern about how the funds obtained online are being used.
7. There is concern about the algorithms used to screen applications, which might be biased, resulting in implicit discrimination by race, sex, religion, among others.
8. Once platforms have established a client base, with enough users on both sides of the market, costs reductions may not translate into better terms for borrowers and investors, because platforms might be interested in charging more to them to obtain higher profits.
9. There is also concern about the information that P2P platforms reveal, because asymmetries could arise and this would limit the access to accurate information that investors have about the risk-return ratio of their investments. The amount of information revealed by the platform to both sides of the market becomes a strategic decision and can affect the extent of trade, market allocation and the distribution of surplus among users. ([Albano & Lizzeri, 2001](#)).
10. These platforms' growth has potentially significant consequences for the monetary policy that central banks formulate and implement. P2P lending model still retains a marginal role in financial activity, but if lending mechanisms increase outside the traditional system, the central bank must consider how this affects monetary policy transmission and financial stability.

9 Regulation

The lack of regulation in P2P lending business has helped it to innovate and grow at a very fast pace. However, as the size of this market is continuously increasing and not only individuals but also institutional investors are participating, a failure in this market could actually have a relevant impact on the financial system. Thus, it is important to examine how this business should be regulated in order to manage its inherent risks, without hindering its development while increasing users' confidence.

In this sense, [Aveni \(2015\)](#) mentions that even though regulation is still scant in many countries, France and England have issued new rules regarding this issue, among which are:

1. Raise standards of business management. That is, the managers of these platforms should have a minimum education level and knowledge to be allowed to operate.
2. Transparency. Platforms must be obliged to publish all relevant information so that investors are fully aware of the risks of the business.
3. Investment limits. Platforms should set a ceiling on the amount to be invested to help inexperienced investors to diversify their risk. For example, in France the law allows a maximum investment of 1,000€ in each loan.
4. Contingency plans. If the platform goes bankrupt or fails to deliver the service, there must be an alternative to continue managing the transfer of resources from borrowers to investors. For example, in the UK, crowdfunding regulation requires platforms to have a contract with another platform or an agent that manages portfolio.

Moreover, in some cases P2P platforms have self-regulated in order to protect the business' reputation. For example, in the United States, Lending Club, one of the largest platforms in the country, completed the registration process with the Securities and Exchange Commission (SEC) as an issuer of securities. Accordingly, all the securities they issue must be registered with the SEC. In the case of the U.K., platforms have formed an agency to regulate themselves and maintain high market standards.

10 Conclusions

Given the rapid expansion that P2P lending has presented worldwide, it is very likely that this business is developed in Colombia. Therefore, it is important to assess the impact it may have in the financial system and how it should be regulated in order to preserve financial stability. Given the particularities of this business, where platforms act as intermediaries but cannot be treated as stock brokerage firms or Collective Investment Funds, because they are dedicated to loan creation and do not intermediate the brokerage of securities (i.e. bonds, stocks), then the establishment of a new class of financial intermediary might be needed. Also, according to Kirby & Worner (2014) it is important to consider a special status in the regulation of this new intermediary in relation to the three agents involved in the business:

1. Investors: It could be considered to set investment restrictions based on income and/or wealth, restrictions on what type of agents may be investors (private and institutional agents) and strategies for promoting awareness about the risks involved in investment operations.
2. Debtors: Limits on the amounts of credits could be set depending on the projects and/or their use. Restrictions on the types of debtors to finance could be imposed and requirements for direct connections to credit bureaus nationwide could be established.
3. Platforms: A special register for the platforms with the regulatory and/or supervising agency of the financial system should be established, as well as limits on the type of business model they want to implement, clear mechanisms of problem solving and processes in case of the liquidation of the platforms. Finally, they could enforce reserve and capital requirements analyzing business risk in a comprehensive way, establish disclosure and transparency processes of operations and contingency plans to mitigate the effects of operating business risk.

For the proper development of P2P lending in countries where this kind of business does not exist yet, it would be important that before venturing into the new market, it considers its legal structure and presents its business plan to the authorities. Additionally, as this type of business depends largely on its reputation and still lacks a historically-proven track record, it is important that platforms act in a transparent way, educate the market about the product they are developing, employ technology to operate efficiently and make a proper assessment of the risk- return

ratio that investors face. Finally, it is important that platforms perform adequate monitoring of the resources they manage in order to comply with the rules relating to money laundering and terrorist financing.

From the analysis of the screening that an active agent in the credit market must carry out in order to differentiate good projects from bad ones, we conclude that lower screening costs, a better economic outlook and higher profits from good projects incentivizes the platform and the bank to screen more. Additionally, participation in the market of the platform increases the amount of loans granted, supplying the product to a new part of the population and improving financial inclusion.

As long as the platform has lower screening costs and better screening quality, then it will grant more loans than the bank. A lower quality in screening reduces the incentives of screening of both agents and therefore they provide less credit to the market. It is important noting that the gap between the optimal amounts of screening under imperfect and perfect screening conditions reduces as the economic outlook improves.

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Appendix

Appendix 1

Replacing equation 6.11 in 6.10:

$$k_A = \frac{\lambda(r - \pi^L)}{\frac{\lambda}{2}(r - \pi^L) - 2z_B \left[\frac{\frac{\lambda}{2}(r - \pi^L) + 2z_A}{\frac{\lambda}{2}(r - \pi^L) + 2z_B} \right]} \quad (10.1)$$

$$k_A = \frac{\lambda(r - \pi^L)}{\frac{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B}{\frac{\lambda}{2}(r - \pi^L) + 2z_B}} \quad (10.2)$$

$$k_A = \frac{\frac{\lambda^2}{2}(r - \pi^L)^2 + 2\lambda(r - \pi^L)z_B}{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B} \quad (10.3)$$

Equation 10.3 in 6.11

$$k_B = \left[\frac{\lambda(r - \pi^L) \left[\frac{\lambda}{2}(r - \pi^L) + 2z_B \right]}{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B} \right] \left[\frac{\frac{\lambda}{2}(r - \pi^L) + 2z_A}{\frac{\lambda}{2}(r - \pi^L) + 2z_B} \right] \quad (10.4)$$

$$k_B = \frac{\frac{\lambda^2}{2}(r - \pi^L)^2 + 2\lambda(r - \pi^L)z_A}{\frac{\lambda^2}{4}(r - \pi^L)^2 - 4z_A z_B} \quad (10.5)$$

Appendix 2

$$\begin{aligned} A &= \frac{[\lambda\pi^L + (1-\lambda)\beta_A\pi^H][\lambda\pi^L + (1-\lambda)\beta_B\pi^H]}{2} & B &= \lambda\pi^L + (1-\lambda)\beta_A\pi^H & C &= \frac{r[\lambda + (1-\lambda)\beta_A][\lambda + (1-\lambda)\beta_B]}{2} \\ D &= r[\lambda + (1-\lambda)\beta_A] & E &= \lambda\pi^L + (1-\lambda)\beta_B\pi^H & F &= r[\lambda + (1-\lambda)\beta_B] \\ X &= A - B - C + D \\ Y &= A - E - C + F \end{aligned}$$

The first order conditions:

$$\frac{\partial \Pi_A}{\partial k_A} = Ak_B + (1 - k_B)B - Ck_B - D(1 - k_B) - 2k_A z_A = 0 \quad (10.6)$$

$$\frac{\partial \Pi_B}{\partial k_B} = Ak_A + (1 - k_A)E - Ck_A - F(1 - k_A) - 2k_B z_B = 0 \quad (10.7)$$

From the first order conditions:

$$k_B = \frac{k_A Y + E - F + D - B + 2k_A z_A}{X + 2z_B} \quad (10.8)$$

(10.8) in (6.25):

$$k_A Y + E - F - 2z_B \left[\frac{k_A Y + E - F + D - B + 2k_A z_A}{X + 2z_B} \right] = 0 \quad (10.9)$$

$$k_A = \frac{[F - E][X + 2z_B] + 2z_B[E - F + D - B]}{XY - 4z_a z_b} \quad (10.10)$$