A Theory of Crowdfunding Dynamics

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What is Crowdfunding?

Crowdfunding:
Open call to many small contributors (usually online).

Reward-based crowdfunding:
- Funders buy a product that the entrepreneur will produce after the campaign.
- Crowdfunding is a form of pre-selling to cover production costs.
- Funders bid the price of the crowdfunding product.
  (we call them bidders)
Reward-Based All-or-Nothing Crowdfunding

Canonical format

- **Aggregate Fund Threshold**: funding goal
- **AoN**: succeeds if funds reach goal by deadline, else fails
  
  \[ S \text{ (success)} \rightarrow \text{Bids paid, production occurs, rewards delivered}; \]
  
  \[ F \text{ (failure)} \rightarrow \text{Bids reimbursed, no production}. \]

- Reward-based AoN crowdfunding is a popular choice because:
  
  It is easy to initiate in practice;
  
  Gives to entrepreneurs a market-test that protects from demand uncertainty.
Popular reward-based crowdfunding platforms

- **Kickstarter (US)**
  235 ML financed projects, 7 BN USD raised from 2009 as of 2023.

- **Indiegogo (US)**
  800 K financed projects, 2 BN USD raised since 2009 as of 2023.

- **Kisskissbankbank (FR)**
  33 K financed project, 150 ML EUR raised from 2009 as of 2023.

- **Verkami (SP)**
  12 K financed projects, 50 ML EUR raised from 2010 as of 2023.

- **Produzioni Dal Basso (IT)**
  8 K financed projects, 23 ML EUR raised from 2005 as of 2023.
Popular reward-based crowdfunding platforms

- **Kickstarter** (US)
  235 ML financed projects, 7 BN USD raised from 2009 as of 2023.
  (Recently announced future integration with the blockchain Celo)

- **Indiegogo** (US)
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There is also crowdfunding taking place outside big platforms.
(Radiohead’s album “In Rainbows” was financed with crowdfunding in 2007 directly on the band’s website)
Anatomy of a crowdfunding campaign

**KICKSTARTER**

**Name and slogan**

**KINDALU**: a new cable case, that solves all cable problems

All your cable frustrations - solved with a twist of your finger! 3D PRINTED - UNTANGLE THE CHAOS

---

**Promotional video**

**Blog**

**Remind me button**

**Funding gap = 1.000€ - 875€ = 125€**

**Contribution without reward**

Support him because you believe in this project.
Support the project without any reward, do so if it really inspires you.

**Contribution of €50 or more**

KICKSTARTER ALL 3 PACK (1.5M + 2M + 3M)
10% OFF
Get a super discounted KINICAL ALL THREE PACK (1.5M + 2M + 3M)

KINDALU 1.5M - Holds cables up to 1.5 meters (50") long.
KINDALU 2M - Holds cables up to 2 meters (80") long.
KINDALU 3M - Holds cables up to 3 meters (100") long.

Shipping costs will be determined once the campaign is over in order to secure the best shipping option.

Estimated delivery date: Jun 2020 Worldwide

<table>
<thead>
<tr>
<th>Pledge Level</th>
<th>Quantity</th>
<th>Limitation</th>
<th>Delivery Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 supporters</td>
<td>100</td>
<td>Worldwide</td>
<td>Jun 2020</td>
</tr>
</tbody>
</table>
Statistics from Kickstarter

- **Bids**:  
  Heavily right-skewed funding distribution:  
  60 bidders in median, most bidding once per campaign.

- **Duration**: often 30 or 60 days.

- **Goal**: 5 K USD in median (median pledge: 25 USD), but heterogeneous across categories:  
  (bigger for technology, games, design; smaller for music, food, crafts).

- **Success rate**: 30-40%.
Empirical puzzle

- Average time profile of bids is a “U-shape” for successful campaigns and an “L-shape” for failed campaigns.

What incentives drive these patterns?

Can we use them to assess the welfare implications of current crowdfunding practices?

Can we use them to optimize platform and campaign design?
Bid dynamics originate when production uncertainty faced by bidders combines with sunk bidding costs:

- **Aggregate Fund Threshold**: funding goal $\Rightarrow$ strategic complementarity
- **AON**: succeeds if funds reach goal by deadline, else fails
  - $S$ (success) $\rightarrow$ Bids paid, production occurs, rewards delivered;
  - $F$ (failure) $\rightarrow$ Bids reimbursed, no production
  $\Rightarrow$ no sunk costs in prior works

But inspection involves sunk costs.

So real-time disclosure of bidding aggregates creates dynamic interactions:

Bidders sunk the bidding cost only if their estimate of the campaign’s success probability is sufficiently high.
Contribution of this paper

- Characterize co-evolution of bidding and project success rates.
  - Pivotality often substantial given sequential moves
    (30% of campaigns attract < 20 bids)
- Welfare implications of funding disclosure (transparency).
- Optimal price and threshold.
- Price dynamics via price menus with limited quantities.

Closest Papers

- Deb et al (2021)
- Ellman & Hurkens (2019)
Model

**Campaign**

- Price $p$
- Bidder gap $g_0 \in \mathbb{N}_+$.
  (everyone pays the same price: funding gap $\rightarrow$ bidder gap)
- Deadline $\tau \in \mathbb{R}_+$ (outcome determined at $\tau_+$).
- Time $t \rightarrow$ time left $\tau - t$

**Bidders**

- Poisson arrival rate $\lambda$ of bidders over $[0, \tau]$
- Valuations $v_t = \begin{cases} v & q \\ 0 & 1 - q \end{cases}$
- Inspection costs $c_t$ drawn from CDF $F(\cdot)$ on $[0, q]$
Model

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Bidder $t$ observes the funding state $(t, g)$ on arrival

- He also knows $(c_t, g_0, \tau, p, \lambda, q)$

Success probability — (funding) state $(t, g)$:

$$S_{(t,g)} \triangleq \mathbb{P}(S|(t, g)) = \mathbb{E}_{(t,g)} \left( I_{g_{\tau^+} \leq 0} \right)$$

Strategies $a : (t, g, c) \rightarrow \{A, B, C\}$ and their expected payoffs

- A — no inspection, no bid $\rightarrow U^A_{(t,g)} = 0$
- B — no inspection, bid
- C — valuation-contingent bid $\rightarrow$

$$U^C_{(t,g)} = qS^{bid}_{(t,g)}d - c_t \quad d = v - p \quad S^{bid}_{(t,g)} = S_{(t,g-1)}$$
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Strategies and equilibrium

- Bidder $t$ observes the funding state $(t, g)$ on arrival
  - He also knows $(c_t, g_0, \tau, p, \lambda, q)$

- Success probability — (funding) state $(t, g)$:
  $$S_{(t,g)} \triangleq \mathbb{P}(S|(t,g)) \equiv \mathbb{E}_{(t,g)} \left( \mathbb{1}_{g_{\tau+} \leq 0} \right)$$

- Strategies $a : (t, g, c) \rightarrow \{A, B', C\}$ and their expected payoffs
  - $A$ — no inspection, no bid $\rightarrow U_{(t,g)}^A = 0$
  - $B'$ — precluded by low $q$ or large $p$
  - $C$ — valuation-contingent bid $\rightarrow$
    $$U_{(t,g)}^C = q S_{(t,g)}^{\text{bid}} d - c_t \quad d = v - p \quad S_{(t,g)}^{\text{bid}} = S_{(t,g-1)}$$
Bidder $t$ observes the funding state $(t, g)$ on arrival
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Success probability — (funding) state $(t, g)$:

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Success probability — (funding) state $(t, g)$:

$$S_{(t,g)} \triangleq P(S \mid (t, g)) \equiv \mathbb{E}_{(t,g)} \left( \mathbbm{1}_{g_{\tau+} \leq 0} \right)$$

Strategies $a : (t, g, c) \to \{A, B', C\}$ and their expected payoffs
- $A$ — no inspection, no bid $\rightarrow U^A_{(t,g)} = 0$
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- $C$ — (valuation-)contingent bid $\rightarrow$

$$U^C_{(t,g)} = qS^{\text{bid}}_{(t,g)} - c_t \quad \text{normalization: } d = 1 \quad S^{\text{bid}}_{(t,g)} = S_{(t,g-1)}$$
Unique PBE; threshold strategies:

\( C \) if \( c_t \leq qS_{(t,g)}^{\text{bid}} \triangleq qS_{(t,g-1)} \), else \( A \).

Bidding rate: \( \beta_{(t,g)} = \lambda qF \left( qS_{(t,g)}^{\text{bid}} \right) \).

Success rate

Using terminal conditions, \( S_{(\tau,g)} = 0 \) for \( g > 0 \), \( S_{(\tau,g)} = 1 \) for \( g \leq 0 \),

\[
S_{(t,g)} = \int_t^\tau \left[ \exp \left( -\int_t^x \beta_{(u,g)} \, du \right) \beta_{(x,g)} \right] S_{(x,g-1)} \, dx \quad \text{(REC-S)}
\]

\( \text{(REC-S)} \) is an opaque expression, so we use stochastic calculus and a martingale insight to disentangle it.
Equilibrium

Unique PBE; threshold strategies:

\[ C \text{ if } c_t \leq qS_{(t,g)}^{\text{bid}} \triangleq qS_{(t,g-1)}, \text{ else } A. \]

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C if $c_t \leq qS_{(t,g)}^{\text{bid}} \triangleq qS_{(t,g-1)}$, else A.

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(REC-S) is an opaque expression, so we use stochastic calculus and a martingale insight to disentangle it.
Two effects describe the evolution of bidding rates from an initial date $t$, at a known gap $g$, to a future date $x$ with a stochastic future gap $g_x$:

$$E_{(t,g)} \left( \beta_{(x,g_x)} \right) - \beta_{(t,g)} = \lambda q \left[ \mathcal{E}_{x}^{(t,g)} + \mathcal{N}_{x}^{(t,g)} \right]$$
By LIE, $S_{(t,g_t)}$ is a martingale w.r.t. to the natural filtration of $g_t$. That is,

$$\mathbb{E}_{(t,g)} \left( S_{(x,g_x)} \right) = S_{(t,g)}$$

On the other hand, **Pivotality**, 

$$\Delta S_{(t,g_t)} \triangleq S_{(t,g_t-1)} - S_{(t,g_t)}$$

is a supermartingale (decreases in expectation).

Strategic complementarity falls (on average) since a later bidder expects to have fewer bidders arriving after him.

Combining the two insights, the bid-conditional success rate

$$S_{(t,g_t)}^{\text{bid}} = S_{(t,g_t)} + \Delta S_{(t,g_t)}$$

is also a supermartingale.
Decreasing pivotality (DP)

- By LIE, $S_{(t,g_t)}$ is a martingale w.r.t. to the natural filtration of $g_t$. That is,

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- Strategic complementarity falls (on average) since a later bidder expects to have fewer bidders arriving after him.

- Combining the two insights, the bid-conditional success rate

$$
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By LIE, \( S_{(t,g_t)} \) is a martingale w.r.t. to the natural filtration of \( g_t \). That is,

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\mathbb{E}(t,g) \left( S_{(x,g_x)} \right) = S_{(t,g)}
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On the other hand, **Pivotality**, \( \Delta S_{(t,g_t)} \triangleq S_{(t,g_{t-1})} - S_{(t,g_t)} \)

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Strategic complementarity falls (on average) since a later bidder expects to have fewer bidders arriving after him.

Combining the two insights, the bid-conditional success rate \( S_{(t,g_t)}^{\text{bid}} = S_{(t,g_t)} + \Delta S_{(t,g_t)} \)

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Decreasing pivotality (DP)

- By LIE, \( S_{(t,g_t)} \) is a martingale w.r.t. to the natural filtration of \( g_t \). That is,

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\mathbb{E}((t,g) \left( S_{(x,g_x)} \right)) = S_{(t,g)}
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- On the other hand, \textit{Pivotality},

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- Combining the two insights, the bid-conditional success rate

\[
S_{(t,g_t)}^{\text{bid}} = S_{(t,g_t)} + \Delta S_{(t,g_t)}
\]

is also a supermartingale.
The first is the **pivotality effect (PE):** $\mathcal{E}_{x}^{(t,g)}$.

PE is the effect of the *expected* decreasing pivotality trend.

It is *always* negative or null (in trivial cases).

\[
\mathcal{E}_{x}^{(t,g)} \triangleq F \left( \mathbb{E}_{(t,g)} \left( qS_{(x,g_x)}^{\text{bid}} \right) \right) - F \left( qS_{(t,g)}^{\text{bid}} \right)
\]
The second effect is the **News effect (NE)**: $N_x^{(t,g)}$.

NE is the effect of the **variance** in the funding gap:

Bidding is stochastic simply because of preference shocks and random arrivals. Bidders learn good or bad news depending on the gap they observe upon arrival.

NE is determined by the sensitivity to news of the bidder population:

- Null NE with linear cumulative inspection cost distribution $F$
- Negative NE with a concave $F$ (↓ returns to good news)
- Positive NE with a convex $F$ (↑ returns to good news)

Technically, the sign of the NE results from Jensen’s inequality:

$$N_x^{(t,g)} \triangleq \mathbb{E}_{(t,g)} \left( F \left( qS_{(x,g_x)}^{\text{bid}} \right) \right) - F \left( \mathbb{E}_{(t,g)} \left( qS_{(x,g_x)}^{\text{bid}} \right) \right)$$
Combining the two effects:

\[ \implies \text{Bid rate falls with concave or linear } F \]
\[ \implies \text{Bid rate rises with convex } F \text{ if } |N| > |E| \]
Empirically salient funding patterns
Welfare

\[ W = V + R S_0 \]

- We assume \( E \)'s utility from success = \( R \) & neglect revenues.
- Realized arrival sequence \( \{t_n\}, n = 1, 2, ..., N \).
- Bidder surplus:

\[
V = \mathbb{E} \left( \sum_{n=1}^{N} u^{a(t_n, g_n, c_n)} \right) = \lambda \tau \mathbb{E} \left( U^{a(t, g_t, c_t)} \right) \quad \text{Poisson arrivals}
\]
Welfare: $W = V + RS_0$

- We assume E’s utility from success $= R$ & neglect revenues.
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Poisson arrivals
Welfare

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\]

Poisson arrivals
In the baseline model the gap is disclosed in real time.

Is transparency good for welfare?

To answer this question, we compare our baseline (SEQ) to a no-information benchmark (SIM).

In SIM, bidders arrive sequentially but do not observe $g_t$.

Equilibrium strategies use a constant threshold type $\hat{c}(t, g_t) = \hat{c}$
Welfare comparison of SIM and SEQ

- While in SIM surplus contributions are constant over time, in SEQ they decrease.
- DP and NE manifest themselves also in the welfare analysis:
  1. (infra-marginals): Surplus of types $c_t \leq \hat{c}$ decreases due to DP.
  2. (semi-marginals): Good-news effects from a bid activates types $c_t \in (\hat{c}_{(t,g)}, \hat{c}_{(t,g-1)})$.
- SEQ yields higher welfare than SIM for polarized inspection costs.
- SIM yields higher welfare than SEQ when inspection costs are sufficiently concentrated (homogenous case).
- Intermediate information structures can improve on both SIM and SEQ.
Conclusion

Main takeaways

- Characterization of bidding profiles with 2 new forces: pivotality and news effects
  - These effects combined with heterogeneous costs explain observed bidding profiles.

- Cost diversity and adverse conditions can explain real-time disclosure.
  - Partial disclosure can raise welfare

- Framework reveals price-threshold tradeoff, identifies optimal price dynamics, and allows for study of welfare effect of gap-dependent pricing.

Next:

- Endogenous timing via option to delay (E and F 2021).
- Common value.
Thank you for your attention!

For the paper and the blog post, scan the QR codes below:

Paper

BSE Focus