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Conference Paper

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2014: Evidenzbasierte Wirtschaftspolitik - Session: Financial Markets and Information, No. G09-V1

Provided in Cooperation with:
Verein für Socialpolitik / German Economic Association

Tapping the Financial Wisdom of the Crowd*

— Crowdfunding as a Tool to Aggregate Vague Information —

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February 28, 2014

Abstract

Crowdfunding, a novel form of financing, has seen massive growth over the last few years. Under crowdfunding, a large number of small households offers small loans to a firm. But if some threshold is missed, the firm cannot draw the loans. We construct a model to argue that this mechanism can be used to aggregate vague information by many households (for example, potential future consumers of the firms product). Each household can spend an effort to produce a bit of vague information – too vague to justify a straight loan. But if the firm sets the threshold high, a household knows that his money will be drawn only if many other households also get positive information. We describe the equilibrium behavior of households and firms. A welfare analysis reveals that with crowdfunding, firms set the loan rate too low and the threshold too low, inducing households to generate too much information. In comparison to straight finance, crowdfunding is employed too often.

Keywords: Crowdfunding, Gatekeeper Function of Finance, Wisdom of the Crowds, Entrepreneurial Finance, Information Efficiency, Signaling.

JEL-Codes: G23. L15.

*We thank Benny Moldovanu, Volker Nocke, Martin Peitz and Frank Rosar for discussion. All errors are our own.

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1 Introduction

Crowdfunding is on the rise. Consider a specific example. In February 2014, a letter from the chairman of Roberts Space Industries announced that the amount of 38 million USD of funding for its video game Star Citizen is surpassed. The company could raise this enormous sum via an internet campaign on its own website and via the platform Kickstarter.[1] People may earn different benefits such as digital downloads, hard copies of books or a CD with the game soundtrack in return for their funding depending on the amount they have given.[2]

From a theoretical perspective, crowdfunding is not straightforward to understand. From the perspective of transaction costs, crowdfunding should be more expensive than, for example, bank finance, because of the sheer number of contracts and relations. The model of Diamond (1984) argues that, with costly state verification, a delegated monitor (bank) should get between investors and firms. So, what economic value does crowdfunding bring to the table? Under what conditions can crowdfunding dominate traditional forms of financing? And is a firm's decision to use crowdfunding optimal from a welfare perspective? All of these questions are answered by our model.

In our model economy, there is a firm that needs finance for an investment project, and a number of households. Firms can be interpreted as firms that produce consumption products. They come in two types, good and bad. Good firms will later have a high probability to produce a good product, creating a positive net present value for the project. Bad firms have a low probability to produce a good product. Now importantly, the households are potential future consumers for the product. If they think hard (which is costly), they get a hunch on whether they will later like the product even before it is actually produced. This information is, of course, valuable in the firm's financing stage. If many households have a negative hunch, the product will likely be bad, and the firm should not get finance.

With traditional finance, e. g., direct loan finance, households might not be willing to invest because their information on the firm's prospects is too vague. Also a loan officer in a bank cannot aggregate the information. At this point, crowdfunding comes in. Crowdfunding exists in different types, discussed below in this section. Let us first concentrate on lending-based crowdfunding. Here, firms fix an interest rate and, importantly, some minimum aggregate loan volume. Households can then pledge to participate. If sufficiently many

[1] `robertsspaceindustries.com/comm-link/transmission/13550-Letter-From-The-Chairman-38-Million`

[2] `www.kickstarter.com/projects/cig/star-citizen`

households make a pledge, and the threshold is reached, the pledged loan volumes are transferred from the households to the firm. If the threshold is not reached, the funding fails, and no monetary transfers are made.

In this contractual setting, households can pledge money even if their information is only vaguely positive. They anticipate that the firm can only draw the money if sufficiently other households also have positive information, otherwise the threshold could not have been reached. On the other hand, the contract contains a free-rider problem. A household knows that the issue is only successful if many other households have gotten positive information, he may not trust his only vague signal. Anticipating this, he would not gather any information at all, free-riding on the information gathered by others. The incentives of households to gather information, or free-ride, or do nothing, depend on the firm's choice of the loan rate and the threshold (minimum loan volume).

We show that, in equilibrium, the firm sets these contract parameters such that all households get the information, but participate only if the information is positive. To do so, the threshold is set sufficiently low, such that even bad firms get financed with a significant probability. To avoid (or rather, mitigate) the winner's curse, a household needs to get informed. That way, the firm endogenously eliminates the free-rider problem completely.

Then, we compare the firm's choice with the welfare optimum, asking two questions. *First*, given that the firm uses crowdfunding, does it set the contract's parameters right? The answer is negative. The firm sets both the loan rate and the threshold too low. That way, it induces *all* households to get informed, whereas the optimal number of informed households may be lower. Only if the firm does not know its own type, it chooses the parameters exactly right. *Second*, does the firm use the tool of crowdfunding too often (or too little)? We show that crowdfunding raises welfare in many parameter constellations, hence it should not be banned. However, it is used inefficiently often. Regulating crowdfunding may be difficult, because crucial parameters are non-verifiable.

Examples and Institutional Background. Barack Obama could collect about 750 million USD for his presidential campaign in 2008. Most of this amount was raised via the internet and came from small donors who contributed 200 USD or less. The crowdfunding method helped Obama to surpass all of his White House opponents.[3] In this case, funders did not receive anything in exchange for their money besides the hope, the support would bring their favorite candidate to winning the presidential election.

[3] `http://abcnews.go.com/Politics/Vote2008/story?id=6397572&page=1`

In the examples above, projects could collect a huge amount of money via internet either for a political campaign or the development of a video game. This method is not only useful for donations or fan support, it can also help companies to get essential funding. For entrepreneurs, it is still difficult to attract outside capital even if a lot of possibilities exist. Many articles discuss different ways to fund projects such as venture capital, IPOs, bootstrapping or conventional banks. One potential concept that is getting more and more important is the concept of crowdfunding. Before 2006, crowdfunding was mostly unknown. But as of today, many projects only could come to life by the assistance of crowdfunding platforms that help to connect private investors and entrepreneurs. The investment form is gaining ground especially when it comes to financial support for start-ups. As in the examples above, crowdfunding was initially used to support things as films, books, music recordings, and charitable endeavors. However, the interest in crowdfunding as a business strategy and an offer to investors is growing (Cross, 2011).

In the literature, crowdfunding is defined as an "open call, essentially through the Internet, for the provision of financial resources either in form of donation or in exchange for some form of reward and/or voting rights in order to support initiatives for specific purposes"(Belleflamme, Lambert, and Schwienbacher, 2013a). Another definition comes from Cross (2011): " The term "crowdfunding" is used to describe a form of capital raising whereby groups of people pool money, typically comprised of very small individual contributions, to support an effort by others to accomplish a specific goal."

The process of crowdfunding usually involves an online crowdfunding platform as intermediary. The fundraiser starts with a request and gives information about the investment amount that is needed and what is offered in exchange (Ahlers, Cumming, Günther, and Schweizer, 2013). Potential investors are provided with detailed information about the project for which the funding is required. On this basis, interested investors decide how much they are willing to pledge. However, if a predefined minimum amount of funding could not be reached in a certain time, the funding process will be unsuccessful and no investments at all are made. This feature of crowdfunding protects the single investor. Only if enough people are convinced by the project, a single person has the chance to take part in the investment. Usually, no fundraising limit exists but the call is restricted on a certain time period. The crowdfunding platform provides the technical service for the exchange of the information and the funds and typically receives a percentage of the funding amount for this service. Crowdfunding is used in order to attract a large group of investors.

Four different business models of crowdfunding exist: donation-based crowdfunding, reward-based crowdfunding, lending-based crowdfunding and equity-based crowdfunding (Griffin, 2012). The determination of these four categories depends on what the investors receive in exchange for their funds (Ahlers, Cumming, Günther, and Schweizer, 2013). In donation-based crowdfunding, people are interested to support a special project for charitable or sponsoring reasons. They have no expectation of a monetary repayment. Investors in reward-based crowdfunding receive a product or any other non-financial benefit in exchange for their funds. For example, pre-selling a product can be designed as reward-based crowdfunding. In lending-based crowdfunding, funders will get a fixed amount as a periodic payment, as it is the case in peer-to-peer loans. Finally, equity crowdfunding is a concept of giving small pieces of ownership to investors.

The crowdfunding market did see a massive growth over the last years. Kickstarter, the world's largest crowdfunding platform, was founded in 2008 and has raised over 775 USD for different projects. In 2010, people pledged over 27 million USD for projects on Kickstarter. In 2011, already 99 million USD could be pledged. And from 2012 to 2013 this number further increased from 319 to 480 million USD.[4]

Literature. Our paper is related to three strands of literature. First, of course, there is a specific literature on crowdfunding (both theoretical and empirical). As the phenomenon of crowdfunding is relatively new, this literature is also young and not very extensive. Second, crowdfunding is in some aspects similar to an initial public offering (IPO), on which there is a vast literature. Third, crowdfunding is related to crowdsourcing. With crowdfunding, finance comes from the crowd; with crowdsourcing, the crowd offers labor.

Let us start with the *theoretical* literature specifically on crowdfunding. The studies of Agrawal, Catalini, and Goldfarb (2013) and Hemer (2011) give good overviews of the crowdfunding market. Both papers are qualitative studies that examine recent developments and the outlook for crowdfunding. Schwienbacher and Larralde (2012) also give a review of the new way of financing projects and add a case study by having a closer look at the French startup Media No Mad.

There exist some few articles that analyze crowdfunding from a theoretical perspective. Belleflamme, Lambert, and Schwienbacher (2013a) compare two forms of crowdfunding and the respective benefits for the entrepreneur. Depending on the initial capital requirement, an entrepreneur should decide for either a form of pre-ordering or advancing a fixed amount in exchange for equity. Rubinton (2011) uses simulations to analyze different factors influencing the success of different forms of crowdfunding. A mechanism that is similar to crowdfunding is studied by Louis (2011). In this paper, the agents decide for

[4] www.kickstarter.com

investment not at the same time but are structured in a certain order which results in a winner's curse for those agents at the end of this order.

The crowdfunding market is also subject to several *empirical* studies. Factors for successful projects are analyzed by Belleflamme, Lambert, and Schwienbacher (2013b) and by Ahlers, Cumming, Günther, and Schweizer (2013). Agrawal, Catalini, and Goldfarb (2011) have a closer look on the geographic distribution of investor and entrepreneur especially in the music market. A different approach in the paper of Hildebrand, Puri, and Rocholl (2013) finds evidence of adverse incentives of which the market is not aware.

Literature on IPOs. Our paper is also related to the paper of van Bommel (2002) and other articles that discuss the flow of information from the market to the entrepreneur (for example Welch, 1989). Based on the famous model of Rock (1986), van Bommel (2002) provides a setting in which managers try to increase the information they receive from market participants by a certain price policy in IPOs. The evidence of information production in IPOs is studied by Corwin and Schultz (2005).

Literature on crowdsourcing. There is a large literature on crowdsourcing in the computer science community. Just to cite a non-representative few, see Archak and Sundararajan (2009), DiPalantino and Vojnovic (2009), and Chawla, Hartline, and Sivan (2012). Our paper differs in a couple of aspects. First, in crowdsourcing, the cost structure may differ between different programmers (private value), whereas in our setting, the firm has the same value for all bidders (common value). Second, with crowdsourcing, one (or very few) programmers attracts the work order; in our setting, it is crucial that a large number of households participates.

The rest of the paper is organized as follows. In section 2, we introduce the model. Section 3 serves as a benchmark and discusses the outcome with standard debt finance. Section 4 analyzes the equilibrium with crowdfunding. It compares crowdfunding to standard finance, and also includes comparative statics and a welfare discussion. Section 5 concludes. Proofs are in the appendix.

2 The Model

In our model, a firm seeks funding in order to start a new project and has the possibility to decide between standard debt finance and crowdfunding. We consider conditions under debt finance and also discuss the perspective of investing households in the crowdfunding environment. Table 1 summarizes the various variables used in our model and includes the parameters of our numerical example.

Table 1: Index of Parameters and Variables

α	$\frac{1}{4}$	probability to get a bad signal though the a firm is good
β	$\frac{1}{4}$	probability to get a good signal though the a firm is bad
I		aggregate investment
μ	$\frac{1}{10}$	fraction of good firms
q_G	$\frac{2}{3}$	success probability of a good firm
q_B	$\frac{1}{3}$	success probability of a bad firm
c	$\frac{1}{80}$	cost of information
R	$\frac{5}{2}$	firm's return (if successful)
N	15	number of households
r		loan rate
ι		probability of a households to get ιnformed
υ		probability of households to remain υuninformed yet participate

The second column shows the parametrization we use for numerical examples.

Consider an economy with two types of agents: a firm and a large number N of households. Firms have a constant returns to scale technology: investing I, their project yields RI with probability q at the end of the period, otherwise (probability $1-p$) they receive nothing. There are two types of firms: a fraction μ is good (index H) and has a success probability of q_G, the fraction $(1-\mu)$ consists of bad firms (index L) that have a success probability of q_B.

There is a number N of households, each owning an endowment of 1. Households have access to an information technology: spending c, they get an information about the true type of the firm. The information, however, is noisy: with probability α, a good firm sends a bad signal; with probability β, a bad firm sends a good signal.[5]

The risk-free interest rate is normalized to zero. All agents are risk neutral. The nature chooses the type of the firm (H or L).

The timeline of the funding process is as follows: at date $t=0$, the firm chooses the type of finance with which it is seeking funding. If the firm prefers standard debt finance, it sets a loan rate r. Under crowdfunding, a loan rate r and a minimum investment $I_{\min}$ is

[5] As a possible interpretation, different firms may have products of different quality. If the quality is high, the firm is likely to be successful (q_G); if the quality is low, the firm is less likely to have success (q_B). The information of households may then stem from the fact that they are possible future consumers. They spend some time (cost c) in order to determine whether they will likely buy the product, once it has been produced.

determined. Only if $I_{\min}$ is reached, the funding will be successful and the project can be implemented.

The households choose whether to gather information at private cost c about the project. The information is independent between households and can be noisy as defined above (with wrong-negative rate α and wrong-positive rate β). The households choose whether to pledge to provide finance and announce their decision. Only if an amount $\geq I_{\min}$ can be collected, the investment of households will be made. In this case, the project is started.

At date $t = 1$, the project returns RI with probability q_G for a good firm and with probability q_B for a bad firm. Finally, the loans are paid back.

3 Standard Debt Finance

Let us first consider the case of Standard Debt Finance. The firm raises capital by borrowing money at a fixed rate of interest. Let us assume that the firm has the market power, hence it can make the households take-it-or-leave-it offers. As before, each household can spend its endowment of 1.

There are four potential regimes. *First* (1), and most importantly, households may gather the information before investing by spending c. There are two subcases: (1a) they invest only if the info is positive, and (1b) they invest even if the info is negative, but at a higher loan rate. *Second* (2), the information may be so noisy that households do not get informed at all. Again, there are two subcases: (2a) the households may grant loans at an average rate, or (2b) they may not grant loans at all. We are interested in a comparison of standard debt finance and crowdfunding. Therefore, we focus here on case (1a) as the situation of informed households and one single loan rate is on the lines of the crowdfunding situation. The other cases are discussed in the appendix.

Case 1a. The expected profit of an informed household is $\mu\,(1-\alpha)\,(q_G\,r-1)+(1-\mu)\,\beta\,(q_B\,r-1)-c$, where r is the gross loan rate per unit of investment. With probability μ the firm is good, but as the signal is noisy, only with probability $(1-\alpha)$ it is recognized as good. $(q_G\,r-1)$ is the expected return of the household if the firm is good. With probability β, even a bad firm (fraction $1-\mu$) is declared as good. Households must break even, hence the loan rate will solve

$$0=\mu\,(1-\alpha)\,(q_G\,r-1)+(1-\mu)\,\beta\,(q_B\,r-1)-c,$$

$$r = \frac{c + \beta\,(1-\mu) + (1-\alpha)\,\mu}{\mu\,(1-\alpha)\,q_G + (1-\mu)\,\beta\,q_B}. \tag{1}$$

A good firm's expected financing volume is $(1-\alpha)\,(R-r)$, with r as in (1).

4 Crowdfunding

Now consider a different regime. The firm guarantees a minimum volume of $I_{\min}$ (called the "threshold" in the following) at a predefined loan rate r. The issue is stopped and no transfers are made if the threshold $I_{\min}$ is not reached in the issue. Because each household owns \$1, $I_{\min} = n_{\min}$ is also the number of households that need to participate in a successful issue. The decision of the household to pledge its whole endowment is discussed in section (4.1).

In the words of auction theory, the game is a simultaneous common value sealed bid fixed price auction with unlimited supply. Instead of a reservation price, there is a reservation volume (the threshold $n_{\min}$). The assumption of simultaneous bids helps us to abstract from information cascades (see Bikhchandani, Hirshleifer, and Welch (1998), the book by Chamley (2004), or recently Kremer, Mansour, and Perry (to appear)).

One potential equilibrium will look as follows. Some households will become informed and pledge only if the information is positive. Some households will choose to remain uninformed. However, these will also make a pledge with a positive probability, trying to free-ride on the information provided by the informed households. If their pledge would be only successful for good firms, it would be a dominant strategy for all households to remain uninformed. Therefore, the bid of uninformed households will be successful for bad firms with positive probability in equilibrium. This is an important property: bad firms must successfully get funding with positive probability.

Let ι denote the probability with which an household becomes ιnformed. These households will make a pledge if the information is positive, otherwise not. If they pledged with negative information, even only with a small probability, they would have to be indifferent between investing or not *after* getting the information, hence it would not pay to acquire the information in the first place. Spending the cost c would bring no improvement for the household which makes the gathering of information too expensive. The same argument applies if informed investors chose to not pledge after a positive information, even with only a small probability.

The number of informed households follows a binomial distribution, $n_i \sim B(N, \iota)$, thus the probability for n_i informed households is

$$p_i(n_i) = \binom{N}{n_i} \iota^{n_i} (1-\iota)^{N-n_i}. \tag{2}$$

Uninformed households may still make a pledge with positive probability. Let υ denote the probability that a household remains υninformed and pledges nevertheless. Thus, in equilibrium, a households chooses to get informed with probability ι, it pledges even without information with probability υ, and with probability $1-\iota-\upsilon$, it remains completely inactive: it neither gets information, nor does it pledge. A good firm receives money from informed households if those got a positive signal which happens with probability $(1-\alpha)$. Therefore, the probability of funding for a good firm is $\iota\,(1-\alpha)+\upsilon$.

With these definitions, we can also calculate the distribution of the number n_G of pledging households if the firm is good, which is $n_G \sim B\big(N, \iota\,(1-\alpha)+\upsilon\big)$, thus

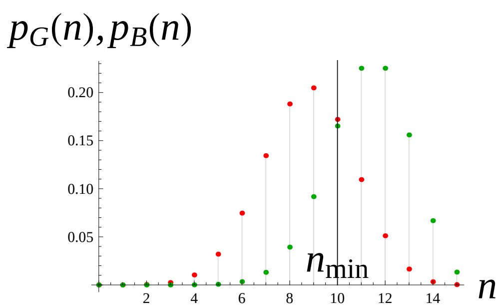
$$p_G(n_G) = \binom{N}{n_G} \big(\iota\,(1-\alpha)+\upsilon\big)^{n_G} \big(1-\iota\,(1-\alpha)-\upsilon\big)^{N-n_G}. \tag{3}$$

The number of non-pledging households $N-n_G$ for a good firm follows the binomial distribution with the counter-probability, $N-n_G \sim B\big(N, 1-\iota\,(1-\alpha)-\upsilon\big)$. The distribution of the number n_B of pledging households if the firm is *bad* is $n_B \sim B\big(N, \iota\,\beta+\upsilon\big)$, thus

$$p_B(n_B) = \binom{N}{n_B} \big(\iota\,\beta+\upsilon\big)^{n_B} \big(1-\iota\,\beta-\upsilon\big)^{N-n_B}. \tag{4}$$

The following Figure 1 shows the probabilities $p_G(n)$ and $p_B(n)$ of a numerical simulation.

Figure 1: Probabilities of Investors n (Example)



Parameters are as in Table 1 on page 6. Furthermore, $\upsilon = \frac{1}{2}$ and $\iota = \frac{1}{3}$.

Here, we have assumed a threshold of $n_{\text{min}} = 10$. Hence whenever $n \geq n_{\text{min}}$, the issue is successful.

4.1 The Households' Pledging and Information Choice

We solve the model by backward induction. At this stage, we consider the household's information and pledging choices for given loan rate r and threshold $I_{\min}$. An informed household will always pledge its entire wealth of \$1 if his information is positive. Without loss of generality, we can assume that an uninformed also pledge its entire wealth of \$1, if it pledges at all. As a consequence, aggregate investment equals the number of pledging households. The investment is canceled if this number falls below the threshold $I_{\min}$, thus if the number of pledging households falls short of some $n_{\min}$, with $n_{\min} = I_{\min}$.

From the perspective of a single household, let P_G define the probability that a good firm has a successful issue, and P_B the probability that a bad firm has a successful issue (both under the condition that the household makes a pledge). P_G and P_B will depend on the firm's choices of r and $I_{\min}$, and on the ensuing households' choices of ι and υ in equilibrium.

If the firm is good, a household's expected return is $q_G\, r - 1 > 0$, if it is bad, the return is $q_B\, r - 1 < 0$. The aggregate expected return of a household that gets informed is

$$\Pi_i = \mu\,(1-\alpha)\,P_G\,(q_G\, r - 1) + (1-\mu)\,\beta\,P_B\,(q_B\, r - 1) - c. \tag{5}$$

The expected return of a household that pledges without information is

$$\Pi_u = \mu\ P_G\,(q_G\, r - 1) + (1-\mu)\,P_B\,(q_B\, r - 1). \tag{6}$$

The expected return of a household that does not participate at all is, of course, zero. In a mixed-strategy equilibrium, all three must be equal. Hence, we can solve for P_G and P_B,

$$P_G = \frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\, r - 1)}, \tag{7}$$

$$P_B = \frac{c}{(1-\alpha-\beta)\,(1-\mu)\,(1-q_B\, r)}. \tag{8}$$

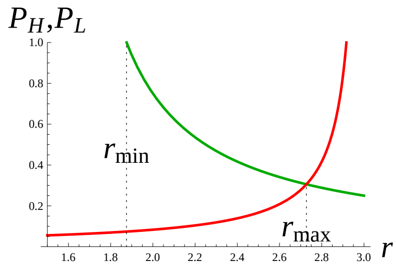
The two, P_G and P_B, are plotted in the following figure.

Here, the green curve represents P_G, the red curve P_B. The first dotted line is at the point $r_{\min}$ where P_G becomes 1, which happens at

$$r_{\min} = \frac{1}{q_G} + \frac{c}{\mu\,(1-\alpha-\beta)\,q_G}. \tag{9}$$

At this point, good firms would have to issue successfully with probability 1, which is technically impossible ($n_{\min}$ would have to become zero). In the numerical example,

Figure 2: Equilibrium Probabilities of Successful Issue



Parameters are as before (see Table 1 on page 6).

$r_{\min} = 1.875$. This number will play an important role later on. The other dotted line is at the point $r_{\max}$ where P_G and P_B are equal, which happens when

$$r_{\max} = \frac{1}{\mu\, q_G + (1-\mu)\, q_B}. \tag{10}$$

This is the loan rate a completely uninformed household would demand without crowdfunding, hence it corresponds to $\upsilon = 1$ and $\iota = 0$. It is a theoretical upper limit for r, but because we will see that the firm sets r as small as possible, it will be of no further importance.

There are a number of important properties in Figure 2. First, the probability P_G that a good firm issues successfully decreases in the loan rate r. The according probability P_B for a bad firm increases. Why? If the firm raises the loan rate r, it becomes more attractive both to pledge after getting the information, and to pledge without information. In the mixed-strategy equilibrium, households must remain indifferent. This is only possible if both informed and uninformed participation become less attractive because good firms have a successful issue with a lower probability, and bad firms with a higher probability.

The probabilities P_G and P_B can also be calculated from the binomial distributions. P_G is an auxiliary variable. It takes the perspective of a single household that has already gotten informed and wants to participate, and measures the probability that the issue is then successful (the number of participating households n_G does not fall short of the threshold $n_{\min}$). Analogously for P_B. Hence,

$$P_G = \sum_{n=n_{\min}-1}^{N-1} \binom{N-1}{n} \big(\iota\,(1-\alpha)+\upsilon\big)^n \big(1-\iota\,(1-\alpha)-\upsilon\big)^{N-1-n}, \tag{11}$$

$$P_B = \sum_{n=n_{\min}-1}^{N-1} \binom{N-1}{n} \big(\iota\,\beta+\upsilon\big)^n \big(1-\iota\,\beta-\upsilon\big)^{N-1-n}. \tag{12}$$

In both equations, the sums start from $n_{\min} - 1$, because apart from the investor ...

We have two equations for P_G, (7) and (11), and two equations for P_B, (8) and (12). This gives us an implicit set of equations for ι and υ. For given r and $n_{\min}$, ι and υ must be such that (7) = (11) and (8) = (12).

4.2 The Firm's Choice of r and $I_{\min}$

We have not yet determined whether the firm knows its own type, or not, or something in between (noisy information on its own type). The firm's choice of r and $I_{\min}$ might depend on what it knows. Let us start with discussing the first case, the firm has perfect information about its own type. Hence, as in many games with asymmetric information, the good type of firm will choose r and $I_{\min}$, and the bad type will have to follow suit, in order not to reveal its true type (otherwise, it would not get finance at all).

First, note one property. The firm will set parameters such that all households participate in some way: they either get informed (and then pledge according to their information), or pledge without information. Formally, $\iota + \upsilon = 1$. If this were not the case, the good firm would leave part of the potential investment for a positive-NPV project on the table. It could start a larger project, with economies of scale in information gathering. There, in equilibrium, we must have $\upsilon = 1 - \iota$.

A good firm's expected profit is

$$\Pi_G = q_G \,(R - r) \sum_{n=n_{\min}}^{N} p_G(n)\, n. \tag{13}$$

An decrease in the loan rate r will have a double positive effect on the good firm's profits. First, it increases the interest margin $(R - r)$. Second, we know from (7) that it increases the probability P_G that the issue is successful, which equals $\sum_{n=n_{\min}}^{N} p_G(n)$. We will later even see that an increase in r will also entail a decrease in $n_{\min}$. Therefore, the good bank wants to set the loan rate r as low as possible.

We can thus rewrite the firm's optimization problem,

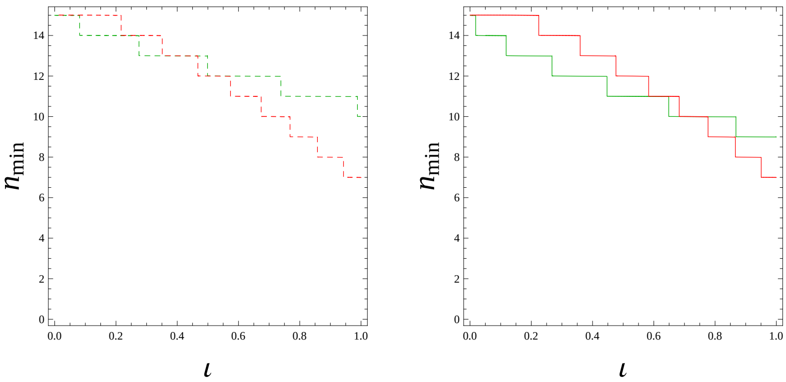
$$\begin{aligned} &\max_{r, n_{\min}, \iota} \; r \\ \text{s.t.} \quad &\frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\, r - 1)} \\ &\quad = \sum_{n=n_{\min}}^{N} \binom{N}{n} \big(\iota\,(1-\alpha) + (1-\iota)\big)^n \big(1 - \iota\,(1-\alpha) - (1-\iota)\big)^{N-n} \end{aligned}$$

and $$\frac{c}{(1-\alpha-\beta)\,(1-\mu)\,(1-q_B\,r)}$$
$$= \sum_{n=n_{\min}}^{N} \binom{N}{n} \big(\iota\,\beta + (1-\iota)\big)^n \big(1 - \iota\,\beta - (1-\iota)\big)^{N-n}. \tag{14}$$

In other words, the firm maximizes r such that the two constraints still have a solution for $n_{\min}$ and ι.

To get some intuition, let us plot the two constraints for our numerical example, for different choices of r (Figure 3).

Figure 3: Constraints on ι and $n_{\min}$ in Optimization Problem (14)



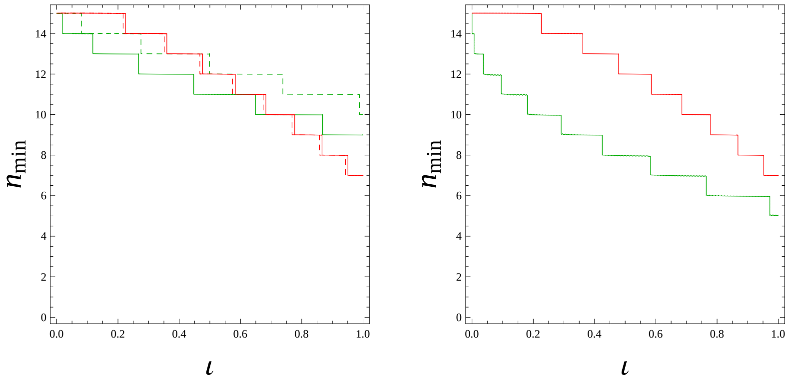
Parameters are as before (see Table 1 on page 6). In the left graph, we have set $r = 2.0$; in the right graph, $r = 1.9$. The red curve marks the combinations of $n_{\min}$ and ι where (8) = (12), i. e., the equality for the bad firm. The green curve marks combinations where (7) = (11), i. e., the equality for the good firm.

An eyeball comparison shows that the red curve hardly changes, whereas the green curve moves a bit. Let us plot both in one graph (Figure 4, left graph), to see what changes if the firm lowers the loan rate.

We see that the red curve hardly changes. The green curve moves downward. If the firm lowers the loan rate even further, the green curve moves downward even more. At some point, the green curve is so low that red and green no longer intersect. This is the case in the right graph in Figure 4, for $r = 1.8751$. From this point on, there is no combination of $n_{\min}$ and ι that satisfies both (8) = (12) and (7) = (11). Economically speaking, the firm has lowered the loan rate so much that it is no longer able to attract investors.

There is an equilibrium only as long as the curves intersect. Because of integer problems, the curves zigzag, and there is not a single intersection point, but a whole intersection region. For larger N, the zigzags become smaller, and in the limit, the curves become differentiable. The intersection region then turns into an intersection point.

Figure 4: The Constraints on ι and $n_{\min}$ in Optimization Problem (14)



In the left graph, $r = 2.0$ (dashed curves) and $r = 1.9$ (solid curves). The red curves mark points with (8) = (12), the green curves mark points with (7) = (11). In the right graph, $r = 1.8751$. Red and green curve no longer intersect.

There is one further important property. As the firm tries to lower the loan rate more and more, the intersection region (point) moves southeast. The ι increases and the $n_{\min}$ decreases. At the point where the curves intersect only just, we have $\iota = 1$ and $0 < n_{\min} < N$. Economically, this means that in equilibrium, the firm will set the interest such that it induces *all* households to get informed. Households with positive information then pledge, those with negative information do not pledge. The threshold $n_{\min}$ is set such that good firms fail in the issue with positive probability, and bad firms succeed in the issue with positive probability.

Knowing that the firm will choose r and $n_{\min}$ such that $\iota = 1$ and $\upsilon = 0$ in equilibrium, the solution is given by (14), which transforms into

$$\frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\, r-1)} = \sum_{n=n_{\min}-1}^{N-1} \binom{N-1}{n} (1-\alpha)^n\, \alpha^{N-1-n} \quad \text{and} \tag{15}$$

$$\frac{c}{(1-\alpha-\beta)\,(1-\mu)\,(1-q_B\, r)} = \sum_{n=n_{\min}-1}^{N-1} \binom{N-1}{n} \beta^n\,(1-\beta)^{N-1-n}. \tag{16}$$

The following Proposition 1 is summing up the main results of this analysis.

Proposition 1 (Equilibrium with Crowdfunding) *In equilibrium, the good firm sets loan rate r and threshold $n_{\min}$ such that all households get informed, and pledge money only if their information is positive. The values for r and $n_{\min}$ are implicitly defined by equations* (15) *and* (16)*.*

4.3 Comparative Statics

In this section, we first simplify the above (15) and (16) as much as possible. We then plot a number of numerical examples, to arrive at comparative statics. The binomial distribution has some general symmetry properties,

$$\sum_{n=n_{\min}-1}^{N-1} \binom{N-1}{n} (1-\gamma)^n \, \gamma^{N-1-n} = \sum_{n=0}^{N-n_{\min}} \binom{N-1}{n} \gamma^n \, (1-\gamma)^{N-1-n}. \tag{17}$$

Here, the second term follows from the first by substituting $n \mapsto N-1-n$ and the property $\binom{N-1}{n} = \binom{N-1}{N-1-n}$. Using this, we can rewrite the system of equations (15) and (16) to

$$\frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\,r-1)} = \sum_{n=0}^{N-n_{\min}} \binom{N-1}{n} \alpha^n \, (1-\alpha)^{N-1-n} \quad \text{and}$$
$$\frac{c}{(1-\alpha-\beta)\,(1-\mu)\,(1-q_B\,r)} = \sum_{n=0}^{N-n_{\min}} \binom{N-1}{n} (1-\beta)^n \, \beta^{N-1-n}. \tag{18}$$

Typically, N will be large, and the information will be vague (both α and β smaller than but close to $1/2$), hence by the de Moivre-Laplace theorem, the binomials can be approximated by normal distributions. In general, we have

$$\sum_{n=0}^{n_0} \binom{N-1}{n} \gamma^n \, (1-\gamma)^{N-1-n} \approx \Phi\Big(\frac{n_0-\gamma\,(N-1)}{\sqrt{\gamma\,(1-\gamma)\,(N-1)}}\Big). \tag{19}$$

In particular, this turns (18) into

$$\frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\,r-1)} = \Phi\Big(\frac{N-1-n_{\min}-\alpha\,(N-1)}{\sqrt{\alpha\,(1-\alpha)\,(N-1)}}\Big) \quad \text{and} \tag{20}$$
$$\frac{c}{(1-\alpha-\beta)\,(1-\mu)\,(1-q_B\,r)} = \Phi\Big(\frac{N-1-n_{\min}-(1-\beta)\,(N-1)}{\sqrt{\beta\,(1-\beta)\,(N-1)}}\Big). \tag{21}$$

To ease the computation, we make one further observation. In equilibrium, the loan rate r^* will be close to $r_{\min}$. For example, in our numerical example, $r_{\min} = 1.875$, and $r^* \approx 1.8753$. From (9), we see that for small c and $\mu > 0$, $q_G > 0$ and $\alpha + \beta < 1$, the equilibrium rate r^* will also be close to $1/q_G$. This implies that a change in r will have a large impact on the green curve, but not on the red curve. For practical purposes, one can approximate $r \approx r_{\min}$ in (21). This allows us to solve the system of equations recursively. (21) turns into

$$\frac{\mu}{1-\mu}\,\frac{q_G\,c}{(q_G-q_B)\,\mu\,(1-\alpha-\beta)-q_B\,c} = \Phi\Big(\frac{N-1-n_{\min}-(1-\beta)\,(N-1)}{\sqrt{\beta\,(1-\beta)\,(N-1)}}\Big),$$

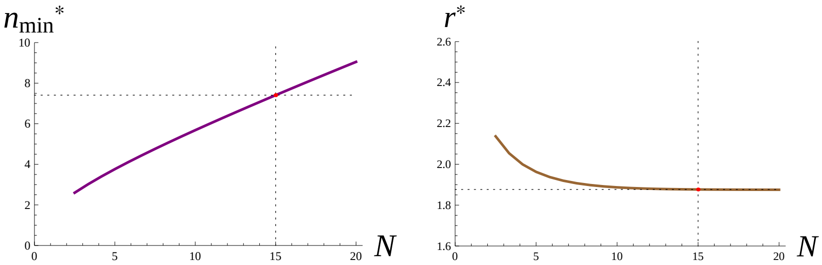
$$\frac{\beta\,(N-1)-n_{\min}}{\sqrt{\beta\,(1-\beta)\,(N-1)}}=\Phi^{-1}\Big(\frac{\mu}{1-\mu}\,\frac{q_G\,c}{(q_G-q_B)\,\mu\,(1-\alpha-\beta)-q_B\,c}\Big),$$
$$n^*_{\min}=\beta\,(N-1)-\sqrt{\beta\,(1-\beta)\,(N-1)}\,\Phi^{-1}(\cdot),\qquad(22)$$

where $\Phi^{-1}(\cdot)$ is short for the longer term above. The solution $n^*_{\min}$ can be plugged into (20), yielding

$$\frac{c}{(1-\alpha-\beta)\,\mu\,(q_G\,r-1)}=\Phi\Big(\frac{(1-\alpha)\,(N-1)-n^*_{\min}}{\sqrt{\alpha\,(1-\alpha)\,(N-1)}}\Big),$$
$$r^*=\frac{1}{q_G}\Big(\frac{c}{(1-\alpha-\beta)\,\mu\,\Phi(\cdot)}+1\Big),\qquad(23)$$

where again $\Phi(\cdot)$ is short for the longer term above. Let us start with calculating the optimal $n^*_{\min}$ and r^* in the numerical example (see Table 1 on page 6). It is $n^*_{\min}=5.741$ and $r^*=1.876$. Now, how do these solutions change when we move the parameters? In the following figures, we have changed one parameter at a time. The dotted lines and red dots always mark the equilibrium values for the original parameters.

Figure 5: Comparative Statics: The Number of Households N

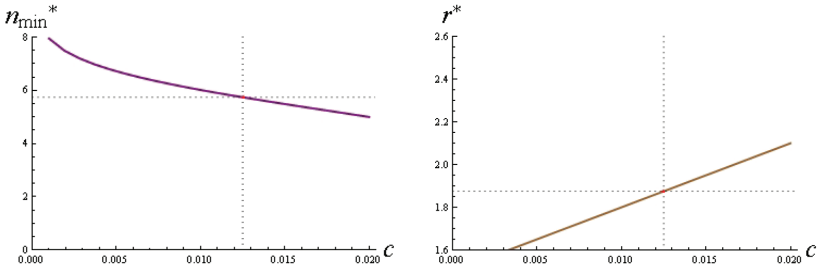


Here and in the next figures, parameters are as before (see Table 1 on page 6).

Figure 5 shows the threshold ($n^*_{\min}$, purple, left graph) and the loan rate (r^*, brown, right graph) as function of the number of households N. The two comparative statics are very intuitive. *First*, remember that in equilibrium, $\iota=1$, thus all households get informed with probability 1. Hence, the number of informed households equals the aggregate number of households N. If $n_{\min}$ would remain constant (or even fall) for increasing N, then at some point, the probability of good firms to obtain finance P_G would converge to zero. This cannot be optimal: $n^*_{\min}$ must increase in N. *Second*, because more households get informed, the probability of a bad firm to obtain finance P_B must converge to zero. Consequently, the loan rate must converge to the fair rate for a good firm, taking information costs into account. We already know this number, $r_{\min}=1.875$.

The next figure (Figure 6) shows the threshold ($n^*_{\min}$, purple, left graph) and the loan rate (r^*, brown, right graph) as function of the fraction of good firms μ. In our numerical

Figure 6: Comparative Statics: Information Costs c



example, the minimum investment $n^*_{\min}$ falls in c, but the loan rate increases in c. Again, there is a robust intuition for these comparative statics. *First*, as c increases, households must be incentivized to still gather the information, and not pledge blindly. As firms lower the threshold level $n^*_{\min}$, the probability to pledge into a bad firm increases, hence also the incentive to get informed increases. *Second*, the loan rate must compensate households for their information costs. Consequently, a higher information cost c entails a higher loan rate.

Figure 7: Comparative Statics: Fraction of Good Firms μ

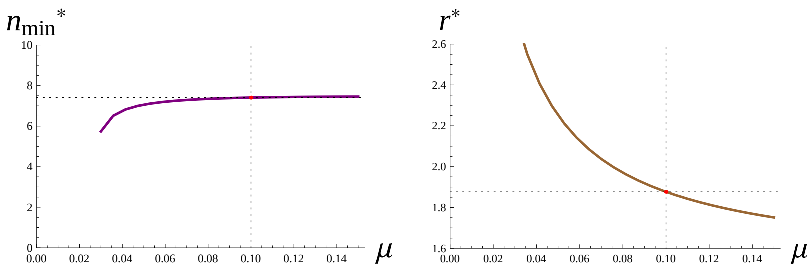
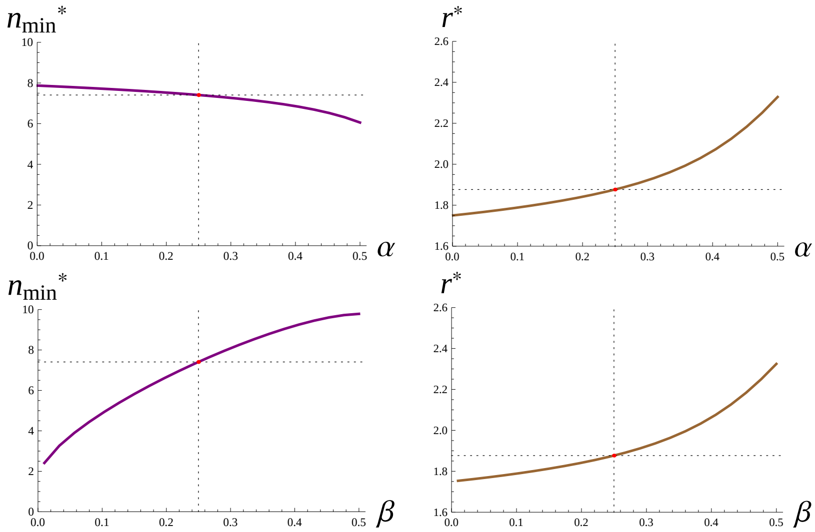


Figure 7 shows equilibrium values depending on the fraction of good firms, μ. *First*, the threshold $n_{\min}$ increases in μ. If there are more good firms, the households' confidence in their pledge is already relatively high. Firms do not need a high threshold $n_{\min}$ to induce further confidence. *Second*, the loan rate r falls in μ. Of course, if there are more good firms in the pool, firms need to offer a lower loan rate.

Finally, Figure 8 shows how equilibrium values depend on the quality of the information, that is, the α-error (first line) and the β-error (second line). The reaction of the loan rate r is the same in both cases. As households make more mistakes, the aggregate financing decision (whether the issue is successful) becomes less informed. As a compensation, the firm must offer a higher loan rate. The effect on the threshold $n_{\min}$ goes in opposite

Figure 8: Comparative Statics: α and β Error



directions. The threshold $n_{\min}$ decreases in α. With increasing α, households receive more bad information from good firms. Based on their information, more households do not pledge. Consequently, the threshold $n_{\min}$ must fall, otherwise at some point there would be no finance, even for good firms. Finally, the threshold $n_{\min}$ increases in β. With increasing β, households receive more good information from bad firms. Based on their information, more households pledge money, although the average quality of firms falls. To countervail this effect, the threshold $n_{\min}$ must increase.

4.4 Welfare

Concerning welfare, there are two possible questions. First, do firms choose crowdfunding whenever it is optimal? Possibly, firms could choose crowdfunding although standard debt finance is welfare-optimal, and vice versa. Second, given that a firm uses crowdfunding, does it set the parameters (loan rate r and threshold level $n_{\min}$) right?

Standard Debt Finance. In equilibrium, firms set the loan rate such that households only just break even. Hence, households enter the welfare function with a zero. Good and bad firms' expected profits enter into welfare. Under standard debt finance, welfare is

$$\begin{aligned} W_{\text{SDF}} &= \mu\,(1-\alpha)\,N\,q_G\,(R-r) + (1-\mu)\,\beta\,N\,q_B\,(R-r) \\ &= \mu\,(1-\alpha)\,N\,(q_G\,R-1) + (1-\mu)\,\beta\,N\,(q_B\,R-1) - c\,N, \end{aligned} \tag{24}$$

where we have substituted the r from (1).

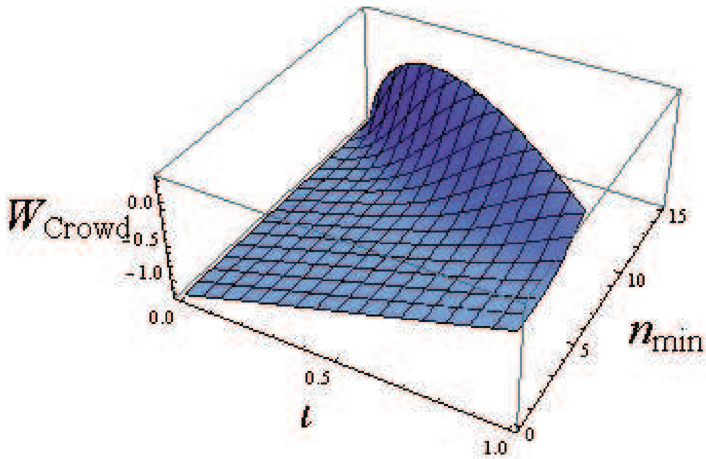
Crowdfunding. With crowdfunding, welfare is defined as

$$W_{\text{Crowd}} = \mu\, q_G\, (R - r) \Big[\sum_{n=n_{\min}}^{N} n\, p_G(n) \Big] + (1-\mu)\, q_B\, (R - r) \Big[\sum_{n=n_{\min}}^{N} n\, p_B(n) \Big] \tag{25}$$

$$= \mu\, (q_G\, R - 1) \Big[\sum_{n=n_{\min}}^{N} n\, p_G(n) \Big] + (1-\mu)\, (q_B\, R - 1) \Big[\sum_{n=n_{\min}}^{N} n\, p_B(n) \Big] - \iota\, N\, c. \tag{26}$$

Here, the first term consists of three factors, the fraction of good firms μ, the positive NPV per good project $q_G\, R - 1$, and the distribution over possible investment sizes, ranging between $n_{\min}$ and N, with the according probabilities. The second term consists of the same factors for bad firms. The third part equals the aggregate information costs. Conveniently, (26) does not depend on the equilibrium loan rate r^*. Hence, we could go ahead and plot welfare as a function of $n_{\min}$ and ι. However, a large $n_{\min}$ might be consistent only with negative expected profits for the household: if $n_{\min}$ is large, they spend the information cost c, but the issue is successful only with low probability. Therefore, we use (11) and (12) to calculate P_G and P_B for given ι and $n_{\min}$. Then, we enter these values into (5). We solve for the minimal r that still leaves informed households a non-negative profit, $\Pi_i = 0$. We then substitute P_G, P_B, and the ensuing r into (6) to check whether an uninformed household's expected profit is still non-negative. Only in that case, the combination of $n_{\min}$ and ι is feasible. Figure 9 shows welfare in this feasible region.

Figure 9: Welfare



We see that welfare is maximized at the border, which implies that $\Pi_i = 0$ and $\Pi_u = 0$. To be precise, in the numerical example, the welfare-optimal point has $n_{\min} = 9.2852$ and $\iota = 0.7099$. The according loan rate is $r = 1.895$. In equilibrium, the firm makes a different choice ($n^*_{\min} = 5.741$, $\iota = 1$, and $r^* = 1.876$). Hence, the firm sets the loan rate r too low, and the threshold $n_{\min}$ too low, inducing too many households to get informed.

There is a robust intuition for this result. A firm chooses r and $n_{\min}$ such that in equilibrium, all households become informed ($\iota = 1$). From a welfare perspective, this may not be optimal (depending on parameters): the marginal benefit of another piece of information gets very small for large N. Hence, in the welfare optimum, we may have $\iota < 1$, such that a positive expected number of $\upsilon = 1 - \iota$ households participates without any information. Now a smaller fraction of informed households implies that more bad firms obtain finance. Consequently, the loan rate r must increase. And because some households make a pledge although they have no information, the critical $n_{\min}$ must also increase (otherwise, too many bad firms would obtain finance).

Crowdfunding by Uninformed Firms. We have assumed that a firm knows its own type. In reality, this may not be the case. For example, a computer game designer may not know how large the demand for his game will be later on. Looking at (25) reveals that, due to the binding participation constraint of households, welfare equals exactly the expected profit of a firm that does not know its own type. A number of results follows immediately from the welfare analysis.

- An informed firm sets a lower loan rate than an uninformed firm.
- An informed firm sets a lower threshold level $n_{\min}$ than an uninformed firm.
- An informed firm induces households to gather more information (ι) than an uninformed firm.

Especially the third point may seem counterintuitive, but it makes sense from a financial perspective. If the firm knows it is good, it wants the market to know, hence it wants the information to be as precise as possible. That way, it obtains a low loan rate, and very few bad firms obtain finance. If the firm does *not* know its type, it takes into account it may be a bad firm. Hence, it takes into account the positive expected profits that bad firms make when they obtain finance. Consequently, in interior level of information gathering ($\iota < 1$) may be optimal for an uninformed firm. The following proposition wraps up these results.

Proposition 2 (Optimality of the Crowdfunding Parameters) *From a welfare perspective, a good firm sets interests rate r and the threshold $n_{\min}$ too low.*

5 Conclusion

In the paper, we have presented a microeconomic model in which crowdfunding arises endogenously. In our model, the benefit does not come from tapping the crowd (this could also be achieved by bank finance, where the bank "taps" its depositors, or by market finance). The benefit of crowdfunding stems from tapping the information of the crowd. Many households have tiny pieces of personal information. They know whether they might like a product or not. But that is exactly the information that is necessary in the financing decision: will consumers like the firm's future product?

The crucial feature of crowdfunding is not that it uses the internet, or some networking platform (that just helps to reduce transaction costs). The fact that the funding does not proceed if the pledged volume falls short of some threshold is crucial. Due to this feature, households participate even if they can assess the firm's product's future success only vaguely. They know that they will participate only if many many households have positive information. In that case, this multitude of vague hunches accumulates to a relatively precise aggregate information.

Our welfare analysis has shown that crowdfunding is used too much, and parameters (loan rate and the threshold) are not set right. There is one single reason: the good type of firm makes the decision, and it does not take into account the negative externality on the bad type.

To concentrate on basic effects, we have kept the model as stylized as possible. There are a number of important extensions that we will discuss in a follow-up paper. *First*, we have discussed only crowdfunding in the form of debt, where the participants grant a loan to the firm. In reality, there are four relevant forms of crowdfunding: debt-based, equity-based, rewards-based and donation-based. We want to endogenize the firm's decision especially between the first three (donation-based would probably require a model with non-standard utility functions).

Second, given that crowdfunding is used mostly by firms that produce consumption goods, especially cultural goods like movies, computer games, fashion and the like, the households' information may be influenced by fads. We want to analyze whether crowdfunding is more susceptible to fads than conventional finance.

Third, in our model, the firm used a crowdfunding platform that made zero profits. In reality, there are many crowdfunding platforms, but not infinitely many. Some consolidation is under way. As of April 2012, the top five platforms accounted already for 95% of the total funds raised in Europe and 73% of the total funds raised in North America.[6] Arguably, crowdfunding may be a natural monopoly due to network externalities, just like online auction websites (eBay), search machines (Google) or online retailing (amazon.com). If that is the case, after the consolidation has come to an end, the winner will start to charge higher fees from firms. We want to analyze how our results change with a monopolistic crowdfunding platform. Especially the welfare results may be interesting. In the current paper, crowdfunding is used too much. With a monopolistic platform, welfare may thus increase.

Summing up, our paper has integrated crowdfunding into the literature that sees finance as a gatekeeper. Given the recent development of crowdfunding, it is important to have some good theory on what is going on, and why. Given the simplicity of the model, the door for fruitful extensions is wide open.

A Appendix

Alternative Settings under Standard Debt Finance We have already analyzed the case where all firms offer the same loan rate, all households get informed, and accept the offers only from the firms on which they have positive information. This is a pooling equilibrium.

Let us now discuss a semi-separating equilibrium where some bad firms "admit" that they are bad by offering a higher loan rate r_B. That way, they attract a higher loan volume, at the downside of paying a higher loan rate. In equilibrium, they will make the households' participation constraint bind, $q_B\, r_B - 1 = 0$, thus $r_l = 1/q_l$. There are two more conditions. The participation constraint will bind also for the lower loan rate,

$$\mu\,(1-\alpha)\,(q_G\, r_G - 1) + (1-\mu)\,\beta\,\theta\,(q_B\, r_G - 1) = 0, \tag{27}$$

where θ is the probability that a bad firm "cheats" and offers only a low loan rate. Furthermore, in a mixed-strategy equilibrium, bad firms must be indifferent between offering r_G and r_B,

$$q_B\,(R - r_B) = \beta\, q_B\,(R - r_G). \tag{28}$$

[6] http://www.forbes.com/sites/suwcharmananderson/2012/05/11/crowdfunding-raised-1-5bn-in-2011-set-to-double-in-2012/

Solving these equations for r_G yields

$$r_G = \frac{1}{q_B} - \frac{1-\beta}{\beta}\, R. \tag{29}$$

Substituting this loan rate into the good bank's profit function yields

$$\Pi_G = (1-\alpha)\, p_G\, (R - r_G) = \frac{q_G}{q_B}\, \frac{1-\alpha}{\beta}\, (q_B\, R - 1). \tag{30}$$

Obviously, a positive NPV for the bad project is a necessary condition for the existence of this equilibrium. Otherwise, even the good bank would make a negative expected profit, and would prefer not to make an offer at all.

Next, there is a pooling equilibrium where all firms offer the same loan rate, but households to not get informed. In this case, the households' participation constraint defines the equilibrium loan rate,

$$\begin{aligned} 0 &= \mu\, (q_G\, r - 1) + (1-\mu)\, (q_B\, r - 1), \\ r &= \frac{1}{\mu\, q_G + (1-\mu)\, q_B}. \end{aligned} \tag{31}$$

The ensuing expected profit for a good firm is

$$\Pi_G = p_G\, (R - r) = p_G\, Big(R - \frac{1}{\mu\, q_G + (1-\mu)\, q_B}\Big). \tag{32}$$

Finally, or course, there is an equilibrium with no lending at all, and zero profits for all firms.

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