



Unleashing Innovation

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How to foster innovation?

- Innovation is critical for economic growth (Solow, 1957) and competitive advantage (Porter, 1992)
- Highly developed financial markets affect innovation (Schumpeter 1911; Brown, Fazzari, and Petersen 2009; Hsu, Tian, and Xu 2013)
 - Reduced cost of capital
 - Improved capital allocation
 - More efficient manager monitoring and project evaluation
- Adverse externalities such as short-termism, rent-seeking, and opportunistic behaviors



This paper

- Focuses on the venture capital (VC) market
 - A key ingredient of the financial market
 - A main driver of entrepreneurship and technological innovation in the US
- Studies how VC's investment structure (staging) affects innovation



VC staging

- **Unique** investment structure of VC financing
 - The stepwise disbursement of capital from VCs to entrepreneurial firms
 - Rather than an upfront, lump sum capital infusion, a VC splits financing into multiple rounds
- VCs retain the option to abandon the venture if it fails to meet stage targets



The agency hypothesis

- Entrepreneurs can hold up VCs
 - By threatening to leave the venture in which his unique human capital is critical to innovation
- VC staging mitigates the hold-up problem
 - Gradual embodiment of the entrepreneur's human capital in the venture's physical capital
 - Neher (1999)
 - Enforce entrepreneur's commitment → Enhance innovation



The leashing hypothesis

- VC staging **stifles innovation** by keeping a “tight leash” on entrepreneurs
- Innovation is an exploration of untested approaches
 - A long, risky, and idiosyncratic process
 - Pressure to meet short-term targets discourages managers from undertaking innovation
- VC staging imposes such pressure
 - To secure the next round VC financing, the entrepreneur may forgo long-term, risky innovative projects but aim for short-term success
 - “Window dressing”

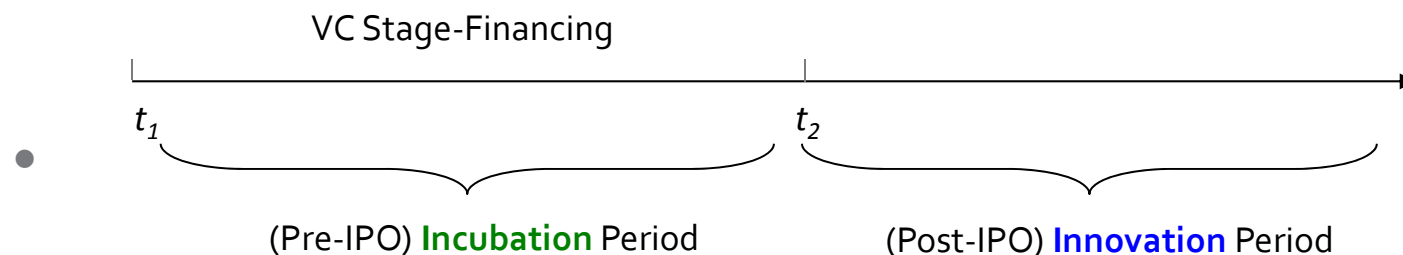


Related literature

- Motivating innovation
 - Holmstrom (1989), Aghion and Tirole (1994), Manso (2011)
 - Aghion et al. (2005), Lerner et al. (2011), Nanda and Rhodes-Kropf (2012), Seru (2012), Aghion et al. (2012), Tian and Wang (2012), Hirshleifer et al. (2012), Fang, Tian, and Tice (2013), He and Tian (2013), Chemmanur et al. (2013), Cornaggia et al. (2013), etc.
- VC's value creation
 - Lerner (1994, 1995), Gompers (1995, 1996), Lerner and Gompers (1999, 2000), Hellmann and Puri (2000, 2002), Hochberg et al. (2007), Sorensen (2007), Gompers et al. (2009), Tian (2011, 2012), Puri and Zarutskie (2012), Da Rin et al. (2013), etc.

Research design

- Measure of VC staging
 - # of VC financing rounds during a firm's **incubation period**
- Measures of innovation
 - # of patent applications filed in a given year **after IPO** that are eventually granted
 - # of citations that each granted patent receives in subsequent years
- Timeline
 - Before a firm goes public, VC staging and firm's innovation are mingled together
 - Difficult to establish a causal link between the two
 - After a firm goes public, # of rounds is a done deal





Identification

- VC staging is likely endogenous due to selection
- Instrumental variable to address endogeneity
 - [Frequency of direct flights](#) between VC domiciles and IPO firm headquarters
- Tian (2011): VC staging and monitoring are substitutes
 - Costs of VC staging
 - Negotiation and contracting costs
 - Foregone economics of scale due to divided capital infusion
 - Underinvestment in early-stage viable ventures
 - Induced short-termist behavior by entrepreneurs
- Easy access to ventures → Ease of monitoring → Reducing reliance on costly stage financing



What determines direct flight?

- Airline's strategic considerations
 - Industry peer competition and dominance (Borenstein and Netz, 1999)
 - "Point-to-point" vs. "hub-and-spoke" networks (Brueckner, 2004)
 - Alliances with other airlines (Bamberger, Carlton, and Neumann, 2004)
- Physical distance and operation costs
 - Reiss and Spiller (1989)
- Passenger composition and market segmentation
 - Borenstein and Rose (1994)
- Route concentration and competition
 - Borenstein (1989); Gerardi and Shapiro (2009)
- Government regulations, airport and aircraft fleet characteristics
 - Evens and Kessides (1993); Pai (2010)
- Local population and labor force composition
 - Pai (2010)
- Features of airlines' frequent flyer programs
 - Lederman (2007)

Check: IV exclusion restriction

- City-pair direct flight service market structure is not directed at the locations of *small start-ups* that may or may not go public in the *unforeseen future*
- Availability and frequency of direct flights are unlikely to be directly related the innovativeness of firms after IPO
 - Should affect innovation only through its effect on a VC investor's monitoring cost and thus staging decisions



But *maybe*...

- (Omitted) local shocks that may drive the frequency of direct flights and local firms' innovation
- Frequency of direct flights may be related to local economic conditions
 - Local economic conditions can be spurred by the innovation of local firms
- Entrepreneurs with innovative projects endogenously choose to locate in cities that have more frequent direct flights to their investing VCs



Refining the IV

- Focusing on airline restructuring events
 - Bankruptcies
 - Mergers and acquisitions
 - Strategic alliances
- Variation in the frequency of direct flights driven by restructuring plans and strategic re-alignment, unrelated to local economic conditions
 - Kim and Signal, AER 1993
 - Park and Zhang, 1998
 - Borenstein and Rose, AER 2003
 - Ciliberto and Schenone, IJIO 2012

More controls for local shocks

- **Unobserved time-invariant** local factors that affect VC financing and an entrepreneurial firm's innovation potentials
 - VC state FE and IPO firm state FE
- **Unobserved time-varying** local factors
 - More IPO firms/direct flights because of local economic boom?
 - *Refined IV approach*
 - **Local IPO market**: # of (other) firms located in the same state that went public during firm i 's incubation period.
 - More IPO investments/direct flights because VC is doing well?
 - *Refined IV approach*
 - **Local VC market**: # of (other) IPO firms that VC j has invested during firm i 's incubation period.



Control for factors affecting an IPO firm's innovation

- VC characteristics
 - VC syndicate size, Reputation
- IPO firm's *ex ante* characteristics
 - Innovation ability: # of patents and # of cites per patents
 - Age
 - Development stage
 - Incubation period
- Post-IPO characteristics
 - Size, Investments in intangible assets (R&D/Assets), Profitability (ROA), Asset tangibility (PPE/Assets), Leverage, Product market competition (the Herfindahl index based on sales), Institutional ownership



Data

- VC investment (1980-2004): Thomson VentureXpert
 - Locations: Google maps/Mapquest
- IPO sample (1980-2004): SDC Global New Issues
- Innovation (1976-2006): NBER patent database
 - Fix the patent and citation truncation problems (Hall, Jaffe, and Trajtenberg, 2001)
- Direct flights (1987-present)
 - US Department of Transportation's Bureau of Transportation Statistics
- Final
 - 1840 VC-backed firms that went public between 1980-2004
 - 25 unique carriers providing direct flight services between VCs and IPO firms' cities
 - 54 airline restructuring events occurred
 - 1,115 firms are affected by such events during their incubation periods

Descriptive statistics

	25 th	Mean	Median	75 th	Std. Dev.	# of obs.
Full Sample						
# of Rounds	2	4.75	4	6	2.94	1,840
Firm Stage	0	0.70	1	1	0.46	1,816
# of Patents at 1 st Round	0	0.21	0	0	1.05	1,840
# of Citations at 1 st Round	0	2.48	0	0	12.62	1,840
VC Reputation	0	0.02	0.00	0.02	0.03	1,840
VC Syndication Size	3	7.88	7	11	5.59	1,840
Incubation Period	2.05	4.25	3.55	5.58	3.08	1,840
Firm Age	0.33	3.18	1.37	4.00	4.55	1,837
Direct Flights	23.27	76.24	85.67	128	50.38	1,668
Subsample for Airline Restructuring						
# of Rounds	3	5.34	5	7	2.94	1,115
Firm Stage	1	0.75	1	1	0.43	1,094
# of Patents at 1 st Round	0	0.19	0	0	1.00	1,115
# of Citations at 1 st Round	0	2.36	0	0	12.47	1,115
VC Reputation	0	0.02	0.00	0.02	0.03	1,115
VC Syndication Size	5	8.87	8	12	5.35	1,115
Incubation Period	2.44	4.59	3.97	6.07	3.04	1,115
Firm Age	0.27	2.70	1.07	3.16	4.13	1,113
Direct Flights	21.41	68.23	66.99	127.68	46.81	1,078



Descriptive statistics: Geographic distribution

- Entrepreneurial firms: distributed among 42 states
 - CA (41%)
 - MA (11.01%)
 - TX (5.62%)
 - NY (4.31%)
 - NJ (3.49%)
- VCs: distributed among 39 states
 - CA (35.76%)
 - NY (18.68%)
 - MA (14.23%)
 - CT (5.3%)
 - IL (3.48%)

OLS results

Innovation

$$= \beta_0 + \beta_1(\#of\ Rounds) + \Omega'Z + \alpha_{IPO\ Year} + \alpha_{Industry} + \alpha_{VC\ State} + \alpha_{Firm\ State} + \varepsilon$$

Dependent variable	Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)
# of Rounds	0.006	0.005	0.003	0.002
	(0.008)	(0.008)	(0.012)	(0.012)
Control Variables	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	8,294	8,294	8,294	8,294
R Squared	0.281	0.282	0.239	0.240

2SLS results – 1st stage

Dependent variable	# of Rounds	
	(1)	(2)
Direct Flight	-0.006***	-0.006***
	(0.001)	(0.001)
Control Variables	Yes	Yes
Local IPO Market	No	Yes
Local VC Market	No	Yes
Industry Fixed Effects	Yes	Yes
IPO Year Fixed Effects	Yes	Yes
Firm State Fixed Effects	Yes	Yes
VC State Fixed Effects	Yes	Yes
First-stage F-test	17.63	15.95
# of obs.	7,577	7,577
R Squared	0.574	0.578

2SLS – 2nd stage

Dependent variable	Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)
# of Rounds (Instrumented)	-0.283***	-0.310***	-0.308**	-0.339**
	(0.104)	(0.114)	(0.126)	(0.138)
Control Variables	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	7,577	7,577	7,577	7,577
Root MSE	0.934	0.960	1.374	1.397

Economic significance

- When considering only the variation in # of financing rounds due to the frequency of direct flights between the locations of VCs and entrepreneurial firms
- One additional round → 28.3% decrease in # of patent applications
 - One more round
 - Brings # of rounds from the sample mean (4.75 rounds) to the 66th percentile
 - 28.3%
 - Translate to a change which brings the patent counts from the sample mean (1.90 patents) to 1.36, or from the 82nd percentile to the 77th percentile

Refined IV: 2SLS results – 1st stage

Dependent variable	# of Rounds	
	(1)	(2)
Direct Flight	-0.008***	-0.008***
	(0.002)	(0.002)
Control Variables	Yes	Yes
Local IPO Market	No	Yes
Local VC Market	No	Yes
Industry Fixed Effects	Yes	Yes
IPO Year Fixed Effects	Yes	Yes
Firm State Fixed Effects	Yes	Yes
VC State Fixed Effects	Yes	Yes
First-stage F-test	15.34	14.05
# of obs.	4,798	4,798
R Squared	0.560	0.562

Refined IV: 2SLS – 2nd stage

Dependent variable	Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)
# of Rounds (Instrumented)	-0.272**	-0.294**	-0.296**	-0.311**
	(0.110)	(0.120)	(0.131)	(0.140)
Control Variables	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	4,798	4,798	4,798	4,798
Root MSE	0.950	0.971	1.369	1.378



Subsample analysis

- To further identify the causal effect of VC staging on innovation
 - Difficult or easy to achieve innovation
 - More or less product market competition
 - VCs with more or less industry experience
- **Unlikely** an omitted variable biases our results *equally* along *all dimensions* in the firms in these industries
 - Less likely the results are entirely driven by VCs' endogenously selecting to invest fewer rounds in more innovative firms



Innovation difficulty

- Induced short-termism should be particularly detrimental in industries in which innovation is difficult to achieve
- Classify firms into two categories based on their patent technology class (Hall et al., 2001)
 - More demanding industries
 - Pharmaceutical, medical instrumentation, chemicals, computers, communications, and electrical
 - Less demanding industries
 - Software programming, internet applications, and other low-tech industries

Innovation difficulty (refined IV)

	More Demanding Industries				Less Demanding Industries			
Dependent variable	Ln(Patents)		Ln(Citations)		Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.327**	-0.347**	-0.354**	-0.371**	-0.110	-0.126	-0.167	-0.189
	(0.136)	(0.143)	(0.154)	(0.161)	(0.142)	(0.169)	(0.234)	(0.271)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	2,742	2,742	2,742	2,742	2,056	2,056	2,056	2,056
Root MSE	1.103	1.123	1.459	1.471	0.580	0.589	1.136	1.143



Product market competition

- Product market competition exacerbates short-term pressure (Aghion et al., 2013)
 - Firms more likely engage in short-term actions in a highly competitive market to keep competitive advantage over their rivals to survive
- VC staging should be more detrimental to innovation if the venture is operating in a more competitive product market
 - Split the sample based on HHI

Product market competition (refined IV)

	More Competitive Industries				Less Competitive Industries			
Dependent variable	Ln(Patents)		Ln(Citations)		Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.164*	-0.172*	-0.248**	-0.252**	-0.642	-0.691	-0.720	-0.779
	(0.092)	(0.097)	(0.118)	(0.122)	(0.607)	(0.670)	(0.700)	(0.776)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	2,388	2,388	2,388	2,388	2,388	2,388	2,388	2,388
Root MSE	0.761	0.766	1.213	1.212	1.271	1.327	1.657	1.716



VC's industry expertise

- If VCs have expertise in their venture's industry, they should have better understanding about the nature of the venture's business and innovation
 - Their staging should be less detrimental to firm innovation
- The (lead) VC's expertise about a firm's industry *at the time when the firm receives its first round financing*
 - Based on a 10-year rolling window
 - # of firms invested previously in the same industry of the current firm / # of firms in all industries invested by the VC
 - Split by sample median

VC's industry expertise (refined IV)

	Less Experienced				More Experienced			
Dependent variable	Ln(Patents)		Ln(Citations)		Ln(Patents)		Ln(Citations)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
# of Rounds (Instrumented)	-0.282**	-0.328**	-0.371**	-0.415**	-0.530	-0.568	-0.409	-0.409
	(0.130)	(0.155)	(0.160)	(0.187)	(0.508)	(0.562)	(0.468)	(0.494)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	2,162	2,162	2,162	2,162	2,316	2,316	2,316	2,316
Root MSE	0.967	1.012	1.365	1.401	1.198	1.248	1.430	1.428



Extensions and robustness

- Ease of monitoring or interference?
 - Frequency of direct flights affects directly a firm's innovation via ease of monitoring
 - Not induced short-termism
 - Cannot run a regression of innovation output on # of direct flights
- Innovation differs from routine operations
- Ease of monitoring → both routine operations and innovation are affected
 - Reduced form OLS
 - Operation performance on # of direct flights
 - Post-IPO survival
 - Bhattacharya, Borisov, and Yu (2013)

Ease of monitoring on operations

OLS Regression	ROA				Asset Turnover			
	All Direct Flights		Airline Restructuring		All Direct Flights		Airline Restructuring	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Direct Flight ($\times 100$)	-0.011	-0.008	0.002	0.006	-0.033	-0.038	-0.006	-0.012
	(0.013)	(0.012)	(0.019)	(0.018)	(0.035)	(0.034)	(0.044)	(0.043)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of obs.	6,932	6,932	4,367	4,367	6,963	6,963	4,387	4,387
R Squared	0.425	0.427	0.436	0.440	0.308	0.309	0.308	0.311

Ease of monitoring on survival

Probit Regression	All Direct Flights		Airline Restructuring	
	(1)	(2)	(3)	(4)
Direct Flight ($\times 100$)	0.000	0.000	0.000	-0.000
	(0.003)	(0.003)	(0.004)	(0.004)
Control Variables	Yes	Yes	Yes	Yes
Local IPO Market	No	Yes	No	Yes
Local VC Market	No	Yes	No	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
IPO Year Fixed Effects	Yes	Yes	Yes	Yes
Firm State Fixed Effects	Yes	Yes	Yes	Yes
VC State Fixed Effects	Yes	Yes	Yes	Yes
# of obs.	8,013	8,013	5,125	5,125
Pseudo R ²	0.181	0.183	0.166	0.170

Robustness

- Alternative regression specification
 - Cross-sectional: # of patents filed (average # of cites per patent received) by a firm within the first 3 years after IPO
- Alternative sample restrictions
 - When no direct flights are available
 - When VCs and firms reside in the same state
- Alternative measures of innovation quality
 - **Generality**: 1 - Herfindahl index of the 3-digit technology class distribution of the all the patents that cite the current patent
 - **Originality**: 1 – Herfindahl index of the 3-digit technology class distribution of all the patents that the current patent cites



Conclusions

- Financial intermediaries' tight leash negatively affects innovation
 - FI: VC
 - Tight leash: more stage-financing rounds
- To establish causality, we exploit the plausibly exogenous variation in the frequency of direct flights
- Staging is more detrimental to firm innovation when
 - Innovation is difficult to achieve
 - There is more product market competition
 - VC is less experienced in the industry to which the firm belongs
- Our results *should not* be interpreted as VC staging is damaging overall
 - Staging assumes also positive role
 - Capture the net effect on innovation