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

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Virtual Presentation
9/2/20 Version
(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)
• Han, Hirshleifer & Walden (forthcoming)
  • Stock market investors randomly meet to discuss their strategies
  • \( \text{Pr}(\text{Sender reports return}) \) 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>
<thead>
<tr>
<th>State ($\theta$)</th>
<th>Payoff Outcome ($v$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H$</td>
<td>$p$</td>
</tr>
<tr>
<td>$L$</td>
<td>$1 - p$</td>
</tr>
</tbody>
</table>

Table 1: Payoff Probabilities
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, $\lambda_i$, 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

Agent $i$
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*: $\beta \equiv \frac{\delta}{\pi} > 1$
    • 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:

$$p^H_* = \frac{p}{p + (1-p)/\beta} > p$$

$$1 - p^H_* = \frac{1-p}{1 + p(\beta - 1)} < 1 - p$$

• Up-move probability biased upward by biased censorship
• Same is true in state $L$
Outcome

State $L$, **strong enough** censorship:
• $0 < P(\text{Adopt Forever}) < 1$, increasing in upside salience $\beta$
• Anyone rejects $\Rightarrow$ 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

• 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 $\beta \Rightarrow$ Greater $P(\text{Adopt})$
  • 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 $\beta$ to be greater for moonshots than for sure bets.
• Ex ante probability of success, high conditional payoff make success more surprising, newsworthy
• Since $\beta$ increases $\text{Adopt}$, 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 $\pi$ and $\delta$

• 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 ($\beta$)
  • 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))

\[ \Delta \bar{z}^F = \bar{z}' - \bar{z} \]

\[ = \sum E[q^i z^i | F] - \sum E[q^i z^i | F] \]

\[ = \sum E[q^i (z^i - z^i) | F] + \sum E[(q^i - q^i)z^i | F] \]

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 \(\rightarrow\) 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