Priors, Learning, Experimentation and Persuasion in Entrepreneurial Finance

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1st Bayesian Entrepreneurship Conference
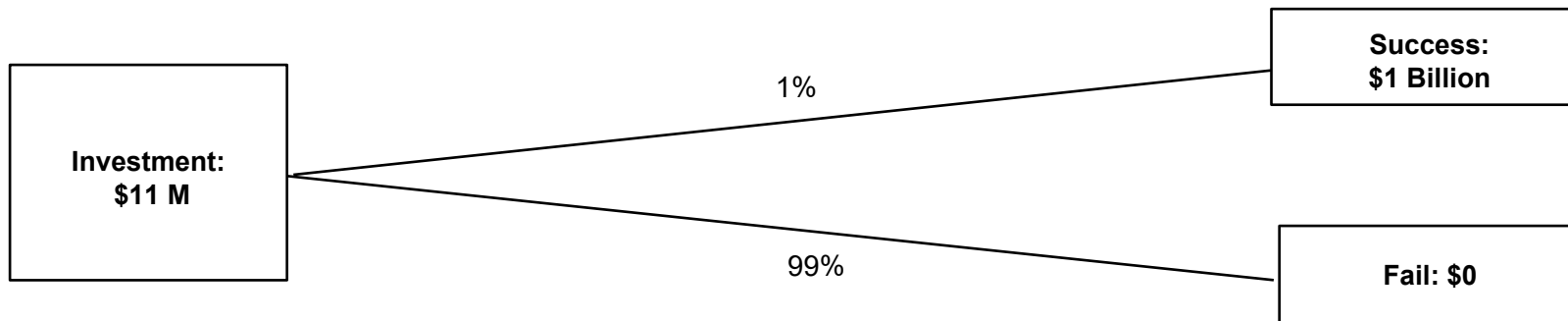
March 22, 2024

My Comments

- Application of Bayesian Entrepreneurship ideas in research, teaching and practice of entrepreneurial finance

- Financing Deep Tech Entrepreneurship (at Imperial)
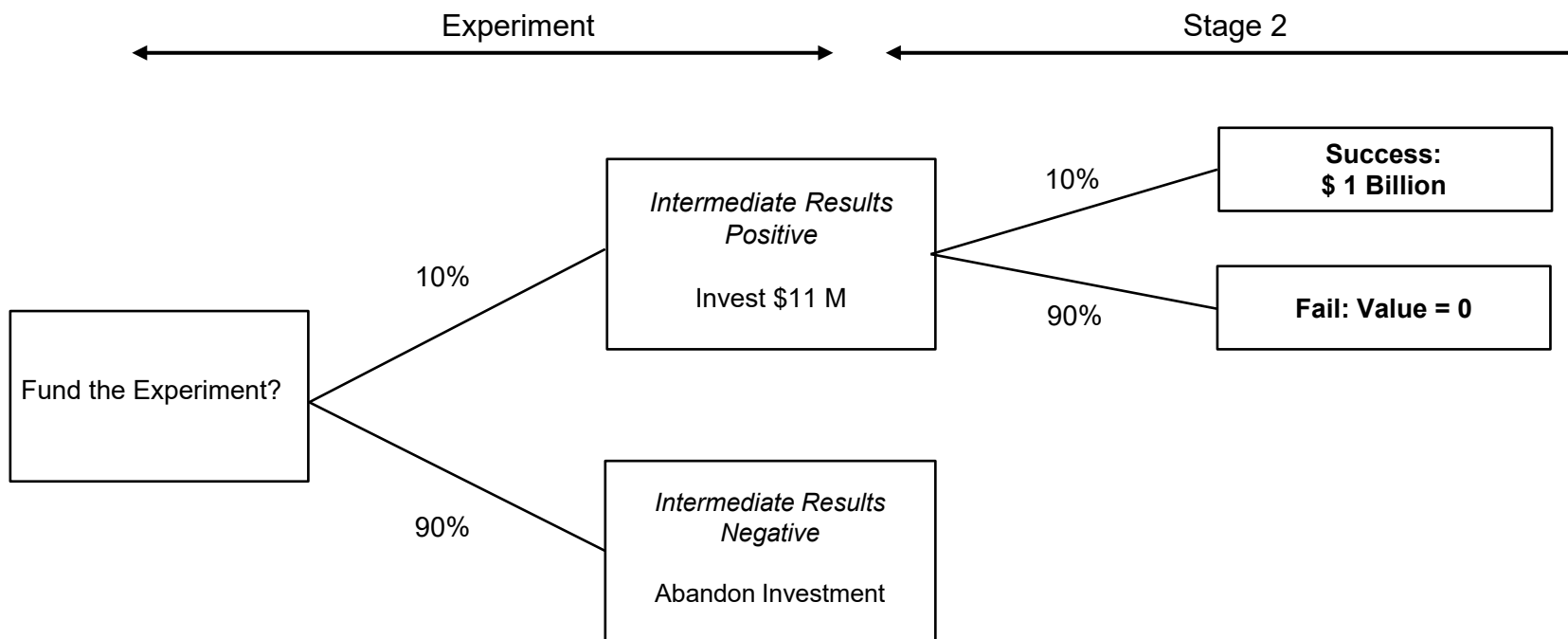
- A few additional Random thoughts

Multi-stage financing

- Regardless of my priors, there are instances where I need to convince others to give me money to get my venture off the ground

- Some 'advisable' actions
  - Break financing into stages (where investor has right to abandon)
  - Tied to milestones that enable value-inflection if the milestone is achieved (e.g. *step-up in value* from Series A to B)

- Related to the literature on real options in multi-stage financing

PANEL A: ALL OR NOTHING BET

Investment: $11 M

1% → Success: $1 Billion

99% → Fail: $0

PANEL B: STAGED FINANCING

← Experiment →   ← Stage 2 →

Fund the Experiment?

10% → Intermediate Results Positive

Invest $11 M

10% → Success: $1 Billion

90% → Fail: Value = 0

90% → Intermediate Results Negative

Abandon Investment

How much can I learn at what cost?

- You raise money to buy time

- You buy time to run experiments

- You run experiments to produce information

- You produce information to make decisions (open or close options)

- *Experiments that cost less and generate more information are therefore more valuable Real Options!*

Some Implications

- Value inflection across rounds:
  - Tied to surprises: If I thought it wasn't going to work, but it did, I update my priors more as an investor
  - 'High bar' experiments generate more information for the (skeptical) investor (good for entrepreneur if successful since less diluted but also means more likely to fail)

- Clear guidance on how much to raise:
  - How much do I need to get to the next value inflection point? (Plus a little more for unanticipated needs)

Airbnb Financing Rounds

AirBnB Financings

	--- 3 months ---	--- 11 months ---	--- 7 months ---	--- 16 months ---	--- 16 months ---	--- 14 months ---	--- 14 months ---		
	Seed 1/2009	Seed 4/2009	Series A 11/2010	Series B 6/2011	Series C 10/2012	Series D 4/2014	Series E 6/2015	Series F 9/2016	Total Raised ($ 000)
Investment ($ 000)	$20	$600	$7,200	$117,052	$200,000	$475,000	$1,500,000	$555,500	$2,855,372 ($2.9 billion)
% Purchased	6.0%	20.0%	7.2%	9.0%	8.0%	4.8%	5.9%	1.9%	
Post Money Value ($ 000)	$333	$3,000	$100,000	$1,300,000	$2,500,000	$10,000,000	$25,500,000	$29,700,000	
Pre Money Valuation ($ 000)	$313	$2,400	$92,800	$1,182,948	$2,300,000	$9,525,000	$24,000,000	$29,144,500	
	7.2 x	31 x	11.8x	1.8 x	3.8 x	2.4 x	1.2 x		

Capitalization Table

	Pre Funding	Seed 1/2009	Seed 4/2009	Series A 11/2010	Series B 6/2011	Series C 10/2012	Series D 4/2014	Series E 6/2015	Series F 9/2016	W/ Est Options	Allocation @ $29,700,000 ($ 000)
Founders	100.0%	94.0%	75.2%	69.8%	63.5%	58.4%	55.6%	52.4%	51.4%	46.3%	$13,737,608
Y Combinator		6.0%	4.8%	4.5%	4.1%	3.7%	3.6%	3.3%	3.3%	3.0%	876,869
Seed 1 Sequioa			20.0%	18.6%	16.9%	15.5%	14.8%	13.9%	13.7%	12.3%	3,653,619
Series A				7.2%	6.6%	6.0%	5.7%	5.4%	5.3%	4.8%	1,417,352
Series B					9.0%	8.3%	7.9%	7.4%	7.3%	6.6%	1,947,863
Series C						8.0%	7.6%	7.2%	7.0%	6.3%	1,881,157
Series D							4.8%	4.5%	4.4%	3.9%	1,172,638
Series E								5.9%	5.8%	5.2%	1,542,944
Series F									1.9%	1.7%	499,950
Options - est.										10.0%	2,970,000
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	$29,700,000

Source: seed-db.com and various public and government sources. For illustrative purposes only.

MIT
Technology
Review

You Promised Me Mars Colonies.
Instead, I Got Facebook.

We've stopped solving big problems.
Meet the technologists who refuse to give up.

Massive growth in VC industry not evenly distributed across sectors

US$ billion

- IT software and services
- Consumer products and services
- Business products and services
- Financial services
- Healthcare
- IT hardware
- Energy, materials, and resources

2010   2019
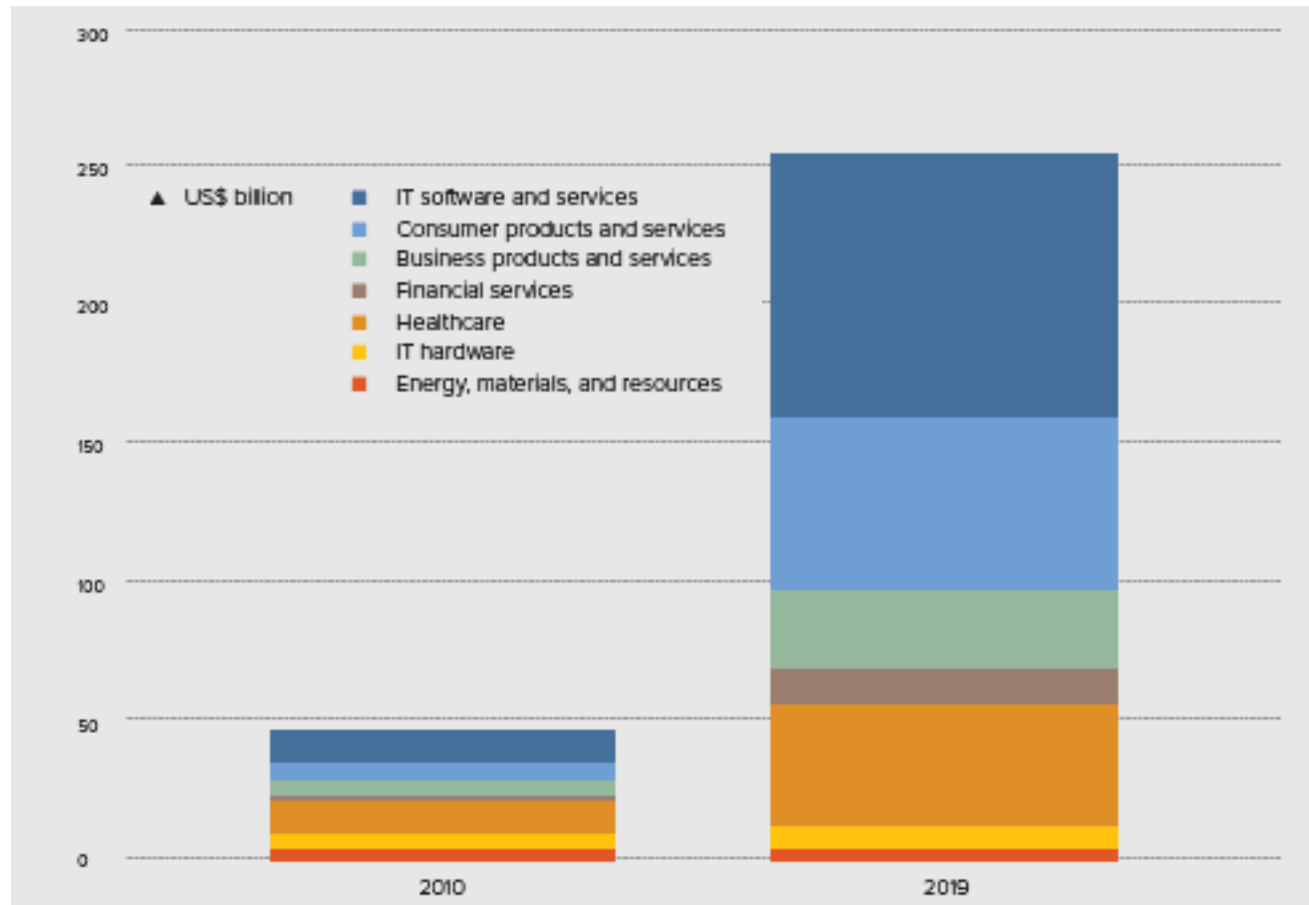
- Particular dearth in capital towards "deep tech" sectors that build on fundamental science and engineering innovations

- Critical to solving global challenges in climate, sustainability, health, defense

- These innovations are increasingly developed inside universities as larger companies pull back

Lots of potential reasons, focus on one here:

- "Low learning efficacy"
  - Early experiments, even when successful, seem to be less predictive of ultimate success (low initial step-ups)
  - Particularly problematic when combined with the larger costs associated with financing these early experiments

Examples of low learning efficacy

The long-term stability of an electrocatalyst [..] is a crucial financial factor for evaluating the prospects of a novel material. So far, long-term experiments > 24 h at relevant current densities are not that frequently employed in catalyst studies. Given the fact, that an industrial setup has to remain operational for several years, degradation effects of even as low as 0.1% over 24h are not negligible, and materials thus cannot be claimed stable. **Hence, either long-time experiments have to be conducted or new rapid-aging tests have to be developed.**

Many of the tested catalytic materials are currently benchmarked at rather low current densities. These data sets are not meaningful for any commercial processes and are obtained outside of the common process conditions that are applied. **It would be particularly desirable to at least test such a system at higher current densities of $>500 mA cm2$ to establish the systems performance...**

Preclinical experiments in isolated systems (cells, tissue preparations, isolated organs) together with animal disease models, which are used for the identification and validation of drug targets to progress into clinical phase testing, **turn out to be poorly predictive of human efficacy**

Rationales for low learning efficacy

- Fundamental differences in predictability (lab exp vs. customer discovery)

- Lack of well developed benchmarks that allow updating from experiments

- Moral Hazard in Experiment Design

Lack of well developed benchmarks (compared to Enterprise Software)

Exhibit 7   Metrics to Benchmark Performance of SaaS Companies with a $6 million to $10 million Revenue Run Rate

	Revenue Growth (Trailing 12mo.)	Revenue Growth (Forward 12mo.)	Sales Efficiency (Magic Number)	Net Retention (Revenue Churn Net, Annualized)	Cash Burn (Operating Income as % Revenue)
25th Percentile	78%	55%	0.5x	-4.3%	-138%
50th Percentile	117%	84%	0.8x	8.3%	-93%
75th Percentile	157%	114%	1.4x	32.9%	-49%
Number of Observations	93	118	108	74	128

Moral Hazard in Experiment Design

- Investor can see whether milestone achieved but entrepreneur can design the experiment to be more or less likely to achieve the milestone

- Leads to large inefficiency and potential for market failure

- One potential solution is for university to help validate the experiment design

DT Prime program at Imperial

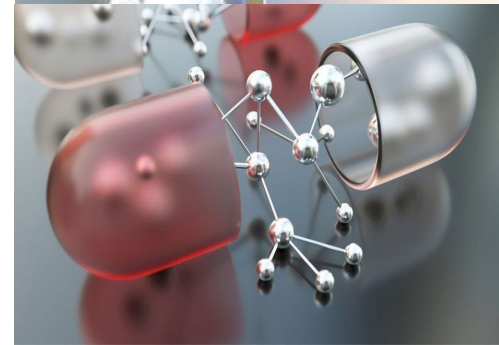## Decarbonization and Sustainability Related Industrial Technologies

Sodium-Ion Battery Anodes (1,2)

Low Carbon Concrete (1)

Low Carbon Ammonia (1)

Perovskite Solar Cells (2,3)

Arsenic removal from water (2,3)

Catalytic Process for Crop Yield Enhancement (3)

Therapeutics and Biotech Platforms

Zinc Finger Gene Therapy (1,2,3)

Self-amplifying RNA platform for vaccine and therapeutic indications (3)

CAR-MAIT-based immunotherapy for cancers (3)

Bio-inspired Nanomedicines for Targeted Thrombolytic Therapy (2,3)

Left ventricle cardiomyocytes based cell replacement therapy for heart failure (3)

Revolutionary approach to therapeutic peptide synthesis (2)

Platform for discovery of new antibiotics (1)

Information and Communication Technology

Neuromorphic Computing hardware (1, 3)

Retinomorphic Computing for Machine Vision (3)

MASER (Microwave Amplification Stimulated Emission of Radiation) in a Box (2)

MedTech and Digital Health

Device for cartilage regeneration (1)

Device to stimulate bone growth (2)

Soft Robot for Endoscopic surgery (2,3)

New adjuvant to accelerate closure of diabetic foot ulcers (1)

Hydrophobic material to substantially reduce blood loss from severe bleeding (2)

Random thoughts

- My prior is that we are really onto something here
  - Scientific, actionable (teachable) approach to decision making under uncertainty that nests easily within language of practitioners, at least in entrepreneurial finance
  - But of course I am optimistic, after all I was invited and chose to attend!

- May need to do more to persuade our counterparts in the literature who don't share the prior
  - Word choice matters
  - May need to balance the tradeoff between being comprehensive and easy enough to be appealing, otherwise risk remaining fragmented