Up-Cascaded Wisdom of the Crowd

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Motivation

- Crowdfunding
  - Arts and creativity-based industries.
  - Donation- and reward-based platforms.
  - JOBS Act and equity-based platforms. MicroVentures;Wefunder;SeedInvest;StartEngine;Republic
  - 34.4 billion in 2016 and heading towards 1 trillion in 2025.
- Salient features:
  - Sequential investors and dynamic learning.
  - All-or-nothing target.
  - Dual purpose of financing and information aggregation.

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- Classical information cascade, plus AoN.
  - Sequential investors with private signals.
  - Dynamic observational learning.
  - Exogenous ordering.
  - Exogenous or endogenous AoN target.
- Other examples
  - Super-majority rule in voting
  - Venture or angel financing.
  - Public-goods provision.
  - Public issuance of securities.
  - Technology and fashion adoption.

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Preview of Results

- Standard cascade vs AoN cascade
- Types: UP & DOWN vs only UP.
- Timing of cascade: immediate vs delayed.
- Endogenous pricing: underpricing vs aggressive-pricing.
- Interaction & multiplicity: absent vs present.
- Options to wait: not robust vs robust.

Preview of Results

- Standard cascade vs AoN cascade
- Financing Efficiency:
  - Success probability: same vs more good projects
  - Good projects with costly production: abandoned vs financed
  - Investor base: independent vs beneficial
- Information Efficiency
  - Information production: no vs yes .
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Literature

- Information cascades, social learning, and rational herding.
  - **Bikhchandani et al (1992)**; **Welch (1992)**; Chamley (2004); Bikhchandani et.al. (1998).
  - Anderson and Holt (1997); Celen and Kariv (2004); Hung and Plott (2001).
  - Guarino et al (2011); Herrera and Horner (2013).
- Crowdfunding
  - Preliminaries: Agrawal et.al. (2014); Belleflamme et.al. (2014)
  - Wisdom and learning: Mollick and Nanda (2015); Zhang and Liu (2012); Burtch et.al. (2013).
  - Entrepreneurial finance: Gompers and Lerner (2004); Kerr et.al. (2014); Gompers et.al. (2016); Abrams (2017).
  - Real option: Chemla and Tinn (2016); Xu (2017); Viotto da Cruz (2016).

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Literature

- Role of AoN
  - Benefits: Strausz (2017); Chemla and Tinn (2016); Chang (2016); Lau (2013, 2015); Cumming et.al. (2014).
  - Bagnoli and Lipman (1989); Bond and Goldstein (2015).
- Information Efficiency and Pricing in Crowdfunding
  - **Brown and Davies (2017)**
  - **Hakenes and Schlegel (2014)**
  - Our paper: endogenous AoN, dynamic learning, cascade benchmark instead of static auction.

Outline

- Introduction
- **Setup & AoN**
- Financing & Information Aggregation
- Discussion & Conclusion

Model Setup

- Standard Bikhchandani, Hirshleifer and Welch (1992 JPE)
- Risk-neutral world.
- Project: payoff $V \in \{0, 1\}$, equal probability.
- Sequence of investors $i = 1, 2, ..., N$.
  - Support or reject. $A_i \in \{S, R\}$.
  - Order is exogenous and known to all.
  - Contribute m, and receives $V \in \{0, 1\}$.
  - Conditionally independent private signal $X_i \in \{H, L\}$.
  - $Pr(X_i = H|V = 1) = Pr(X_i = L|V = 0) = p \in (\frac{1}{2}, 1)$.
- Entrepreneur/Proponent (if present)
  - Potentially sets price m and AoN target T_N.

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Investor Learning and Optimization

- Investor i observes X_i and $\mathcal{H}_{i-1} \equiv \{A_1, A_2, ..., A_{i-1}\}$.
- She maximizes
  $\max_{A_i} \left[E\left(V|X_i, \mathcal{H}_{i-1}, N_S \geq T_N\right) - m\right] \mathbb{1}_{\{A_i = S\}}$
- When $E\left(V|X_i, \mathcal{H}_{i-1}, N_S \geq T_N\right) = m$, we assume that:

Assumption (Tie-breaking)

When indifferent between supporting and rejecting, an investor supports if the AoN target is possible to reach (positive probability), and rejects otherwise.

Entrepreneur Learning and Optimization

- Sometimes price and AoN are exogenous (think of legacy voting rules).
- Sometimes they are endogenously determined by the entrepreneur.
- Per contribution cost ν.
- He maximizes
  $\max_{m,T_N} \ \pi(m, T_N, N) = E[(m-\nu)N_S \mathbb{1}_{\{N_S \geq T_N\}}]$

Posterior Dynamics

- Independent of total number of observations (Bikhchandani, Hirshleifer, and Welch (1992)).
- An investor's expected project cash-flow conditional on observing k more H signals is $E(V|k \text{ more } H \text{ signals}) = \frac{p^k}{p^k+q^k}$.

The AoN Difference

- No DOWN cascades before approaching AoN.
- For investors with H signals:
  - For the investor observes $T_N^* - 1$ support (the "gate-keeper", she chooses to support if and only if $E(V) \geq m^*$ given all information available.
  - So investors with H always support before reaching AoN.
- For investors with L signals:
  - If she deviates to support;
  - All follow investors will misinterpret her action;
  - UP-cascade starts too early (posterior is not high enough);
  - Reaching T_N^* when there are actually not enough good signals.

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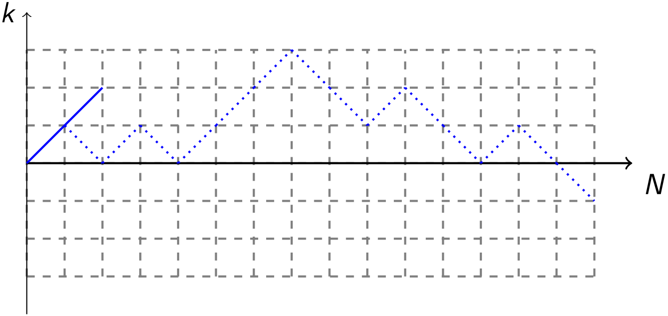
Investor with Negative Signal

- Suppose the price $m^* = E(V|1 \text{ more } H \text{ signal})$;
- Suppose investor 2 deviates:



Misleading Action that Backfires

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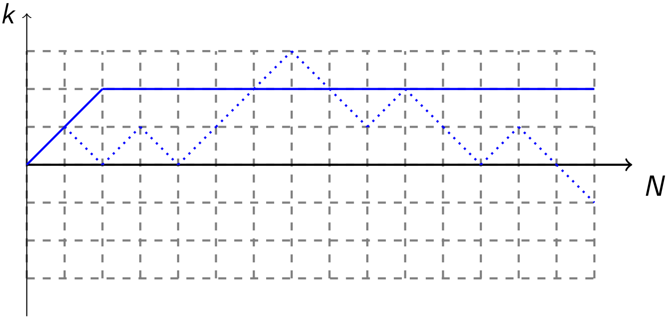

- The UP-cascade starts when the true posterior is $0 < k_m = 1$.

Up-Cascaded Equilibrium

Proposition

1. *Given the investment contribution (price)* $m \in (0,1)$, *the corresponding AoN target* $T_N^* \leq N$ *satisfies:*

$$E(V|T_N^*, N) \leq m < E(V|T_N^* + 1, N), \tag{1}$$

   where $E(V|x, N)$ *is the posterior mean of* V *given there are* x *number of* H *signals out of* N *observations;*

2. *Investors with signal* H *always support the project;*
3. *Investor* i *with signal* L *contributes if and only if:*

$$E(V|k-1 \text{ more } H \text{ signals}) \geq m, \tag{2}$$

   where k *is difference between the numbers of supporting and rejecting predecessors before investor* i.

Equilibrium Paths

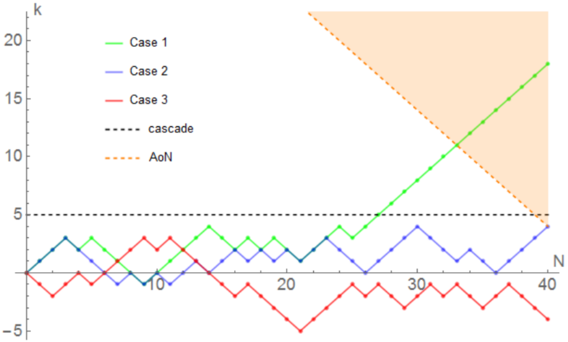

Figure: Evolution of Support-Reject Differential

Simulated paths for $N = 40$, $p = 0.7$, $m^* = m_5 = 0.9673$, and AoN target $T^*(N) = 22$. Case 1 indicates a path that crosses the cascade trigger $k = 5$ at the 26th investor and all subsequent investors support regardless of their private signal; case 2 indicates a path with no cascade, but the project is still funded by the end of the fundraising; case 3 indicates a path where AoN target is not reached and the project is not funded. The orange shaded region above the AoN line indicates that the project is funded.

The Impact of AoN

- For any AoN target:
  - Before the AoN target is reached: No DOWN-cascade;
  - After the AoN target is reached: Standard cascade (possible DOWN-cascade).
- With endogenous pricing Welch (1992)
  - Underpricing to prevent DOWN cascades.
  - Price independent of N and costly projects are abandoned.
  - UP-cascade starts from the beginning and no information aggregation.
- With AoN:
  - Optimal AoN is essentially the smallest possible target that excludes DOWN-cascade.
  - Two instruments (T_N and m) to avoid down-cascade.

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Intuition for Pricing

- Benefit of higher price: Collect more money conditional on implementation;
- Cost of higher price:
  - Delay of UP cascade implies a smaller number of supporting investors;
  - Lower probability of implementation.
- Large investor base N mitigates the potential cost.

Pricing with AoN Target

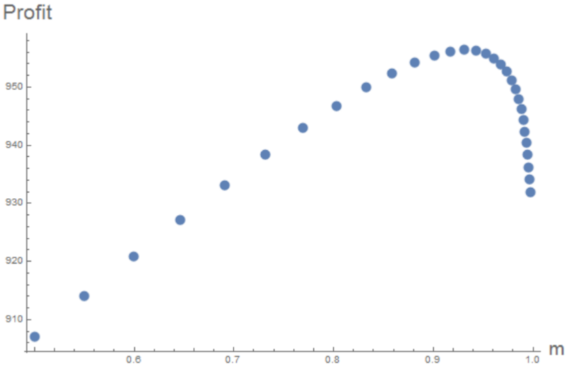

Figure 2: Optimal Pricing: An Illustration with $N = 2000$ and $p = 0.55$.

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- Exclusion of DOWN cascades.
- Upper bounds for pricing in standard cascades.
- Interim information generation.

Proposition

Without AoN, no project with $\nu > p$ is financed and information aggregation is infeasible; committing to an AoN target enables fundraising and information aggregation even when $\nu > p$.

- E.g., good projects with $\nu > p$ cannot be financed without AoN.

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Benefits of a Large Crowd

Lemma

[Less Underpricing] For $\forall\ m_k$, there exists a a finite positive integer $N_\pi(m_k)$ such that for $\forall\ N \geq N_\pi(m_k)$, $m^* > m_k$.
$\lim_{N\to\infty} m^*(N) = 1$

Proposition

As $N \to \infty$, a good project with $V = 1$ is financed almost surely with an UP-cascade.

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Harnessing the Wisdom

- Correct cascade (UP cascade when $V = 1$)

$$Pr(V = 1 | cascade\ at\ i^{th}\ investor) = \frac{p^k}{p^k + q^k} \mathbb{I}_{\{i \geq k \& k+i\ is\ even\}} \tag{3}$$

- Higher price $m \rightarrow$ delayed UP cascade;
  - More information aggregation;
  - The probability of a cascade being correct is increasing.
- Larger $N \rightarrow$ higher m.
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Entrepreneur (Proponent)'s Real Option

- Further use of the information
  - Crowdfunding: Xu (2017) and Vitto da Cruz (2016)
  - 33% continue despite failure. 50% increase in proceeds leads to 9% higher commercialization.
  - IPO: van Bommel (2002); Corwin and Schultz (2005)
- Suppose V reflects transformed aggregate demand, and I is commercialization cost, then expected payoff from commercialization is

$$\max\{\mathbb{E}[V - I|H_N], 0\} \tag{4}$$

- The posterior of V is increasing in equilibrium support gathered.

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Further Discussion

- Main results robust to agents' options to wait.
- Strategic forward-looking
  - Subsequent actions and higher-order beliefs matter.
  - Only two types: informer equilibrium (which we focus on) and free-rider equilibrium (a variant of informer euqilibrium).
- Free-rider equilibrium
  - Free-rider: subsequent agents ignore her action even before up-cascade.
  - As $N \to \infty$, prob of less than I informers goes to zero.
  - Optimal pricing still goes to 1 as $N \to \infty$.
  - In terms of financing efficiency and information production, two equilibria converge in the limit.

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Conclusion

- Mechanism
  1. Uni-directional cascade before AoN.
  2. Strategic interactions with future agents.
  3. Information aggregation before UP cascade.
  4. Aggressive pricing, full-range for large N.
- Economic implications.
  1. Increased financing efficiency.
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  3. Crowdfunding with large N can be beneficial.
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