Moonshots, Investment Booms, and Selection Bias in the Transmission of Cultural Traits

David Hirshleifer

UC Irvine

Joshua Plotkin

University of Pennsylvania

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(will be updated)

Why booms/busts in real financial activities?

- Periods of heavy adoption, collapse:
    - M&A, IPOs, industry-specific investment…
- Individual irrational exuberance?
- Social dynamics?

Biased transmission of information about others' project payoffs

- Large successes (+ Actions that led to them) more visible, salient to others than failures
  - Google, Facebook, heavily noticed
  - Hundred of failed startups little noticed
- Why are successes more visible?
  - Associated with extensive continuing economic transactions, which garners attention
  - Projects that fail tend to vanish

Selection neglect

- Failure of observers to adjust for bias
  - Nisbett & Ross (1980), Brenner, Koehler & Tversky (1996)
  - Financial context:
    - Koehler & Mercer (2009)
- These are the two key premises of our model
  - Payoff-selection-biased information transmission
  - Selection neglect

Quick intuition

- Project Adopt vs. Reject:
  - A cultural trait that is transmitted stochastically between firms
    - With bias
- Biased censorship
  - Failures more than successes

➔ Observers overestimate probability of success of risky projects

- Overadoption, especially of innovative “moonshots”
  - Moonshot:
    - Low Pr(Success), high upside
  - May be temporary (boom/bust)
- These dynamics reflect standard evolutionary effects on cultural traits
  - Darwinian selection
  - Mutation bias

Related literature

- Denrell (2003)
  - Firm failure less likely to be observed than success
  - Biases learning about traits characteristic of upper tail of successful firms
    - Suggests that promotes spread of high-variance, unreliable management practices
      - Concentrated organizational resource allocation, strong/inflexible corporate culture, tightly coordinated organizations, and confident/decisive/intuitive decision-making procedures

Related literature (2)

- Vs. our paper:
  - Focus on beliefs about whether a project should be adopted rather than about general firm/managerial practices
  - Allow for sequential choices
    - Explicitly model how selection bias affects firm *behavior*, not just beliefs
    - Observer in turn becomes the target of observation for the next agent
    - So implications for market outcomes, cascading effects of selection bias, booms and busts.
    - Analyze evolutionary effects of selection versus mutation pressure
    - Rather than just variance, we derive key results about effects of payoff asymmetry (moonshotness)

Related literature (3)

- Han, Hirshleifer & Walden (forthcoming)
  - Stock market investors randomly meet to discuss their strategies
  - Pr(Sender reports return) increasing in return
  - Investor has exogenous probability of copying sender's strategy
    - Increasing with reported return

  ➔ High variance strategies spread through population
- Our paper:
  - Focus on project choices by firms that update beliefs in a quasi-Bayesian fashion based on observation of a *sequence* of past payoffs by other firms
    - Vs. HHW, switching probability based upon the single observation during a meeting

  ➔ Boom/bust dynamics, novel comparative statics about moonshotness, decomposition of outcomes into the effects of selection vs. mutation pressure

The model

- Firms 1, 2, 3 … in sequence decide whether to adopt (A) or reject (R) a project
- Observe some payoffs/actions of predecessors
- Two states, *H* and *L*
- Payoff if reject: 0
- Payoff if adopt:

Table 1: Payoff Probabilities

	Payoff Outcome (v)	
State (θ)	V	-1
H	p	$1-p$
L	$1-p$	p

Adopt/reject expected payoffs

- Adopt/reject based on net expected value
- Parameter values such that:
  - Agent 1 adopts
  - Adopt better in state *H*, Reject better in state *L*
  - Prior expected value of adopting is positive
    - First firm adopts

Preliminary: No censorship of past payoffs/actions

- Standard rational Bayesian updating
- Consider a history in which everyone adopts
- Degree of optimism about *H* vs. *L* state bounces up and down randomly based on payoffs *V* or −1.
- History summarized by difference between # of each payoff, d_i

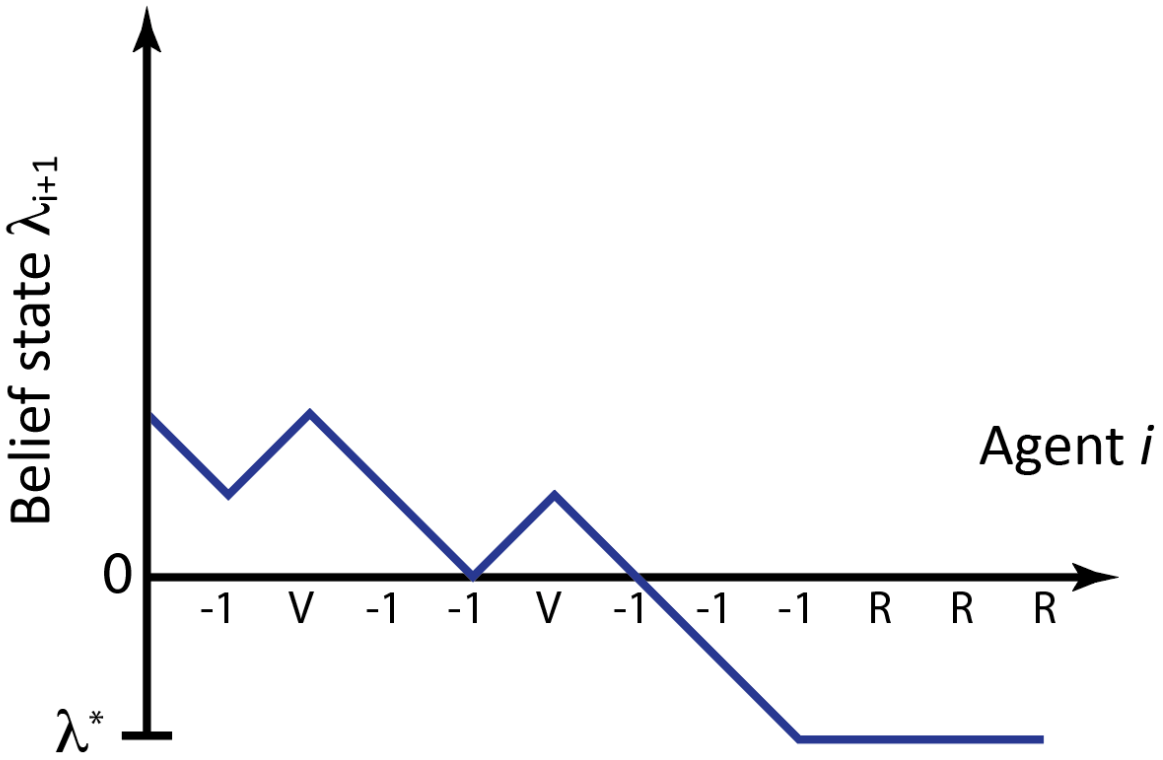
Preliminary: No censorship of past payoffs/actions

- Optimism:
  - Log Likelihood Ratio for beliefs about the two states, λ_i follows a random walk:

$$\lambda_{i+1} \equiv \log\left(\frac{P(H|d_i, v_{i+1})}{P(L|d_i, v_{i+1})}\right) = \log\left(\frac{P(v|H)}{P(v|L)}\right) + \lambda_i$$

  - State H: up probability p, down probability $1 - p$
  - State L: up probability $1 - p$, down probability p
- As long as agents still adopt, learning continues.
- Otherwise, absorption at $\lambda^* < 0$.
  - Thereafter rejection

A random walk in beliefs with no censorship



Lower absorbing barrier

- As soon as an agent rejects, no new payoff information

➔ All later agents reject

- Early bad news ➔ (possibly-mistaken) rejection forever

Proposition 1:

- State *H*:
  - $0 < P(\text{Adopt Forever}) < 1$
- State *L*:
  - $P(\text{Adopt Forever}) = 0$

Biased censorship of low payoffs, selection neglect

- Agents with high payoff, *V*, uncensored with probability $\delta \leq 1$
- Agent *i* with low payoff, –1
  - Action and payoff uncensored with probability $\pi \leq \delta$
  - Downside censorship probability: $1 - \pi$
  - *Upside salience*: $\beta \equiv \delta/\pi > 1$
    - Greater censorship of downside outcomes
- Missing observation:
  - "The dog that did not bark"
    - Should infer good chance that payoff = –1
    - Instead, neglect

The uncensored subsequence

- Only uncensored agents matter for long-run evolution of beliefs, actions
  - The *uncensored subsequence*
- Agents think there is no censorship
- So beliefs of agents in the uncensored subsequence follow a random walk
  - Censorship biases the up-move probability upward

Up and down probabilities in random walk on LLRs

- Conditional on state *H*, up and down move probabilities in the uncensored subsequence:

$$
\begin{aligned}
p^{H*} &= \frac{p}{p + (1-p)/\beta} > p \\
1 - p^{H*} &= \frac{1-p}{1 + p(\beta - 1)} < 1 - p
\end{aligned}
$$

- Up-move probability biased upward by biased censorship
- Same is true in state *L*

Outcome

State *L*, **strong enough** censorship:

- 0 < P(Adopt Forever) < 1, increasing in upside salience β
- Anyone rejects ➔ All later agents reject

State *H*, **regardless of** censorship:

- Same conclusions as above

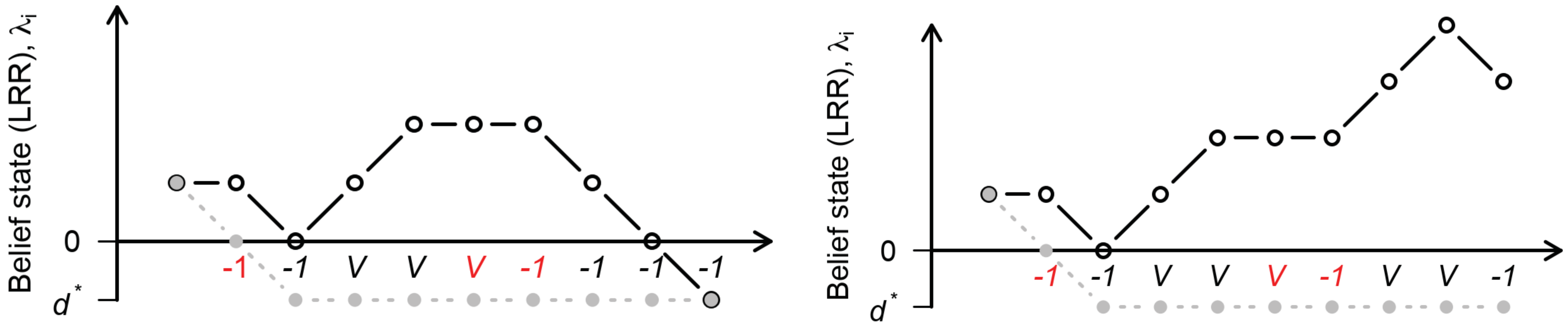
Intuitively, biased censorship boosts adoption.

- In state *L* that makes adoption forever possible.

Action boom/bust patterns

- Even in rational setting, owing to limited information, can be action boom followed by bust (*L* state)
  - People not omniscient
- Neglect of biased censorship
  - Extra probability of mistaken booms
    - Mistaken even relative to the limited information agents possess
  - These extra mistaken booms can:
    - Last forever (high censorship)
    - Later collapse (low censorship)
- A new explanation for real financial boom/bust phenomena
  - Investment, IPO, mergers…

Boom/bust patterns



Even in cases tilted against booms

A new explanation for real financial boom/bust phenomena

- Real investment booms and busts
  - Chirinko & Schaller (2001, 2012)
- IPO waves and overoptimism
  - Ritter (1991), Rajan, Servaes (1997), Lowry & Schwert (2002)
- Value-reducing merger waves
  - Moeller, Schlingemann & Stulz (2005), Bouwman, Fuller & Nain (2009)

Explanation differs from some past explanations that require payoff externalities:

- DeMarzo, Kaniel & Kremer (2007)

Or shifts in investor sentiment

- Gilchrist, Himmelberg & Huberman (2005)

Comparative statics of long-run adoption

- Greater upside salience β ➔ Greater P(Adopt)
  - Deriving from either less upside censorship or greater downside censorship

Two promoters of Adopt:

- Higher probability of *H* state, q
- Higher upside payoff, V

Moonshots vs. sure bets

- A *moonshot* is a project with
  - Low probability of success, reflected in low probability of the *H* state, *q*
  - High upside payoff *V*
- Vs. 'Sure bet' project: high *q*, low *V*
- Specifically, suppose increase moonshotness, for *constant project expected payoff*
  - Increase upside payoff (moonshotness) *V* , decrease P(*H*) = *q*
  - So have parameterized variation: q is decreasing with *V*
- Since *q*, *V* both favor adopt, effect of greater moonshotness not obvious

Moonshots vs. sure bets (2)

- Key psychological premise:
  - Upside salience β to be greater for moonshots than for sure bets.
- Ex ante probability of success, high conditional payoff make success more surprising, newsworthy
- Since β increases Adopt, moonshotness increases adoption relative to the pure effects of q, V
- Formally, greater moonshotness increases *excess adoption*
- Intuitively, moonshotness biases observation toward past successes over failures.
  - As with example of Google earlier
  - Promotes adoption

Upside salience and firm size

- Large firms, projects receive more media attention

➔ Stronger evolution toward overadoption for startups, small firms

- Survey evidence that entrepreneurs highly overoptimistic about likely success
  - Cooper, Woo & Dunkelberg (1988)

Upside salience and firm size (2)

- Recall that upside salience is $\beta = \delta / \pi$
  - Greater attention by media, observers tends to increase both π and δ
- Large firms receive much more attention than small firms
  - E.g., analyst following analyst following
    - O'brien & Bushan (1990)
- Similarly for large projects
  - Disastrous failure of major project likely noticed
- So for well known firms (e.g., Apple): $\pi = \delta \approx 1$, upside salience weak

➔ Stronger overadoption for startups, small firms

➔ More investment booms/busts

Upside salience and firm size (2)

Implications:

- Greater mythology about garage startups than large-scale moonshots
- Low returns to private equity
  - Moskowitz & Vissing-Jorgensen (2002)
- Helps explain survey evidence that entrepreneurs highly overoptimistic about their prospects for success
  - Cooper, Woo & Dunkelberg (1988)

Upside salience and sexy projects

- Again, moonshots as projects with rare and very high upside payoff (*q* and *V*)
  - Owing to upside salience ($\beta > 1$), moonshotness promotes adoption
- But even for given *q* and *V*, upside salience varies
  - Project `sexiness‘
- Sexy projects:
  - Innovative, fun, exciting, life-changing (e.g., self-driving cars)
  - Should have high upside-salience (β)
  - So heavily adopted, strong boom/bust patterns

Evolution of project adoption and evolutionary theory

Decomposing trait evolution into selection vs. mutation pressure

- Change of gear:
  - Putting our findings into context of evolutionary theory
  - Why?
    - Understanding more deeply the cultural evolutionary forces driving the effects
    - Provide general insight into cultural evolutionary modeling of economic issues
- The Price Equation (Price 1970):
  - Decomposes evolutionary change into *selection* and *nonselection* effects
    - Darwinian selection—differential reproduction
- Nonselection component: ***mutation pressure***
  - Trait shift directly through biased inheritance/transmission
  - Instead of differential reproduction

Approach of the Price Equation

- Designate a group of ancestors, and of descendants
  - Early firms, late firms
- A set of trait values
  - Adopt, Reject project
- Inheritance relationships
  - Each descendant has some designated set of ancestors
- LHS: change in average trait in the population
- RHS: Change derived from
  - Evolutionary selection
  - Mutation pressure

A stochastic Price Equation (based on Frank (1997)

$$
\begin{aligned}
\overline{\widehat{\Delta z}}^{\mathcal{F}} &= \overline{\hat{z}}' - \overline{\hat{z}} \\
&= \sum \mathrm{E}[q'^i z'^i | \mathcal{F}] - \sum \mathrm{E}[q^i z^i | \mathcal{F}] \\
&= \underbrace{\sum \mathrm{E}[q'^i \left(z'^i - z^i \right) | \mathcal{F}]}_{\text{mutation pressure}} + \underbrace{\sum \mathrm{E}[(q'^i - q^i) z^i | \mathcal{F}]}_{\text{selection}}
\end{aligned}
$$

Selection: differential reproduction

Mutation pressure: trait shift via inheritance/transmission

Trait z = 1 (Adopt)
z = 0 (Reject)

Defining terms in Price Equation

- Descent based on **causality**
- A ***descendant*** of some agent observes that agent's action and informative payoff
  - Ancestor’s trait has potential **causal influence** on descendant’s trait
- Reject ➔ Payoff always zero ➔ Uninformative ➔ **No descendants**
- Censored ➔ Ignored ➔ **No descendants**
- Adopt, Uncensored ➔ **All** in descendant generation **are descendants**

Conclusions about evolutionary selection and mutation pressure (1)

- Discussions of cultural evolution, evolutionary finance issues often **only** recognize selection
- In our model, mutation pressure also plays crucial role
- Selection bias effects do **not** imply evolutionary selection
  - E.g., all-past-adopt ➔ No selection; only mutation pressure
- Sharp contrast with cultural evolutionary models, evolutionary game theory model, with **direct copying**

  ➔ Only selection
  - Here, agents process information thoughtfully. This cognition induces mutation pressure.

    ➔ Opposition between these two sources of trait evolution
  - Mutation pressure can overwhelm selection

Conclusions about evolutionary selection and mutation pressure (2)

- Price Equation widely applicable to financial/economic models if:
  - Economic traits
  - Earlier and later agents (ancestral & descendant)
  - Causal relationships between traits of cultural `parents’ & `offspring’
- In many cultural economic/finance contexts:
  - Thoughtful information processing rather than pure copying
  - ➔ Mutation pressure likely to be very important

Conclusion

- Upside salience:
  - Greater censorship of low than high investment outcomes
- Upside salience + Neglect of selection bias ➔ Overadoption, Investment booms
  - May collapse, or overadoption can last forever
- Moonshotness (rare big successes), small firm size, project sexiness:
  - Promote overadoption, investment booms
- Model can help explain other stylized facts
  - Entrepreneurial overoptimism, private equity puzzle
- Results can also be applied at industry or sector levels
- Adopting or rejecting as a transmitted cultural trait:
  - Opposing effects of mutation pressure and selection
  - Mutation pressure can dominate, in contrast with many cultural evolutionary models of copying