Consumers as Financiers: Consumer Surplus, Crowdfunding, and Initial Coin Offerings*

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Abstract

We study the efficiency implications of funding directly provided by consumers. Intermediaries fail to finance all efficient projects, and crowdfunding can improve efficiency. Whereas intermediaries value projects based on cash flows, consumers also receive a consumption benefit. Unique to crowdfunding is the ability of consumers to commit to pay for the benefit, and the degree to which they can do so determines its efficiency. We discuss the implications of introducing a resale market for consumers' claims, as in the case of initial coin offerings, and the speculation that necessarily accompanies such markets. Finally, we provide testable and policy-related implications.

Keywords: consumer surplus, market power, efficiency, crowdfunding, initial coin offerings, speculative premium. JEL: G0

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Crowdfunding allows entrepreneurs to raise money directly from a large number of small investors, often potential consumers of their products. In developing economies, the crowdfunding industry is comparable in size to traditional funding schemes, such as bank loans or venture capital (WorldBank (2013)). In the United States, it has been steadily growing. The 2012 Jump Start Our Business Startups (JOBS) act promotes crowdfunding for small businesses. More recently, Initial Coin Offerings (ICOs) have emerged, quickly raising over 18 billion dollars (Howell et al. (2018)). From a purely economic standpoint, ICOs are a new type of crowdfunding, where the innovation over extant crowdfunding is that digital assets they issue ("cryptocurrencies") allow easy trade in the secondary market.[1,2]

Direct participation by small investors, while a key feature of crowdfunding, is restricted in traditional intermediary funding in practice: Depositors do not control banks' lending decisions; Regulations limit venture capital to accredited investors. Accordingly, a large existing literature building on Diamond (1984) provides a rationale for financial intermediaries, to which small investors delegate investment decisions and monitoring. More generally, in the standard corporate finance paradigm (e.g. Tirole (2006)), financiers, entrepreneurs and consumers are distinct. Intermediaries fund entrepreneurs, who then use the money to produce and sell their output to consumers. Consumers are on the sidelines, passively generating revenue for the entrepreneur.

In this paper, we study the role of consumers' direct participation in funding decisions for productive efficiency. To what extent, if any, can crowdfunding help finance productive projects, especially in comparison with traditional intermediary funding? We show that even absent usual frictions such as moral hazard and asymmetric information, intermediary funding fails to finance all socially efficient projects, and crowdfunding can strictly improve efficiency by financing some projects that intermediaries forego. Whereas intermediaries value projects based on the cash flows they generate, consumers also receive a consumption benefit. Unique to crowdfunding, as we shall see, is the ability of consumers to commit to pay for the benefit, and the degree to which they can do so determines productive efficiency of crowdfunding.

To make our argument precise, we present an economic framework with an entrepreneur, an intermediary, and consumers. The penniless entrepreneur has a project, which requires a fixed amount of initial investment. Either an intermediary or consumers may fund the project. If funded, the project produces a stream of output, which is then sold in the

[1] This aspect of ICOs resemble that of conventional initial public offerings (IPOs), except that Rule 501 of Regulation D of the Securities Act limits pre-IPO sales to accredited investors. The application of the rule to ICOs depends on specifics (See https://www.sec.gov/litigation/investreport/34-81207.pdf).

[2] To focus on efficiency implications of crowdfunding, we abstract away technical elements of ICOs. For the blockchain technology underlying ICOs, see Abadi and Brunnermeier (2018) and references therein.

product market. The model has three key assumptions. First, only consumers enjoy the output; it has zero utility value to the entrepreneur or the intermediary. Second, individual consumers' preferences may be variable, and thus their time horizon may be shorter; we model this by an idiosyncratic liquidity shock. Lastly, the entrepreneur's market power in the product market is exogenous and limited; in particular, the entrepreneur cannot extract entire surplus from consumers.

There are five main results. First, intermediary funding fails to achieve first best and suffers from inefficient underinvestment, even absent usual frictions such as moral hazard and asymmetric information. Since the entrepreneur cannot extract the full consumer surplus, cash flows generated by a project may not justify the required investment, even though the value created for consumers does. That is, a project with positive net total surplus may have negative net present value (NPV), which then deters intermediaries from funding it. This only arises because consumers and financiers are distinct in intermediary funding. Consumers would never pay more than the prevailing price, once the initial investment is sunk. Because consumers cannot commit to pay more, they cannot convince the intermediary to fund the project. Hence, intermediary funding results in inefficient underinvestment.

Our result is related to the insights on market power and innovation in the economics literature since Schumpeter (1942) and Arrow (1962). Our contribution is to highlight the connection between the product market power and the mode of financing. We also emphasize that cash flows, which the finance literature focuses on, fail to capture the full efficiency.

Second, crowdfunding can improve productive efficiency by funding some projects that the intermediary foregoes. The efficiency trade-off between crowdfunding and intermediary funding depends on the entrepreneur's market power and the consumers' liquidity shock. Effectively, crowdfunding works as a commitment device for consumers: consumers choose to give up some of their future surplus so that the output can be produced.[3] This, however, does not restore first best since consumers, prone to liquidity shocks, heavily discount the value of output produced in the future. Hence, crowdfunding is more likely to improve efficiency relative to intermediary funding when the entrepreneur has little market power, and the project is short-term.

Third, a resale market for the consumers' claims can improve efficiency but surprisingly does not restore first best. As is standard, the resale market, which gives consumers the

[3]While the voluntary nature of consumers' participation makes crowdfunding susceptible to a free-rider problem, non-negligible agents can easily overcome the problem, as Bagnoli and Lipman (1988) show in their discussion of Grossman and Hart (1980). We note that free riding is even less likely to occur when consumers have altruistic motives in addition to private consumption. The consumer value in our model could comprise both elements. (e.g., during the coronavirus pandemic, customers support their favored businesses: https://www.npr.org/2020/03/20/818797729/how-buying-a-gift-card-can-help-a-small-business).

option to sell their claims, reduces the liquidity discount and so allows consumers to fund more projects. However, the same commitment problem as in intermediary funding again arises. Since future consumers enter after the investment is sunk, they are only willing to pay up to the market price for the product, and so the price they pay for the claims does not reflect their surplus. Hence, crowdfunding with a resale market, as in the case of ICOs, mitigates, but does not eliminate, inefficient underinvestment.

For our fourth main result, we extend the model to study implications of speculation, which frequently accompanies active markets. Following Harrison and Kreps (1978), we introduce speculators, who buy the claim just to sell it back to consumers at higher prices. The resulting speculative premium in the secondary resale market immediately carries over to the primary funding market, absent a mandatory lock-up period as in traditional IPOs. The speculative premium thus redresses underinvestment initially, by counteracting the liquidity discount, but it causes inefficient overinvestment beyond certain levels. Hence, speculation, often viewed as harmful, has nuanced efficiency implications.

Finally, we present various testable implications. Due to the consumption benefit enjoyed by consumers, cash flows and other observable characteristics of crowdfunded projects may appear different than intermediary funded projects. This, however, does not imply that they are socially inefficient, and thus a full analysis of any crowdfunded projects should include an estimate of the consumption benefit. In addition, we note that even though there are no portfolio effects in our model (all agents are risk neutral), crowdfunding with resale necessarily induces a positive correlation between consumers' portfolio performance and the consumption benefit. This should be taken into account when evaluating the size restrictions on individual investments permitted under the 2012 JOBS act.

Related Literature Petersen and Rajan (1995) show that credit market competition affects firms' ability to get funding. Creditors are more likely to finance firms when they can extract more from the firms in the future. By contrast, we focus on market power in the product market and study the mechanism through which consumers mitigate this problem by directly participating in the funding decision, hence "consumers as financiers."

There is a small (but rapidly growing) literature on crowdfunding and ICOs. Strausz (2017) considers the benefit of crowdfunding as a way of acquiring information about the eventual payoff of the project if there is demand uncertainty (see also Astebro et al. (2017), Chemla and Tinn (2018), and Ellman and Hurkens (2019)). The benefit of eliciting information in crowdfunding must be balanced against inefficiencies in controlling entrepreneurial moral hazard. Our focus differs because we abstract from incentive problems and asymmetric information between the entrepreneur and the funder and focus on the extent to which consumers and other funders' valuations for projects differ.

Kumar et al. (2019) consider a monopolist who funds a project with either costly external financing or crowdfunding. They show that crowdfunding may distort product market output decisions as the monopolist pre-commits to a quantity in order to garner crowdfunding. In short, the decision to obtain cheaper funding may lead to product market distortions relative to the standard monopolist solution. By contrast, we consider how limited market power in the product market affects the entrepreneur's ability to generate revenue and thus to obtain funding for his project. The causality is reversed: in their model, costly funding drives product market distortions, while in our model, product market distortions affect funding and efficiency.[4]

Theoretically, ICOs have been examined by Chod and Lyandres (2018), who consider ICOs as a funding method that allows risk averse entrepreneurs to transfer risk to well diversified investors without giving up control rights. Catalini and Gans (2018) assume that under traditional funding, the entrepreneur can commit to charge consumers their valuation of the good (i.e., they receive no surplus), but under an ICO, all purchases are made by token and so the supply of tokens implicitly determines the price of the good. Garratt and van Oordt (2019) show how cryptocurrencies raised through ICOs can align the interests of entrepreneurs and investors better than traditional funding schemes. By contrast, we consider the case in which the products' pricing is independent of how the product is funded, and interpret ICOs as a means to permit the resale of claims among consumers, and hence increase their willingness to fund the project.[5]

The rest of the paper is organized as follows. Section 1 describes the setup of the model. Section 2 solves outcomes of funding decisions by the intermediary and by consumers and compares their productive efficiency. Section 4 discuss testable and policy implications. Section 3 extends the model to allow speculation in the resale market. Section 5 concludes.

[4]Brown and Davies (2018) interpret the "all-or-nothing" feature of crowdfunding as a way of providing credible information about an underlying risky project. Cong and Xiao (2018) show how in a dynamic setting, the all-or-nothing feature can mitigate information cascades and provide information aggregation.

[5]The benefits of ICOs in mitigating network externalities (i.e., affecting the realization of future demand) are developed by Li and Mann (2018). Bakos and Halaburda (2018, 2019) show that tradability of tokens helps overcome the coordination problem, and thus ICOs can be an attractive funding scheme when demand is uncertain. Empirical evidence on the properties of ICOs are presented in Momtaz (2018), while Lee et al. (2018) characterize how information and analysis is aggregated in these offerings. Shakhnov and Zaccaria (2020) emphasize that ICOs and venture capital financing can complement each other. A further literature develops frameworks for valuing cryptocurrencies. For example, Cong et al. (2018) consider how the underlying tokens should be valued in the presence of network effects, as do Pagnotta and Buraschi (2018) and Sockin and Xiong (2018).

1 Model Setup

Consider the following discrete time, infinite horizon model of investment. There are three types of agents: one entrepreneur, an intermediary, and a continuum of consumers. All agents are risk-neutral and have a zero time discount rate. The measure of consumers is normalized to one.

The entrepreneur is penniless, while both the intermediary and the consumers have deep pockets and a zero opportunity cost of capital. At $t = 0$, the entrepreneur is endowed with a project, and the project requires initial investment of a fixed amount $I > 0$. If funded, the project produces an output each period for $t = 1, 2, \ldots,$ until it fails. The marginal production cost is zero. The output is perishable, and the project fails with probability $1 - \delta \in (0, 1)$ at each point in time.

Only consumers consume the output and derive utility $v > 0$ from it. Neither the intermediary nor the entrepreneur derives any consumption value from the output. The utility v captures both immediate enjoyment from consumption and pleasure derived from altruism, if any. We also stress that v is the incremental utility flowing to the consumer from having the good. It is, therefore, in excess of that which he derives from any existing products. In short, v captures the maximum incremental utils to the consumer if the new product is launched.

To allow for the possibility that individual consumers' preferences may be variable, we assume that consumers may have a short time horizon. That is, consumers are subject to an idiosyncratic "liquidity" shock, while the entrepreneur and the intermediary are infinitely lived. At each point in time, he receives the shock with probability $\lambda \in [0, 1]$. Upon receiving the shock, he consumes everything and dies the next period, at which point new consumers are born. This timing assumption, illustrated in Figure 1, ensures that the measure of consumers is held fixed at one.

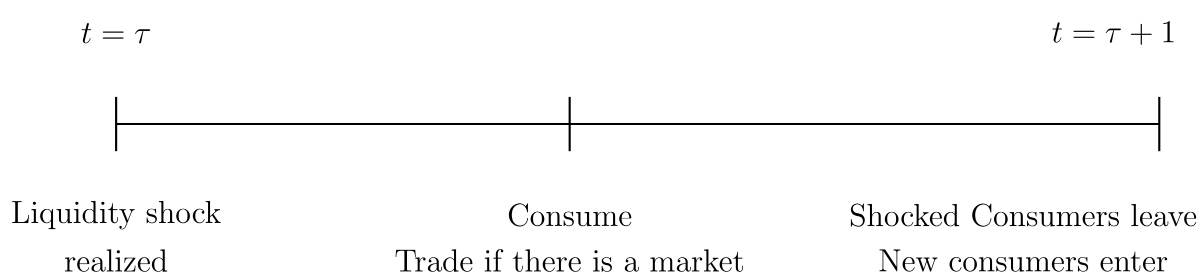

Figure 1: **Life Cycle of a Consumer**

There are three separate markets: a funding market that operates at $t = 0$, and a product market and a (possible) resale market, both of which are in operation from $t + 1$ onwards.

Product market In the product market, the entrepreneur sells the output at a price determined by their market power. This is limited: the market price is strictly less than its total value to consumers v. Limited market power is often observed in the markets for goods and service. If a new technology can be quickly learned or replicated, imminent competition prevents the entrepreneur from extracting full surplus.

Going forward, we are agnostic as to the source of the entrepreneur's market power as our primary research question is how the extent of market power affects the efficiency of traditional funding methods compared to crowdfunding. So, we assume that the product market price is determined every period by generalized Nash bargaining and take as given the allocation of bargaining power. Let $\alpha \in [0, 1]$ denote the consumers' bargaining power with the entrepreneur. When $\alpha = 1$, the consumer extracts full surplus; when $\alpha = 0$, the entrepreneur extracts full surplus. Here, α is a characteristic of the market and remains constant throughout the product's lifespan.

Funding market In the funding market, either the intermediary or the crowd of consumers makes a take-it-or-leave-it offer to the entrepreneur. The take-it-or-leave-it assumption is for simplicity, and does not affect the tenor of our results. If consumers crowdfund the project, they receive rights to a stream of output. The rights, however, are not exclusive because once the project is initiated, other consumers may also buy the output directly in the product market, at the prevailing price. This assumption ensures that the entrepreneur's market power in the product market is not altered by the funding scheme. In short, we keep the product market structure constant, which allows us to isolate the effect of different funding sources on the set of projects that are funded.

Resale market If there is an active resale market, as in Section 2.4, consumers can trade their claims to a stream of output. In particular, when one of the consumers who crowdfunds the project receives a liquidity shock, he can sell the claim to future consumers and consume the proceeds before he dies next period. To simplify the price formation mechanism, we assume that sellers in this resale market make a take-it-or-leave-it offer to buyers.[6] Finally, we do not allow short sales.

[6]The results would be qualitatively the same as long as sellers have any bargaining power with the buyers so that sellers can partly benefit from the resale market.

2 Funding Decisions and Productive Efficiency

2.1 First-Best Funding Outcome

Total surplus from the project is the sum of firm surplus and consumer surplus (Marshall (1890)). Let $\mathbf{V}$ denote the expected present value of the consumer value from a project.

$$\mathbf{V} := \sum_{\tau=1}^{\infty} \delta^{\tau} v = \frac{\delta}{1-\delta} v. \tag{1}$$

Then total surplus net of the initial investment is $\mathbf{V} - I$. A project is efficient if and only if the net surplus is greater than zero. Hence, first-best funding outcome is achieved if all projects with positive net total surplus (i.e. $\mathbf{V} > I$) are funded and no project with negative net total surplus (i.e. $\mathbf{V} < I$) is funded. We refer to productive efficiency as the extent to which the first-best funding outcome is achieved.

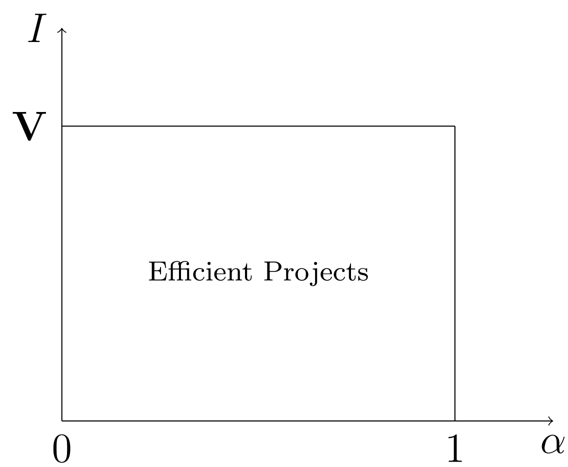

Figure 2: **First-Best Funding Outcome**

The set of efficient projects is independent of α, the enterpreneur's market power in the product market, as depicted in Figure 2.

2.2 Intermediary Funding Decision

We now study whether intermediary funding can achieve first best. The deep-pocketed intermediary has a zero cost of capital. Since it makes a take-it-or-leave-it offer, it funds a project as long as its cash flows justify the initial investment. In other words, it funds a project, whose net present value (NPV) is positive.

When funded by the intermediary, the entrepreneur makes his investment and sells the output in the product market. The price of the output is determined by generalized Nash bargaining. Recall that v is the value in excess of what consumers can enjoy from any existing products. Hence, both the entrepreneur and the consumers have a zero outside option. The price of the output p at each $t = 1, 2, \ldots$ is chosen to maximize

$$(v - p)^{\alpha} \, p^{1-\alpha}. \tag{2}$$

Since the marginal production cost is zero, it is immediate that the price and thus the revenue each period is

$$p = (1 - \alpha) \, v. \tag{3}$$

We note that if $\alpha = 0$, then consumers pay their valuation and the entrepreneur acts as a "perfectly discriminating" monopolist. If $\alpha = 1$, the product market price is zero and equal to the marginal cost of production; the entrepreneur produces in perfect competition.

Let $\mathbf{V}^b$ denote the present value of the revenue stream at $t = 0$. It is the valuation of the project by the intermediary (or "bank").

$$\mathbf{V}^b := \sum_{\tau=1}^{\infty} \delta^{\tau} p = (1 - \alpha) \, \mathbf{V}. \tag{4}$$

The net present value is $\mathbf{V}^b - I$, and the intermediary chooses to fund the project if and only if the NPV is positive.

We present our first main result. (All proofs are in the Appendix.)

Proposition 1. *If and only if consumers have any bargaining power in the product market ($\alpha > 0$), intermediary funding suffers from inefficient underinvestment.*

Intermediary funding based on the NPV rule can be inefficient. When the entrepreneur exercises less than absolute market power, cash flow is a fraction of the value that it generates to the consumers. The intermediary fails to fund projects that have positive surplus, but have negative NPV (i.e. $I \in \left[\mathbf{V}^b, \mathbf{V}\right)$). The difference between the total surplus and the intermediary's valuation is the consumer surplus:

$$\mathbf{V} - \mathbf{V}^b = \alpha \mathbf{V}. \tag{5}$$

Figure 3 illustrates this result: The set of projects funded by the intermediary depends on α. The underinvestment problem becomes more severe, as consumers retain more surplus in the product market.

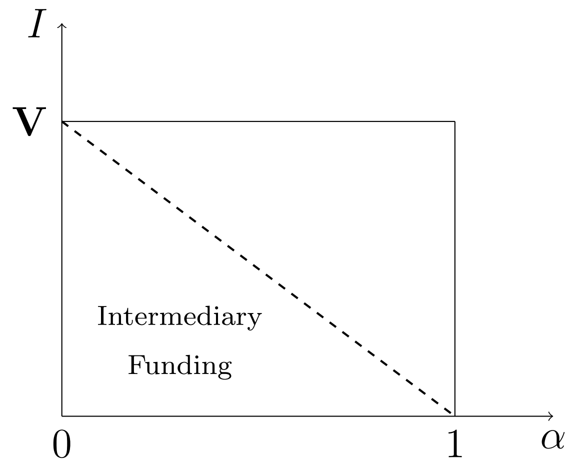

Figure 3: **Underinvestment of Intermediary Funding**

Limited market power for the entrepreneur is typically considered beneficial for consumers. Consumers pay low prices and enjoy a higher surplus. This, however, does not take into account the ex-ante effect such a high consumer surplus has on the intermediary's funding decision. The lower cash flows generated by the project reduces the NPV, and the project may not get funding in the first place, in which case consumers do not enjoy any surplus at all. Hence, market power in the product market is a double-edged sword. When the entrepreneur has lower market power, consumers enjoy a higher surplus, if the project is funded and the output is produced. On the other hand, it also lessens the chance that some efficient projects get funding in the first place.

A long literature in economics going back to Schumpeter (1942) and Arrow (1962) discusses the relationship between market power and entrepreneurial innovation. We, in contrast, consider how market power affects innovation because of the incentive it provides through the funding channel.

The funding market fails to achieve first best even absent usual frictions such as moral hazard and information asymmetry. The key friction at work here is the consumers' inability to commit. In this model, consumers and the intermediary are distinct, and the results would be the same if they have an arm's-length relationship: Consumers cannot dictate details of the intermediary's funding policy. There are efficient projects that the intermediary fails to fund. It would benefit consumers to fund such projects, and consumers would like the intermediary to fund them. However, once initial investment is sunk, consumers can buy the output in the product market, and they would not and need not pay more than the prevailing price. Since the prevailing price alone does not justify the initial investment, the intermediary chooses not to fund.

Separation between consumers and financiers is often the norm in the real world. Consumers delegate decision making to the intermediary who decides which firms and projects to fund. While many consumers directly participate in the secondary market, their participation in the primary market is limited. For example, while many consumers trade stocks and funds on the secondary market, under the federal securities law they must be *accredited* investors to participate in pre-IPO sales.[7] One can envisage frictions so that this separation is optimal. The finance literature discusses various ways in which funding from intermediaries or venture capitalists dominates funding from uninformed consumers.[8]

In this paper, assuming away other frictions, we isolate and highlight the implications of limited market power in the product market for productive efficiency in the funding market. To the best of our knowledge, identifying the inefficiency that arises because of the separation between consumers and financiers and limited market power in the product market is novel.

Next, we study whether and to what extent direct funding from consumers can mitigate this underinvestment problem in intermediary funding.

2.3 Crowdfunding without Resale

Let $\mathbf{V}^c$ denote the value of the project to consumers. At each $\tau \geq 1$, only $(1-\lambda)^{\tau-1}$ fraction of consumers who initially funded the project at $t = 0$ is surviving, while the others are born after the project is funded.

$$\mathbf{V}^c := \sum_{\tau=1}^{\infty} \delta^{\tau} (1-\lambda)^{\tau-1} v = \left(\frac{1-\delta}{1-\delta+\delta\lambda} \right) \mathbf{V}. \tag{6}$$

We present our second main result, which compares productive efficiency of crowdfunding with that of first best and that of intermediary funding.

Proposition 2. *If and only if consumers face any liquidity shock ($\lambda > 0$), then crowdfunding without resale suffers from inefficient underinvestment. If and only if consumer surplus exceeds the liquidity discount ($\alpha > \frac{\delta\lambda}{1-\delta+\delta\lambda}$), crowdfunding without resale strictly improves productive efficiency relative to intermediary funding alone.*

Consumers are different from the intermediary in two respects. First, consumers take into account the consumer surplus. Second, consumers are subject to their idiosyncratic liquidity shock (λ). Consumers crowdfund the project if and only if $\mathbf{V}^c$ exceeds the initial investment I. The liquidity shock prevents consumers from achieving first best.

[7] This is in accordance with Regulation D of the Securities Act.

[8] It is also possible that funding from informed consumers dominates intermediary funding (as in Strausz (2017) or Chemla and Tinn (2018).

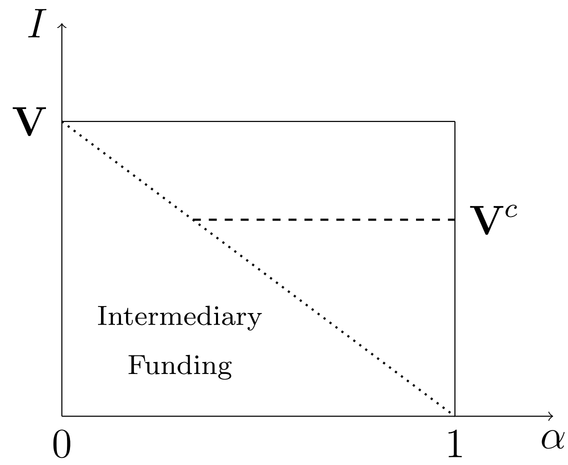

Figure 4: **Trade-off between Intermediary funding and Crowdfunding**

Crowdfunding without resale can be inefficient. Although consumers internalize their own surplus, they do not internalize the surplus of future consumers. The difference between $\mathbf{V}$ and $\mathbf{V}^c$ is the liquidity discount.

$$\mathbf{V} - \mathbf{V}^c = \left(\frac{\delta\lambda}{1-\delta+\delta\lambda} \right) \mathbf{V}. \tag{7}$$

Consumers require compensation for the liquidity shock. That is, the project must generate a sufficiently large value to justify the initial investment before they die.

We can compare the consumers' valuation $\mathbf{V}^c$ with the intermediary's valuation $\mathbf{V}^b$ from Equation (4) to obtain

$$\mathbf{V}^c - \mathbf{V}^b = \underbrace{\alpha \mathbf{V}}_{\text{consumer surplus}} - \underbrace{\left(\frac{\delta\lambda}{1-\delta+\delta\lambda} \right) \mathbf{V}}_{\text{liquidity discount}}. \tag{8}$$

Hence, whether crowdfunding reduces inefficiency relative to the intermediary depends on the trade-off between consumer surplus and the liquidity discount.

Whether crowdfunding can be more efficient than intermediary funding depends on the condition in Proposition 2. On the left hand side is the extent to which market power of the entrepreneur is limited in the product market, captured by consumers' bargaining power α. The right hand side increases both in λ, the consumers' liquidity shock and δ, the continuation probability of the project each period. Intuitively, if consumers have more market power, then crowdfunding supports a larger range of projects because the consumer surplus is larger. Conversely, a higher probability of a liquidity shock makes crowdfunding less attractive because funding consumers do not internalize the surplus of future consumers. This implies that crowdfunding without resale is not suitable for longer-term projects.

The trade-off between intermediary funding and crowdfunding is illustrated in Figure 4. As the product market leaves more surplus for consumers, intermediary funding becomes less efficient whereas crowdfunding becomes more efficient.

One way to interpret the inefficiency of crowdfunding without resale is that there is a missing market. Consumers who crowdfund the project at $t = 0$ secure rights to the output of the project indefinitely. When consumers receive a liquidity shock, they cannot enjoy the consumption value from the next period onwards, and so the rights to future output have no value to them. However, future consumers do value the output. Next, we introduce a market in which consumers can trade claims for future output.

2.4 Crowdfunding with Resale: Initial Coin Offerings

The existence of a secondary market increases consumers' valuation for the project because it provides them with a resale option. When consumers are hit with a liquidity shock, they can sell their claim for future output to other consumers and consume the proceeds before they die. A concrete example of crowdfunding with resale is the recently emerging market of Initial Coin Offerings. In an ICO, a new venture raises capital directly from consumers by issuing digital assets, called "tokens". Tokens typically have a use value in the enterprise but they also allow consumers to re-trade their claims.

Coin offerings do not necessarily restore the first-best funding outcome. This is because of the commitment issue. Recall the consumers' lack of commitment causes inefficiency in intermediary funding. The same problem again arises. Unlike the consumers who provide initial funding, new consumers enter after the initial investment is sunk. Hence, they cannot commit to pay their entire consumer surplus but can only commit to pay the prevailing market price p for the output each period.

Let $\mathbf{P}$ be the price that new consumers commit to pay for the claim to future output. Since sellers make a take-it-or-leave-it offer, this is the resale price of the claim. Then

$$\mathbf{P} := \sum_{\tau=t+1}^{\infty} \delta^{\tau-t} p = \frac{\delta}{1-\delta} p = (1-\alpha)\,\mathbf{V} = \mathbf{V}^b. \tag{9}$$

Notice, the resale price of the claim is the same as the intermediary's valuation of the project. The consumers' liquidity shock, λ, does not affect the resale price, since future shocked consumers know they will be able to sell their own claims forward.

Given the resale price of the claim $\mathbf{P}$, the initial consumers' valuation for the project is now given by

$$\mathbf{V}^r := \sum_{\tau=1}^{\infty} \delta^\tau (1-\lambda)^{\tau-1} (v + \lambda \mathbf{P}). \tag{10}$$

Conditional on not having received a liquidity shock until $t = \tau - 1$, consumers always get v and additionally receive $\mathbf{P}$ in exchange of the claim if they get the shock at $t = \tau$. Substituting Equation (9) into Equation (10), we have

$$\mathbf{V}^r = \left(1 - \frac{\alpha\delta\lambda}{1-\delta+\delta\lambda}\right)\mathbf{V}. \tag{11}$$

We present our third main result on productive efficiency of resale in crowdfunding.

Proposition 3. *Crowdfunding with resale is at least as efficient as crowdfunding without resale or as intermediary funding. Whenever intermediary funding or crowdfunding without resale fails to achieve first best, crowdfunding with resale strictly improves productive efficiency, but still fails to achieve first best.*

The valuation of consumers with resale $\mathbf{V}^r$ coincides with the first-best cutoff $\mathbf{V}$ if and only if $\alpha = 0$ or $\delta = 0$. In other words, crowdfunding with resale achieves first best if and only if either consumers have no bargaining power ($\alpha = 0$), in which case intermediary funding alone is efficient, or consumers have no liquidity shock ($\lambda = 0$), in which case crowdfunding without resale is efficient.

Even though it does not achieve first best, consumers' valuation with resale, $\mathbf{V}^r$, is at least as high as the consumers' valuation without resale $\mathbf{V}^c$ or the intermediary's valuation $\mathbf{V}^b$. From Equations (4), (6), and (11),

$$\mathbf{V}^r = \mathbf{V}^c + \underbrace{(1-\alpha)\left(\frac{\delta\lambda}{1-\delta+\delta\lambda}\right)\mathbf{V}}_{\text{liquidity discount}} = \mathbf{V}^b + \left(\frac{1-\delta}{1-\delta+\delta\lambda}\right)\underbrace{\alpha\mathbf{V}}_{\text{consumer surplus}}. \tag{12}$$

Hence, crowdfunding with resale always improves efficiency (at least weakly) relative to intermediary funding and crowdfunding without resale. The higher valuations are more efficient since the valuations $\mathbf{V}^b$, $\mathbf{V}^c$, and $\mathbf{V}^r$ do not exceed the first-best cutoff $\mathbf{V}$, meaning that the source of inefficiency is underinvestment, rather than overinvestment.

Thus, ICOs can improve efficiency by allowing resale, but they do not achieve the first-best funding outcome. The inherent friction that consumers cannot commit to pay a high price after the investment is sunk cannot be overcome by simply opening a resale market for the claims. This commitment problem is reminiscent of the durable good monopolist problem presented by Coase (1972).

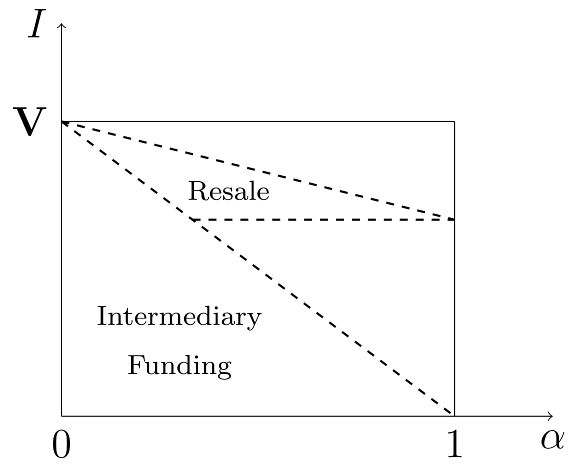

Figure 5: **Benefit of the Resale Market in Crowdfunding**

In Figure 5 we illustrate the benefit of introducing the resale market to crowdfunding. With resale, consumers can always fund more efficient projects than intermediary funding. As the entrepreneur's market power in the product market decreases, the role of resale becomes limited due to future consumers' lack of commitment.

Since the resale price is the same as the intermediary's valuation of the project, crowdfunding with resale allows strictly more efficient projects to be funded than intermediary funding if and only if initial consumers contribute strictly more than the late consumers who purchase the claim in the resale market.

If the future consumers enjoy the output without paying for their surplus, a natural concern with a continuum of consumers is that there would be a free-rider problem as in Grossman and Hart (1980). Consumers could simply wait for other consumers to fund the project and bear the cost of initial investment so that they can purchase either the claim in the resale market or the output in the product market. In the extreme, crowdfunding with resale would become equivalent to intermediary funding in its scope of productive efficiency.

However, as Bagnoli and Lipman (1988) and subsequent work show, the free-rider problem of Grossman and Hart (1980) is rather fragile. It can go away if agents are non-negligible. In the context of takeovers, Holmström and Nalebuff (1992) show that without the assumption of the one share per shareholder, the free-rider problem does not prevent a successful takeover. This is because in a market with a large but finite number of consumers, each consumer can affect the probability of the project being funded, albeit slightly. Given that consumers do want to see the project being funded and they understand that it would not be feasible with the intermediary funding, the free-rider problem would not prevent crowdfunding with resale from strictly improving productive efficiency relative to intermediary funding.

Finally, recall that the consumer value v includes any pleasure from altruistic motives as well as direct enjoyment from consumption. Altruism may play a key role in certain types of crowdfunding, e.g. supporting local artists and businesses and finding cures and developing drugs for rare diseases, and these would be naturally less susceptible to the free-rider problem. Indeed, one of the first successful crowdfunding projects was funding for the pedestal for the Statue of Liberty. About 125,000 people collected over $100,000 after a much popular article by Joseph Pulitzer. "Let us not wait for the millionaires to give us this money. It is not a gift from the millionaires of France to the millionaires of America, but a gift of the whole people of France to the whole people of America."[9]

3 Extension: Speculation in the Resale Market

Given the benefits to resale that we highlighted above, it is natural to ask how frictions in the resale market affect productive efficiency. One much touted concern, especially in the case of ICOs, is speculative trade and the fact that prices do not necessarily reflect fundamental values. So, in this section, we introduce investment uncertainty and study the effect of speculation on efficiency in crowdfunding with resale.

3.1 Setup

We motivate speculation in the resale market by introducing investors with different beliefs about payoffs to the project, following Harrison and Kreps (1978)).

Specifically, at each $t = 1, 2, \ldots,$ conditional on the project not having yet failed, an aggregate state that can be either high or low ($s_t = s \in \{h, l\}$) is realized and publicly observed. The aggregate state affects the value of the project's output to consumers. Consumers value the output as v in the high state, while the value is normalized to zero in the low state (i.e. $v(h) = v$ and $v(l) = 0$).

At $t = 1$, the state is high with probability one. From $t = 2$ on, the state evolves according to a Markov chain. The transition matrix Q is

$$Q = \begin{bmatrix} q(h,h) & q(h,l) \\ q(l,h) & q(l,l) \end{bmatrix} = \begin{bmatrix} q_h & 1 - q_h \\ 1 - q_l & q_l \end{bmatrix}, \tag{13}$$

where $q_s \in [0, 1]$ is the conditional probability of remaining in state s given that the project continues next period. We assume that the consumers' beliefs are represented by the true

[9]See https://www.nps.gov/stli/learn/historyculture/joseph-pulitzer.htm.

transition matrix Q.

We also allow a continuum of deep-pocketed and risk-neutral speculators to participate in the resale market. Speculators do not derive any value from consuming the output directly. Akin to the intermediary, speculators value the output each period at $p = (1-\alpha)\, v$, the market price of the output as presented in Equation (3). Speculators' beliefs are represented by the transition matrix

$$Q^{'} = \begin{bmatrix} q_h^{'} & 1-q_h^{'} \\ 1-q_l^{'} & q_l^{'} \end{bmatrix}, \tag{14}$$

where $Q^{'}$ may differ from Q.

Speculators and consumers agree to disagree. To highlight the effect of speculation, we assume that speculators are always more pessimistic than consumers (i.e. Q' is such that speculators' valuation for the claim is always lower than the consumers' valuation in each state). This implies that speculators would not participate in the resale market if there were not for the speculative opportunities.

The rest of the model is the same as that in Section 1. Recall that short sales are not allowed in the resale market. For simplicity, we assume $\lambda = 1$, i.e consumers live for one period only.[10]

Our assumption that investors disagree on the state transition matrix flows directly from the off-the-shelf model of Harrison and Kreps (1978). We do so simply to show the interaction between the primary market funding decisions and the secondary market prices of the claims. Of course, any other modeling device that inflates the price of claims would generate similar results. We note in passing that differences in beliefs about the success probability of the project (δ) would also lead to similar results.

3.2 Speculation: Heterogeneous Beliefs

Absent speculators, consumers' willingness to pay for the claim in the resale market in each state $s \in \{h, l\}$ is $(1-\alpha)$ fraction of $\mathbf{V}_s$, where $\mathbf{V}_s$ denotes the discounted sum of all future consumer value generated conditional on the current state s. The characterizations of $\mathbf{V}_s$, along with other results without speculation in this setup are in the Appendix A.1. Absent consumers, speculators' valuation for the claim in each state is given similarly except replacing the consumers' beliefs with the speculators' beliefs $q_h^{'}$ and $q_l^{'}$.

To make the results more interesting, we assume that speculators are always more pessimistic than consumers, i.e. speculators only participate for speculation. (See Assumption

[10]Note that this assumption will only make crowdfunding with resale less efficient, rather than more efficient.

1 in the Appendix for a more formal characterization.) The entry of more optimistic speculators would naturally increase the claims' prices even further.

To illustrate how speculation affects the resale price, consider when the speculator, whose valuation is lower than consumers in both states, would buy the claim in low state. The speculator would pay more for the claim than the consumers if the option to sell it back to the consumers in high state is sufficiently valuable. The fact that they can sell it at $(1-\alpha)\mathbf{V}_h$ to consumers in high state, makes speculators willing to pay

$$\mathbf{P}_l^{'} = \frac{\delta\left(1-q_l^{'}\right)}{1-\delta q_l^{'}}(1-\alpha)(v+\mathbf{V}_h), \tag{15}$$

in the low state. This is strictly greater than consumers' valuation in the low state ($(1-\alpha)\mathbf{V}_l$) if and only if $q_l^{'} < q_l$. As long as speculators believe that the state will change to h more quickly than consumers do, they are willing to pay more for the claim in the low state than the consumers.

In turn, the high price that speculators are paying in low state increases the consumers' willingness to pay for the claim in high state.

$$\mathbf{P}_h = \frac{\delta q_h}{1-\delta q_h}(1-\alpha)v + \frac{\delta(1-q_h)}{(1-\alpha)}\mathbf{P}_l^{'}. \tag{16}$$

Proceeding iteratively, one can construct prices in both states that reflect speculator's resale options. The equilibrium resale price is fully characterized in the proof in the Appendix.

Proposition 4. *If and only if either $q_l > q_l^{'}$ or $q_h < q_h^{'}$ but not both, there is a speculative premium in the resale market and the equilibrium resale price of the claim is higher than the consumers' valuation and the speculator's valuation in each state.*

As in Harrison and Kreps (1978), the mere presence of a speculator, whose valuation is lower than the consumers in each state, can lead to higher prices for the claim in both states. This is because heterogeneous beliefs between the consumers and the speculator presents speculative opportunities. With the short-sale constraint, traders must buy the claim first to take advantage of these opportunities. The price of the claim rises to reflect the value of speculative opportunities, or "speculative premia."

To see this more clearly, consider the following example with $\delta = \alpha = v = q_h = q_l = .5$, $q_h^{'} = .1$ and $q_l^{'} = .4$. Then the consumers' valuation of the claim is .125 in each state and the speculator's valuation is .07 and .12 in high and low states respectively. In each state, the consumers have a higher valuation for the claim than the speculator does. Notice that the condition in Proposition 4 is satisfied since $q_l = .5 > q_l^{'} = .4$ and $q_h = .5 > q_h^{'} = .1$.[11] Therefore, the equilibrium price is .13 and .14 and the speculative premium is .005 and .015 in high and low states respectively.

This speculative premium affects consumers' crowdfunding decision. Since the funding consumers can resell the claim at a higher price, they are willing to fund the project with a higher required investment. The consumers' valuation with the speculative resale market $\tilde{\mathbf{V}}^s$ is therefore

$$\tilde{\mathbf{V}}^s = \tilde{\mathbf{V}}^c + \delta \mathbf{P}_h^* = \delta \left(v + \mathbf{P}_h^* \right). \tag{17}$$

To determine the efficiency implication of speculation, we compare $\tilde{\mathbf{V}}^s$ with the first-best cutoff $\tilde{\mathbf{V}}$ (given by Equation (23)) and obtain

$$\frac{\tilde{\mathbf{V}} - \tilde{\mathbf{V}}^s}{\delta} = \underbrace{\alpha \mathbf{V}_h}_{\text{consumer surplus}} - \underbrace{\left(\mathbf{P}_h^* - \mathbf{P}_h \right)}_{\text{speculative premium}} \tag{18}$$

Whether speculation is efficient or not depends on the trade-off between consumer surplus and speculative premium.

Proposition 5. *Suppose either $q_l > q_l^{'}$ or $q_h < q_h^{'}$ but not both. Define*

$$\alpha_{min} := 1 - \frac{\boldsymbol{P}_h}{\boldsymbol{P}_h^*}, \tag{19}$$

where $\boldsymbol{P}_h = (1 - \alpha) \boldsymbol{V}_h$ and $\boldsymbol{V}_h$ is given by Equation (22) and $\boldsymbol{P}_h^*$ is given as in Proposition 4. Then $\alpha_{min} \in (0, 1)$, and speculation mitigates inefficient underinvestment if $\alpha \geq \alpha_{min}$, while it causes inefficient overinvestment if $\alpha < \alpha_{min}$.

There are two cases, as illustrated in Figure 6. First, some speculation improves productive efficiency. As the consumers' bargaining power α increases, the commitment problem of future consumers becomes more severe, and so does the underinvestment problem. Speculative premia, by raising the price at which initial consumers can sell their claim, mitigates the underinvestment problem.

By contrast, as α decreases, the underinvestment problem becomes less severe, and so the speculative premium can reduce productive efficiency. The possibility of too much speculation in the resale market encourages the initial consumers to fund projects even when the net total surplus is negative. Thus, in this case speculative premia lead to an overinvestment problem.

[11] In fact, Assumption 1 that the speculator's valuation is lower than the consumers' in both states ensures that the two inequalities in Proposition 4 never hold simultaneously.

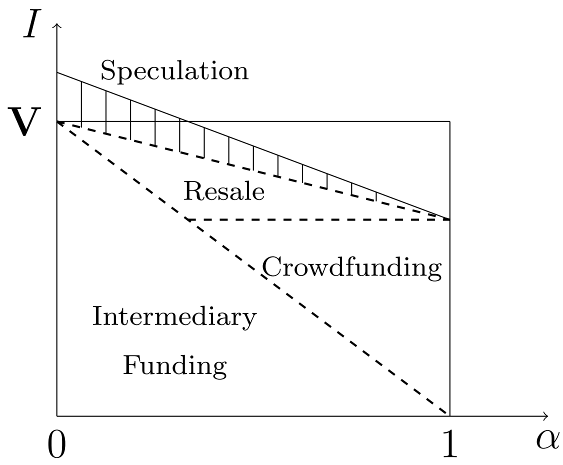

Figure 6: **Efficient and Inefficient Speculation**

Our result shows that speculation can in fact improve productive efficiency given the underinvestment problem we highlighted earlier. Note that this result is not limited to crowdfunding. Indeed speculation in the secondary market for intermediary funding claims, like the stock market, could also increase the productive efficiency.

4 Testable and Policy-related Implications

4.1 Testable Implications

We provide three testable implications. The first two are on characteristics of projects that are suitable for different funding methods. The third is on ex post performance.

Various characteristics affect the likelihood that a project gets intermediary funding or crowdfunding without resale. In Section 2, we analyzed three characteristics: the consumers' bargaining power in the product market (α), the continuation probability of the project (δ), and the consumers' liquidity shock (λ). In Proposition 2, whether a project is sustainable for intermediary funding or crowdfunding (without resale) depends on the trade-off between the competitiveness (α), and the liquidity discount ($\frac{\delta\lambda}{1-\delta+\delta\lambda}$). The liquidity discount is high if the project has a long horizon, i.e. the project is likely to produce output in the far future, or if the consumers have a short horizon, i.e. their preference for the output is likely to change very quickly. Hence, a project is more attractive for crowdfunding (without resale) than intermediary funding if market power outweighs the liquidity discount, or if the following hold:

i. The markup in the product market is low;

ii. The project has a short horizon;

iii. The consumers' preference for the output is persistent.

Second, we analyze the implications of the resale market and speculation. In Section 3, we showed that speculation mitigates underinvestment but can cause overinvestment. A project is more likely to suffer overinvestment due to speculation if either intermediary funding or crowdfunding without resale was already close to achieving first best: either the entrepreneur's market power is high or liquidity discount was low in the first place. In other words if:

i. The output is sold in a non-competitive industry;

ii. The project has a short horizon.

Lastly, we consider ex post (observed) performance. We have demonstrated conditions under which a broader range of projects are attractive for crowdfunding rather than traditional methods. As the intermediary's decision is based on an anticipation of future cash flows, it implies that crowdfunded projects will on average appear to have worse performance. However, even though the financial performance is worse, it does not mean that the projects are socially inefficient. Hence, in a matched sample of intermediary funded and crowd funded projects with the same investment:

i. Crowdfunded projects will have lower cash flows and profitability measures than intermediary funded projects.

ii. Crowdfunded projects with resale markets will have lower cash flows and profitability measures than crowdfunded projects without resale markets.

4.2 Policy Implications

Two natural policy implications arise from considering the interplay between the product and funding markets. First, we consider a lock-up period for the resale market. Second, we discuss potential implications of risk averse consumers.

The investors in IPOs are frequently restricted from trading immediately after their stocks become publicly available. Intuitively, a lock-up period helps insulate the funding decision from speculative premia in the secondary market. The lack of a similar regulation in ICOs can amplify the negative effect of speculation, ending up with funding inefficient projects. Howell et al. (2018) discuss a case of ICO, where the lock-up period is voluntarily imposed. Imposing a lock-up period can help prevent overinvestment. Given our earlier testable implication, this regulation would be especially important when speculation is likely to cause overinvestment, i.e. the industry is less competitive or the project has a short horizon.

In our model, all agents are risk neutral so there is no natural reason for consumers to hold portfolios. However, we note that crowdfunding does have one particular characteristic – by construction, there is an induced correlation between financial wealth and consumption satiety. To see this, assume the econometrician has access to the entire population of consumers. (In this case, we do not have to consider the properties of the sample.) First, it is easy to see that projects that are intermediary funded will not have any obvious effect on the correlation of consumption with portfolio performance. However with crowdfunding, this is not the case.

Proposition 6. *A project that is crowdfunded leads to covariance between the consumer's portfolio performance and consumption. The sign of the covariance is the sign of* $P_h - P_\ell > 0$.

It is difficult to know how to quantify the welfare effects of the increase in variance of utility outcome that a correlation between consumption and wealth induces. As far as we know, this was not part of the discussion around the limits to investment mandated by the JOBS act. However, policy makers should be aware of this natural consequence of crowdfunding with resale.

5 Conclusion

We have presented a simple model of crowdfunding that emphasizes the role of consumer surplus. It is standard to take Fisher separation as given. However, with crowdfunding, this distinction is no longer in place and so we should expect the properties of crowdfunded projects to differ from those that are funded by traditional methods.

We stress that crowdfunded projects are not different because firms and entrepreneurs now have access to cheaper capital and face a smaller regulatory hurdle, but because the criteria for "a good project" differ. Further, given that consumers typically have shorter horizons than traditional funders, whether the crowdfunding method allows them to resell their claims will affect the types of projects that they are willing to invest in, and may also explain part of the interest in ICOs.

Finally, we note that a long literature considers the benefit of patents to encourage innovation and investment. The role of a patent is to protect market share, and allow the innovating firm to extract rents or in other words to reduce the consumer surplus. Crowdfunding in as much as it acts as a pre-commitment by the consumers to buy the output of the project, can encourage projects that might not be financed by traditional financing channels: It is analogous to a patent issued by the consumer.

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A Appendix

A.1 Additional results for Section 3

To determine the total surplus with investment uncertainty, we denote the conditional expectation of future consumer value from the project given the current state by $\mathbf{V}_s$ for $s \in \{h, l\}$. Then for any $t \geq 1$, we have

$$\mathbf{V}_s := \mathrm{E}\left\{ \sum_{\tau=t+1}^{\infty} \delta^{\tau-t} v_\tau \mid s_t = s \right\}. \tag{20}$$

Recursively, $\mathbf{V}_h$ and $\mathbf{V}_l$ solve

$$\mathbf{V}_h = \frac{\delta q_h}{1-\delta q_h} v + \frac{\delta(1-q_h)}{1-\delta q_h} \mathbf{V}_l \qquad \text{and} \qquad \mathbf{V}_l = \frac{\delta(1-q_l)}{1-\delta q_l}(v + \mathbf{V}_h). \tag{21}$$

Here, $\mathbf{V}_h$ is the the present value of v until the first time that the state changes to l, at which point the value is $\mathbf{V}_l$. The $\mathbf{V}_l$ is the present value of $v + \mathbf{V}_h$, which is the value at the first chance the state changes to h. It follows that

$$\begin{aligned} \mathbf{V}_h &= \frac{q_h + \delta(1-q_h-q_l)}{1+\delta(1-q_h-q_l)} \frac{\delta v}{1-\delta}; \\ \mathbf{V}_l &= \frac{1-q_l}{1+\delta(1-q_h-q_l)} \frac{\delta v}{1-\delta}, \end{aligned} \tag{22}$$

which are well defined since $1 + \delta(1-q_h-q_l) > 0$.[12]

Since the state at $t = 1$ is high ($s_1 = h$) by assumption, the present value of all consumer value at $t = 0$ is

$$\tilde{\mathbf{V}} := \delta(v + \mathbf{V}_h) = \left(\frac{1-\delta q_l}{1+\delta(1-q_h-q_l)} \right) \frac{\delta v}{1-\delta}. \tag{23}$$

The first-best is achieved when the project is funded if and only if $\tilde{\mathbf{V}} > I$.

Since the revenue of the project is still a fraction $1-\alpha$ of the consumer value each period, the linearity of the expectation implies that the intermediary's valuation with investment uncertainty is simply

$$\tilde{\mathbf{V}}^b = (1-\alpha)\tilde{\mathbf{V}}, \tag{24}$$

analogous to Equation (4).

To find the consumers' valuation, recall that in this section, for simplicity, we assume $\lambda = 1$. Without resale, the funding consumers enjoy the output for the next period only.

[12] Note $1 + \delta(1-q_h-q_l) \geq q_h + \delta(1-q_h-q_l)$, with equality if and only if $q_h = 1$; the RHS can be written as $(1-\delta) q_h + \delta(1-q_l) \geq 0$, which is strict if $q_h = 1$.

Hence, without resale, the consumer's $t = 0$ valuation is

$$\tilde{\mathbf{V}}^c = \delta v, \tag{25}$$

which is strictly less than $\tilde{\mathbf{V}}$. It is higher than $(1-\delta)\tilde{\mathbf{V}}$, which we would obtain from substituting $\lambda = 1$ into Equation (6) because of the assumption that the state is high at $t = 1$.

With resale, the consumers' valuation increases to

$$\tilde{\mathbf{V}}^r = \tilde{\mathbf{V}}^c + \delta (1-\alpha) \mathbf{V}_h = \delta (v + (1-\alpha) \mathbf{V}_h), \tag{26}$$

where $(1-\alpha)\tilde{\mathbf{V}}_h$ is the price that consumers at $t = 1$ are willing to pay for the stream of output conditional on the project continuation because only the funding consumers can commit to pay for their surplus. Again, the consumers' valuation with resale $\tilde{\mathbf{V}}^r$ is as high as $\tilde{\mathbf{V}}^c$ and $\tilde{\mathbf{V}}^b$. It is less than $\tilde{\mathbf{V}}$ as long as the consumers have any bargaining power ($\alpha > 0$). The efficiency comparisons in Section 2 remain essentially unchanged.

The following formalizes the assumption that speculators are more pessimistic than consumers in both states.

Assumption 1. *The conditional transition matrices Q and $Q^{'}$ are such that the speculators' valuation for the claim is lower than the consumers' valuation for the claim in both states, i.e.*

$$\begin{aligned} \frac{q_h + \delta (1 - q_h - q_l)}{1 + \delta (1 - q_h - q_l)} &> \frac{q_h^{'} + \delta \left(1 - q_h^{'} - q_l^{'}\right)}{1 + \delta \left(1 - q_h^{'} - q_l^{'}\right)}; \\ \frac{1 - q_l}{1 + \delta (1 - q_h - q_l)} &> \frac{1 - q_l^{'}}{1 + \delta \left(1 - q_h^{'} - q_l^{'}\right)}. \end{aligned} \tag{27}$$

A.2 Proofs

Proof of Proposition 1. It directly follows from the main text. □

Proof of Proposition 2. It directly follows from the main text. □

Proof of Proposition 3. It directly follows from the main text. □

Proof of Proposition 4. Denote by $q(h)$ and $q(l)$ the probabilities of staying in state h and l respectively from the perspective of the owner of claim in each state in equilibrium.

Then the equilibrium price $\mathbf{P}_h^*$ and $\mathbf{P}_l^*$ solve

$$\begin{aligned}\mathbf{P}_h^* &= \frac{\delta q(h)}{1-\delta q(h)}(1-\alpha)v + \frac{\delta(1-q(h))}{1-\delta q(h)}\mathbf{P}_l^*; \\ \mathbf{P}_l^* &= \frac{\delta(1-q(l))}{1-\delta q(l)}(v+\mathbf{P}_h^*).\end{aligned} \tag{28}$$

The owner of the claim in each state is the trader who is willing to pay the most for the claim in that state. To determine the owner of the claim in high state, notice that

$$\frac{\partial \mathbf{P}_h^*}{\partial q(h)} = \frac{\delta}{(1-\delta q(h))^2}\left((1-\alpha)v - (1-\delta)\mathbf{P}_l^*\right). \tag{29}$$

Thus, $\frac{\partial \mathbf{P}_h^*}{\partial q(h)} > 0$ if and only if

$$\mathbf{P}_l^* < \frac{(1-\alpha)v}{1-\delta}, \tag{30}$$

which is always the case because the RHS is the present value of receiving $(1-\alpha)v$ in all states. And from (28), we have

$$\frac{\partial \mathbf{P}_l^*}{\partial q(l)} < 0. \tag{31}$$

$\mathbf{P}_h^*$ increases in $q(h)$ holding $\mathbf{P}_l^*$ constant and $\mathbf{P}_l^*$ decreases in $q(l)$ holding $\mathbf{P}_h^*$ constant.

Now, consider the four exclusive and exhaustive cases: (i) $q_h^{'} > q_h$ and $q_l^{'} \geq q_l$; (ii) $q_h^{'} \leq q_h$ and $q_l^{'} < q_l$; (iii) $q_h^{'} \leq q_h$ and $q_l^{'} \geq q_l$; (iv) $q_h^{'} > q_h$ and $q_l^{'} < q_l$.

In case (i), the speculator holds the claim in high state and the consumers hold the claim in low state. In case (ii), the consumers hold the claim in high state and the speculator holds the claim in low state. Hence, the price is higher than their independent valuations, i.e. there is a speculative premium in cases (i) and (ii). In case (iii), the consumers hold the claim in both states. In case (iv), the speculator holds the claim in both states. Hence, there is no speculative premium in cases (iii) and (iv).

To find the equilibrium price, we substitute the owner's probability into Equation (28). In case (i), substituting $q(h) = q_h^{'}$ and $q(l) = q_l$ into Equation (28) and solving for $\mathbf{P}_h^*$ and $\mathbf{P}_h^*$ yields

$$\begin{aligned}\mathbf{P}_h^* &= \frac{q_h^{'} + \delta\left(1-q_h^{'}-q_l\right)}{1+\delta\left(1-q_h^{'}-q_l\right)}\frac{\delta(1-\alpha)v}{1-\delta}; \\ \mathbf{P}_l^* &= \frac{1-q_l}{1+\delta\left(1-q_h^{'}-q_l\right)}\frac{\delta(1-\alpha)v}{1-\delta}.\end{aligned} \tag{32}$$

In case (ii), substituting $q(h) = q_h$ and $q(l) = q_l^{'}$ into Equation (28) and solving for $\mathbf{P}_h^*$ and $\mathbf{P}_h^*$ yields

$$\mathbf{P}_h^* = \frac{q_h + \delta\left(1 - q_h - q_l^{'}\right)}{1 + \delta\left(1 - q_h - q_l^{'}\right)} \frac{\delta\left(1-\alpha\right)v}{1-\delta};$$
$$\mathbf{P}_l^* = \frac{1 - q_l^{'}}{1 + \delta\left(1 - q_h - q_l^{'}\right)} \frac{\delta\left(1-\alpha\right)v}{1-\delta}. \tag{33}$$

□

Proof of Proposition 5 From Equation (19), speculation causes overinvestment (i.e. $\tilde{\mathbf{V}}^s > \tilde{\mathbf{V}}$) if and only if

$$\alpha \mathbf{V}_h < \mathbf{P}_h^* - \mathbf{P}_h. \tag{34}$$

Since $\mathbf{P}_h = (1-\alpha)\mathbf{V}_h$, we can write above as

$$\frac{\alpha}{1-\alpha} < \frac{\mathbf{P}_h^*}{\mathbf{P}_h} - 1. \tag{35}$$

Rearranging this, we have

$$\alpha < 1 - \frac{\mathbf{P}_h}{\mathbf{P}_h^*}. \tag{36}$$

Hence, speculation mitigates underinvestment if $\alpha \geq \alpha_{min}$ and causes overinvestment if $\alpha < \alpha_{min}$.

□

Proof of Proposition 6 Let $[\pi_h \; \pi_\ell]$ denote the unique stationary distribution, where

$$\pi_h = \frac{(1-q_\ell)}{(1-q_h)+(1-q_\ell)} \tag{37}$$

$$\pi_\ell = \frac{(1-q_h)}{(1-q_h)+(1-q_\ell)} \tag{38}$$

If the consumers crowd fund a project, then the covariance of consumption with financial wealth is

$$(\pi_h v \mathbf{P}_h + (1-\pi_h)0\mathbf{P}_\ell) - \pi_h v \left(\pi_h \mathbf{P}_h + (1-\pi_h)\mathbf{P}_\ell\right). \tag{39}$$

which is positive if and only if

$$\mathbf{P}_h \geq \mathbf{P}_\ell. \tag{40}$$

Using the expressions presented in Equations (22), we obtain

$$\mathbf{P}_h \geq \mathbf{P}_\ell \tag{41}$$

$$q_h + \delta(1 - q_h - q_\ell) \geq (1 - q_\ell) \tag{42}$$

A sufficient condition is If $q_h + q_\ell > 1$. $\square$