Co-Utility: Conciliating Individual Freedom and Common Good in the Crowd-based Business Model

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Abstract— **We analyze the application of the notion of co-utility, a new concept describing self-enforcing and mutually beneficial interactions among self-interested agents, to the crowd based business model. Based on the definition of co-utility amenable games, we show that the crowdsourcing market is naturally co-utile without additional incentives. Furthermore, we analyze the equity crowdfunding industry and propose solutions that can neutralize the *fear* and *mistrust effects* underlying its market in order to make it strictly co-utile.**

Keywords- Asymmetric Information; Bayesian Game; Co-utility; Crowdfunding; Crowdsourcing

I. INTRODUCTION

In this paper, we analyze the crowd based business model in the light of the co-utility notion. The core idea behind this novel concept and analysis is to design interaction protocols among agents that conciliate their selfish and rational choices with societal welfare. Hence, in this paper, we aim at applying this concept to two well-known crowd-based business models: crowdfunding and crowdsourcing. Strategic decision making embodied in the rational behavior of the human nature is at the core of game theory. Along this line of thought, we augment utilitarianism with co-utility to consider the mutual benefit of the agents [3]. Specifically, we focus on a specific class of Bayesian games called co-utility amenable games. In such games, we model incentive mechanisms that do keep the business models of the collaborative economy efficiently stable.

The rest of this paper is organized as follows. Section 2 presents related works. In Section 3, the co-utility concept is discussed. Then Section 4 presents case studies focused on crowdsourcing and crowdfunding. Finally, Section 5 summarizes conclusions and directions for further work.

II. LITERATURE REVIEW

Literature on crowdfunding state that, in addition to fund-raising, crowdfunding is used by entrepreneurs/ requesters to demonstrate/estimate the demand for a proposed product (hence operating as a signal for the traditional form of funding), to receive validation, to replicate successful experiences, to pre-sell and introduce a new product (marketing purposes), to create interest in new projects in their early stages of development, etc. ([4] and [6]). On the other hand, these authors also identified the motives for funders to participate in this market as seeking rewards, supporting entrepreneurs, engaging and contributing to a trusting and creative community. Like in crowdfunding, players in crowdsourcing also have heterogeneous motives for participation [8].

III. CO-UTILITY

Co-utility can be viewed as an extension to the utilitarian theory with a basic moral foundation. It is a new concept in which the best way of serving one's own interest is to help in one or more other peers' interest fulfillment. Hence, co-utility promotes the interest of all in maximizing pleasure/satisfaction or minimizing pain/suffering in a harmonious way. In co-utility, the interests of the individual agents in their interaction can be symmetric or not. In the latter case, the agents will still have complementing goals.

In a recent work, the authors of [3] defined a *co-utility amenable game* as a sequential Bayesian game G for n agents such that the utility of any agent is independent of the types of the other agents, i.e., $\forall i,j$ with $i \neq j$ and $\forall t_i$ $t_i' \in T_i$, one has $u_j(s_1,\dots,s_n,t_1,\dots,t_i,\dots,t_n) = u_j(s_1,\dots,s_n,t_1,\dots,t_i',\dots,t_n)$, where $(s_1,\dots.s_n)$ is the strategy profile of agents, T_i is the set of types of agent i, and u_j is the utility for agent j.

Thus, co-utility amenable games are those in which the utility of one agent does not depend on the types (private preferences) of the other agents. With a Bayesian rationality assumption of incomplete information games, each agent optimizes her own expected payoff/utility by her subjective probabilities about the behavior of the rest of the agents. Yet the above definition implies a type-independent rational choice by the individual agents, even if there is information asymmetry between two or more different agents. Given a co-utility amenable game, a self-enforcing protocol (sequence of strategic choices by agents from which no rational agent has interest to deviate) can be designed that yields a *strictly co-utile* outcome, one in which all the agents derive optimal utility, or a *relaxedly co-utile* outcome, one in which at least one agent derives maximal satisfaction and all the rest obtain a reasonably positive level of satisfaction.

Formally stated, a self-enforcing protocol P for a co-utility amenable game G among n agents is *strictly co-utile* if an outcome $(s_1, \dots, s_n)$ of P exists such that $\exists t_1 \in T_1, \dots, \exists t_n \in T_n$, $\forall i \epsilon \{1, \dots, n\}$, $\forall s_i' \in S_i$, it holds $u_i(s_1, \dots, s_n, t_1, \dots, t_n) \geq u_i(s'_1, \dots, s'_n, t_1, \dots, t_n)$, where S_i is the set of possible strategies of agent *i;* thus, strict co-utility implies optimal utility for both the players. On the other hand, *P* is a *relaxedly co-utile protocol* if an outcome $(s_1, \dots, s_n)$ of P exists such that $\exists t_1 \in T_1, \dots, \exists t_n \in T_n$, and $\exists i \epsilon \{1, \dots, n\}$, such that $\forall s_i' \in S_i$, it holds that $u_i(s_1, \dots, s_i \dots, s_n, t_1, \dots, t_i, \dots, t_n) \geq u_i(s_1, \dots, s'_i, \dots, s_n, t_1, \dots, t_i, \dots, t_n)$; thus, relaxed co-utility implies that at least one of the agents has maximal utility. See [3] for more details.

In the games that operate sub-optimally, we can achieve better results by changing the rules of the game for strict co-utility or at least relaxed co-utility. However, there are situations in which relaxed co-utility also fails to hold (for e.g. games that incorporate some element of competition between players). A protocol for co-utility amenable games can be naturally co-utile (without added incentives), or can be made co-utile by adding appropriate incentives.

IV. Demonstrative Examples of Co-Utility Amenable Games

In the case studies that follow, we model the crowd-based markets as co-utile protocols. More specifically, we show that crowdsourcing is naturally co-utile and we examine to what extent crowdfunding can be made co-utile through artificial incentive mechanisms.

A. Case Study I: Crowdsourcing

Crowdsourcing means outsourcing a task to an anonymous group of self-interested individuals by means of an open call to the crowd offering rewards for work. Given a crowdsourcing platform and a vector *U* of agents' utility functions, there exists a co-utile protocol with respect to *U*, which is mutually beneficial for worker and requester. Co-utility in this market is viable provided that the goals of requester and worker are complementary and the qualification type of the worker matches the task. Based on this specification, we define the respective utility function for each agent as follows.

Worker's utility function

The utility worker i gets by performing task *T* through crowdsourcing is given by:

$$u_i(\mathcal{T}, e) = f_i(\mathcal{T})[\alpha_i r_i(e) - c_i(\mathcal{T}, e)] \qquad (1)$$

where the actions available to the worker are to participate or not; $f_i(\mathcal{T})$ is a binary function that specifies whether or not task $\mathcal{T}$ matches worker $i's$ interest and qualifications (ability); $f_i(\mathcal{T})=0$ means worker i is not interested or not qualified to perform the task; $f_i(\mathcal{T})=1$ if worker i is qualified and willing to exert effort towards this task; e is the level of effort to perform the task; $r_i(e)$ is the expected reward to worker i for effort e; α_i is a weight variable reflecting how much the individual values the reward; and $c_i(\mathcal{T}, e)$ is a task-specific cost of effort to worker *i*.

From the above utility function, if $f_i(\mathcal{T}) = 0$, worker i will not exert effort to perform this task even if he values the reward associated with the task. Since he does not participate in the sourcing, he derives no utility with regard to this task. On the other hand, if $f_i(\mathcal{T}) = 1$, worker i obtains some return which will lead him to deriving utility or disutility depending on his expected return, on how he values the associated return and other underlying factors. The participation decision of an individual entails a trade-off between labor-leisure choices (neoclassical model of labor supply). Hence, there should be a reasonable incentive scheme influencing the worker's participation. In this setup, we assume $c(\mathcal{T}, 0) = 0$ implying that, if no effort is exerted, there is no cost to the worker. Given the utility function and the rationality assumption, worker i participates in the crowdsourcing market if $u_i(\mathcal{T}, e) > 0$ and $u_i(\mathcal{T}, e) > u_i(l)$, where l stands for leisure; otherwise he refuses the offer and does not participate.

Requester's utility function

Consider the monetary reward-based crowdsourcing. The goal of the requester is to maximize her expected utility, $Max\ u(\pi)$ of completed work. Here, we assume, for simplicity, that all requesters have identical utility and production functions; output is a function of only labor; rewards are identical; and cost and amount of effort exerted by the crowd workers is unknown to the requester. A requester faces the choice between sending an online request to the anonymous crowd and relying on an off-line traditional employee. Thus, the available actions for the requester are to request to the crowd or not to request. The utility function of requester j can be formulated as:

$$u_j = u_j(\mathrm{y}, \mathrm{w_j}, \mathrm{Crd}, \mu_j, \mathcal{T}) = \alpha_j(\mathrm{y} - \mathrm{w_j}\mathrm{Crd}\text{-}\mu_j(\mathcal{T})) \qquad (2)$$

where α_j is a weight variable reflecting how much the requester values the overall gain from the output; $\mu(\mathcal{T})$ is the minimum threshold she expects to gain from the task accomplishment; y stands for the total output by the crowd workers; Crd stands for the crowd labor supply; w_j is the per task pay offered by requester j.

Note that, when a worker who exerts low effort (shirks) is hired, requester *j* considers the cost to be both wage and disutility from hiring a shirking individual. Hence, we assume that the utility function u_j accounts for the posteriorly disclosed behavior of the individual reflected by the quality or quantity of the output produced. A rational requester who wants a task $\mathcal{T}$ to be performed will post it to the anonymous crowd only if $u_j(\mathrm{y}, \mathrm{w_j}, \mathrm{Crd}, \mu_j, \mathcal{T}) > 0$.

Therefore, based on the utility functions we defined above and the incentive scheme underlying the market, we see that both agents (worker and requester) maximize their respective utilities by taking part in this market. Since this does not depend on the private types of the agents, we can say that strict co-utility is achieved.

B. Case Study II: Equity Crowdfunding

Crowdfunding can take the form of donation crowdfunding (also known as reward-based crowdfunding) or investment crowdfunding (also known as equity crowdfunding). To analyze the equity crowdfunding market and model the respective utility functions for investor and entrepreneur, we take into account the investment decision model under financial market imperfection with asymmetric information [7]. However, unlike Romer [7], who modeled the traditional form of investment, we also consider here a case in which the crowd investor may end up with negative returns (loss of the principal invested plus verification costs) which is an extreme scenario in case the crowdfunded project fails or happens to be a fraud.

Problem Formulation

Assume that an entrepreneur has a creative project to be posted on one of the online platforms for crowdfunding. Let us further consider the following assumptions: Being the owner of the project, the entrepreneur has much more information about her investment project (return, actual output, risk, actions of the entrepreneur, etc.) than the potential crowd investors; the investor incurs a verification cost α to gather enough information on the project details to make an investment decision; this verification cost is assumed to be compensated by the entrepreneur (see [8]); the project financing wholly relies on crowdfunding (it is a special case of Romer's financial markets imperfections analysis [7], we here assume the entrepreneur's wealth invested in this project is zero) and has an expected output of γ, which might be different from the actual output, y; there is large number of crowd investors and there exists competition among them; the investors are risk-averse; entrepreneurs in online platforms also are risk-averse towards publicizing creative projects to the anonymous crowd for fear of being copied.

Given the pre-stated assumptions, investor i 's and entrepreneur j's expected return will respectively be:

$$E(R_i) = (1 + r)C_i + \alpha_i \quad (3)$$

$$E(R_j) = \gamma - [(1 + r)C + \alpha] \quad (4)$$

where C is the total invested amount (by all investors); C_i is the amount invested by individual investor i; α is the total verification cost (by all investors); and α_i is the verification cost incurred by investor i. The entrepreneur becomes indebted to reward the investors with the expected return. Hence, the entrepreneur's optimal strategy is the one that minimizes the verification cost, given their respective basic returns, at some critical level of debt to the entrepreneur, D. Assume that returns are uniformly distributed and the maximum possible level of output is γ^*. Given the agreed upon amount of return D, the entrepreneur is indebted to satisfy that amount without any verification cost by the crowd, and takes the surplus with probability: $\pi = (\gamma^* - D)/\gamma^*$. Unlike the traditional form of investment, this form of investment may end up with zero return and, hence loss to investors even if they pay the verification cost α with probability $(1 - \pi)$.

Crowd Investor's Funding Decision

The expected net returns to the investor (crowd) under this debt contract with the competitive and risk of project failure assumptions will be a function of D given as:

$$E(R_i) = \pi x_i D + (1 - \pi)[-(1 + r)C_i - \alpha_i] \quad (5)$$

where, $x_i$is the proportion of investor i's investment to the project, $\sum_{i=1}^{n} x_i = 1$ and $D_i = x_i D$. From (5), we get that the net return R_i is optimal for $D = \frac{\gamma * -(1+r)C_i - \alpha_i}{2x_i}$. The investment decision of the crowd depends on expected net return of the project, $E(R_i)$. Therefore, investor i takes part in crowdfunding of the project if and only if the required net return, $(1 + r)C_i$, is not more than the optimal expected net return, R_i*. This implies that, in order for her to invest in the project, her return for investing in that project should, at least, match the return of investing in a safe asset. Otherwise, if the latter return is greater than R_i*, she does not take part in the project at any interest rate, r.[1]

The set of actions available to a potential investor i are to invest or not to invest. The utility function of an individual who potentially might take part in the crowdfunding can be formulated as a function of return: $u_i = u(R_i)$. Given the debt contract, D and x_i , if the probability that the project pays the expected return is large enough, close to one and hence $R_i > 0$, then the underlying investment decision depends on the utility a potential investor might derive from this level of return, given the required rate of return. Assuming a classical negative exponential utility function, utility of return for a risk-avert crowd investor with imperfect information can be presented as:

$$u(R_i) = -e^{-\beta_i R_i} \quad (6)$$

where $\beta_i > 0$ is the risk aversion factor for investor i (we assume that investors have different risk-averseness based on their level of information, experience with such investment, invested amount, their income, etc.).

Hence, for $R_i > 0$, $u'(R_i) = \beta_i e^{-\beta_i R_i} > 0$ and $u''(R_i) = -\beta_i^2 e^{-\beta_i R_i} < 0$, where $u'(R_i)$ and $u''(R_i)$ are the first and second derivatives of the utility function w.r.t. return, respectively, fulfilling the properties of non-satiation and risk aversion. Furthermore, this utility function exhibits a property of constant absolute risk aversion and invariant risk in absolute money terms [2].

The investor who is maximizing her expected utility of return invests in the project if she derives positive utility from the funding $(u_i > 0)$, and $u(R_i^*) \geq u_i((1 + r)C_i))$.

[1] This is a so called credit rationing scenario (see [7], who has presented the analysis for the traditional investment financing with risk neutral investors).

That is, if the utility she derives by investing in that project is, at least, as high as the utility she would obtain with a safe asset. With the above formulation, if $\pi \approx 1$, $E(R_i) \approx x_i D$. Then $u(R_i) \approx -e^{-\beta_i x_i D}$ and at the optimal return, R_i^*, $u(R_i^*) = -e^{-\beta_i \frac{\gamma* - (1+r)C_i - \alpha_i}{2}}$. If $\frac{\gamma* - (1+r)C_i - \alpha_i}{2} \geq (1+r)C_i$, then $-e^{-\beta_i \frac{\gamma* - (1+r)C_i - \alpha_i}{2}} \geq -e^{-\beta_i (1+r)C_i}$ by the non-satiation assumption of the utility function, where $u(m+1) > u(m)$, for any money return, m .Therefore, keeping all other factors constant, a risk-averse investor takes part in the crowd investing at the optimal debt contract when deriving higher utility as compared to a safe asset. But if $R_i^*(D) < (1+r)C_i$, say $(1+r)C_i/2$, then $-e^{-\beta_i (1+r)C_i/2} < -e^{-\beta_i (1+r)C_i}$ for $\forall$ r $\in (0,1)$ and $C_i > 0$. Hence, the individual i does not invest (does not take part in the crowdfunding) since it derives less utility by investing at any interest rate *r*. Another interesting scenario is the case in which the investor might end up with negative returns, $R_i < 0$, in case of failure of the project or fraud. A risk-averse investor also tries to avoid this scenario from her investment decision, reflected in the *mistrust effect* which we will discuss later in this paper.

Entrepreneur's Investment Decision

Suppose that if the project idea is sold to some buyer, it can be valued at a value V and if the project idea cannot be transferred to any buyer, then V will be zero. The entrepreneur has a choice to either run the project through crowdfunding with a net expected return of $\gamma - [(1+r)C + \alpha]$ or refrain from resorting to crowdfunding. Here, to avoid complications with more options of traditional investment, we assume that if the project is profitable to run, the entrepreneur prefers to run the project through online funding (see [4] and [6] for such motives of entrepreneurs).

The available actions for the entrepreneur *j* are to request crowdfunding or to refrain from doing so. Hence, the entrepreneur broadcasts the project for public funding if the net return $\gamma - [(1+r)C + \alpha] > V$ given that $(1+r)C \leq R^*$ from the investors' point of view. Due to the *disclosure fear effect* that we will later discuss, the entrepreneur also is risk-averse towards her project being funded through the anonymous crowd. Therefore, assuming our previous risk-averse investor's classical negative exponential utility function, the entrepreneur's utility function can be formulated as:

$$u_j(C, r, \gamma, V) = -e^{-\beta(\gamma - (1+r)C - \alpha - V)} \quad (7)$$

where $V \geq 0$ and $\beta > 0$ is a risk aversion coefficient for the entrepreneur.

A rational entrepreneur broadcasts her project to the crowd if the utility derived from this project is positive, and $u_j(C, r, \gamma, V) \geq u_j(V)$. That is, the entrepreneur goes for crowdfunding for her project if the utility she derives by running the project through seed money financing from an anonymous crowd is, at least, as high as the market value of her project idea, *V*, when sold to some buyer. More generally, if the expected return paid to the outside investors does not result in credit rationing and if the expected net returns to her are higher than what she can earn by refraining from running the project (opportunity cost of investment).

Disutility: The Fear and Mistrust Effects in the Equity Crowdfunding Market

From the discussion above, we see that the crowdfunding market is a co-utility amenable game, because the utilities of the players are independent of the other players' types. However, some practical issues arise which result in negative utilities that deter an individual investor or entrepreneur from taking part in this market. Apart from the net return based investment decisions illustrated in the formulation above, some other factors might discourage the participation of each agent in the industry.

One of the main deterring factors is *mistrust by funders* regarding possible frauds. Funders want to be sure that their investment goes to the right project and they want to be guaranteed the promised return. From the entrepreneur's point of view, *fear of failure, imitation or plagiarism with full content disclosure* (loss of intellectual property) are deterring factors for crowdfunded ventures [1]. This element of fear on the side of entrepreneurs affects the extent they could freely signal quality and preparedness of their project idea to the general public. As a result, the entrepreneur faces a trade-off between a need of raising capital and threat of their idea being copied by other market participants [7].

In order to capture the effects arising from the above disutilities, let us formalize the utilities of investors and entrepreneurs taking them into account. The utility function for crowd investor i, u_i, accounting for the mistrust effect, assuming a negative exponential utility function, is redefined as:

$$u_i(R, \Gamma) = \begin{cases} -e^{-\beta_i \Gamma R} & \text{for } \Gamma \neq 0 \\ 0 & \text{for } \Gamma = 0 \end{cases} \quad (8)$$

where Γ is the variable for trust taking values in the interval between $[0,1]$ where the boundaries are defined as 1 (if the potential crowd investors completely trust the entrepreneur that the project rewards the expected return) and 0 (if the potential crowd investors do not trust the entrepreneur at all). Hence, with no trust on a given project (case $\Gamma = 0$), a potential investor does not take part in the crowdfunding of the project, because she obtains no utility from it.

Likewise, the utility function for entrepreneur, *j*, accounting for the *fear of disclosure effect* is redefined as:

$$u_j(C, r, \gamma, V, \mathcal{F}) = \begin{cases} -e^{-\beta \mathcal{F}(\gamma - (1+r)C - \alpha - V)} & \text{for } \mathcal{F} \neq 0 \\ 0, & \text{for } \mathcal{F} = 0 \end{cases} \quad (9)$$

where $\mathcal{F}$ stands for the fear of content disclosure (loss of intellectual property or being copied), and it takes values between $[0,1]$; $\mathcal{F} = 1$ if the entrepreneur can broadcast her project content with no fear of being copied by others and no other project-related fear (e.g. failure), and $\mathcal{F} = 0$ if the entrepreneur is in complete fear of broadcasting her project content (there is no utility for her in broadcasting the project).

Proposed Mechanisms to Keep the Equity Crowdfunding Market Strictly Co-utile

To keep the equity crowdfunding market strictly co-utile, we provide the following solutions that neutralize the disutility arising from mistrust by investors and fear of intellectual property loss or other project related fear by the entrepreneur. Firstly, the entrepreneur should be guaranteed protection for her intellectual property that does not depend on any legal common framework accepted by all investors (protection should be self-enforcing if we want to achieve co-utility). To do so, any individual entrepreneur before publicly broadcasting her idea should encrypt it and secure the private key with a decentralized timestamp[2] where an individual hash tag is generated for each project description in a common basket for all the projects running in a specific platform. Secondly, we introduce a reputation mechanism to rate entrepreneurs and mitigate mistrust by investors.

There is evidence that funders in crowdfunding respond to signals about the quality and creditworthiness of the project, regardless of their expectations for financial return [6]. Signaling can be through peer ratings or general public ratings. Further, we consider a reputation mechanism in which heads of a special interest team can signal to projects upon a stimulation fee. We assume that an individual can form a team and be a head of her team and there can be varied teams of different nature and interests within the market. An entrepreneur can broadcast her project idea individually or join a team for a signaling effect. Any individual investor who is interested in any of the teams will join the team to avoid the risk of failure with a membership fee which is proportional to her individual investment capacity. An entrepreneur who wants a signaling effect from such team leaders pays a stimulation fee for the signaling effect of the head. The key role of the head in this transaction is to bear the risk of failure, with an insider view assumption, through signaling of a potentially promising project. The head issues protection notes to the members in that it guarantees potential investors (team members who are supposed to pay continual membership fee) to be paid some percentage of their invested amount as compensation in case of failure of a wrongly signaled project. Furthermore, the signaling also has a spillover effect for other potential investors who are not members of the team.

In order to avoid the project idea being leaked or overtaken by the head, the entrepreneur provides a redacted document, with key content being reasonably suppressed. When the project is broadcasted for crowdfunding, the head pledges some amount of money, which will be issued in the form of convertible notes, signaling the trustworthiness and value of the project. In doing so, she takes into account the net gain she draws from the investment. Her return from signaling investment depends on the level of risk she takes, which in turn depends on the level of creditworthiness of the project provided the level of generalized information in the redacted document and other detailed information including the personnel qualifications and general public rating. A rational head aims at maximizing her gain by minimizing the possible risk arising with the failure of the project. The protection note issued is some percentage of the purchased share. The possible loss by the investor who is a member of the team in case of failure of the project will be reduced to the interest, unrecovered proportion of the loan and the time value of money. Therefore, when responding to the signaling effect of the head, investors should take into account the possible scenarios in which the entrepreneur really signals a potentially promising project.

If a potential investor would like to convert her invested amount C_i into a share, the outstanding balance of the loan is automatically converted to equity at a discount rate d. In this case, she will have a greater share amount of $\frac{dC_i}{p-dp}$ over a new individual investing the same amount of money at price p at the valuation of a later funding round, in addition to the expected return on equity. The total return to the head will be the principal C_i, the interest on the invested amount, the service charge for membership to the group β_i, the stimulation fee for the signaling effect and risk taken by the head (takes in two forms, fixed rate of pre-payment, β_s, followed by upon-fulfillment fee which is some percentage of the pledged amount by the head, η, and total money for the protection note, γ, with the probability of success $1 - \pi$). Mathematically,

$$\beta_i + \beta_s + (1-\pi)\left[\gamma + C_i(1+r) + \eta + \frac{d\,C_i}{p-dp}\right] + (\pi)[-\gamma - C_i(1+r)]. \quad (10)$$

As long as the project to invest in is successful through the signaling effect, all the parties (investor, head, and entrepreneur) benefit, thus making it co-utile. Furthermore, in order to avoid false signals from their investment decisions, there should be a clearly cut criterion that filters reasonable signaling with a sufficiently large share of investment by the head (*sufficient skin in the game* [4]).

In case of systematic signaling to a potentially failing project, a total sum of membership fees and equivalent compensation for upon-success return, over her initial signaling investment, C_i, $\beta_i + \beta_s + (1-\pi)\left[\gamma + \theta + \frac{dC_i}{p-dp}\right]$ should outweigh the potential loss (where $\theta = C_i r + \eta$ is some percentage of the total pledged loan by the head). Here, the likelihood of failure of the project is assumed to be known by the head with an insider view assumption,

[2] Refer to the decentralized timestamp mechanisms in crypto currencies like Bitcoin.

while it is unrevealed to the other investors. A potential investor incurs loss by investing in an unsuccessful project with probability of failure π, if the net return in a simplified form is negative. That is,

$$(1-\pi)[C_i(1+r)+\frac{d\,C_i}{p-dp}]-C_i < 0. \quad (11)$$

This is a sufficient condition for a project that fails to reward the investors for sure. In other words, for any project with negative return, the head systematically signals only if the potential gain upon her initial investment level C_i and signaling service fees is greater than the loss incurred. This implies that the net gain from signaling should be greater than the net loss she might incur by signaling:

$$\beta_i+\beta_s+(1-\pi)[\gamma+\theta+\frac{dC_i}{p-dp}] > (1-\pi)[C_i(1+r)+\frac{dC_i}{p-dp}]-C_i. \quad (12)$$

Solving for C_i, we find that $\beta_i+\beta_s+(1-\pi)[\gamma+\theta] > -C[\pi(1+r)-r]$. Note that, in case of failure of the project, $(1-\pi)[C(1+r)+\frac{d\,C(1+r)}{p-dp}]-C$ is negative. Hence, provided that C>0, then $\pi(1+r)-r > 0$ for any project resulting in loss to potential investors, ($\forall\pi > \frac{r}{1+r}$). Therefore,

$$C_i < \frac{\beta_i+\beta_s+(1-\pi)(\theta+\gamma)}{\pi(1+r)-r}. \quad (13)$$

Hence, given the probability of failure for the project, π, a profit maximizing head signals to the project if and only if the required signaling share she is supposed to buy is less than her upper optimal boundary of share, $\frac{\beta_i+\beta_s+(1-\pi)(\theta+\gamma)}{\pi(1+r)-r}$. For example, when the head knows that the project is not promising, $\pi=1$, then $C < \beta_i+\beta_s$, to at least help issue the protection note and gain from the service charge for both the stimulation and service charge to the mass investor in her team. Note that the above equation holds under the assumption that there is some fear of failure of the project and probability of failure cannot be zero.

Therefore, given the online platforms facilitating the equity crowdfunding industry, and the artificial incentives we propose, there exists a co-utile protocol with respect to the respective utility functions of the agents which is mutually optimal at a predefined optimal debt contract through the convertible notes.

V. Conclusions and Future Work

In this paper, we have shown that two well-known business models of the collaborative economy, crowdsourcing and equity crowdfunding, are co-utility amenable games. The paper contributes to the literature of crowd-based business models with its analysis through the novel concept of co-utility, which has a potential for extension to other co-utility amenable games beyond these business models. We considered uniform distribution of returns and classical negative exponential utility functions for the analysis of equity crowdfunding. In addition, we took a reputation-based incentive mechanism, while there might be some other possible incentive schemes that can also ensure a safe transaction by changing the rules of the game. Hence, directions for future modeling would be: i) to consider other distributions of returns; ii) to consider other forms of risk-averse investors' utility functions with modifications of the underlying assumptions; and iii) to allow for other possible incentive schemes that can help to design a co-utile protocol for the market. Additional future directions of our work include extending the application of co-utility to other potential co-utility amenable games in the collaborative economy and also tackling other scenarios like international environmental agreements, self-enforcing antitrust cases, trans-boundary water issues, tax policies, etc.

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