

Motivation for research question

- **Entrepreneurial exits typically equated with success**

- ▶ Exit (liquidity event) as a key performance metric for venture capital-backed start-ups (equity investments illiquid until exit)

- **But little understanding of consequences of exit mode choice on organizational innovation**

- ▶ Changes in organizational structure, ownership, incentives
- ▶ Also potential public policy implications of shift toward M&A

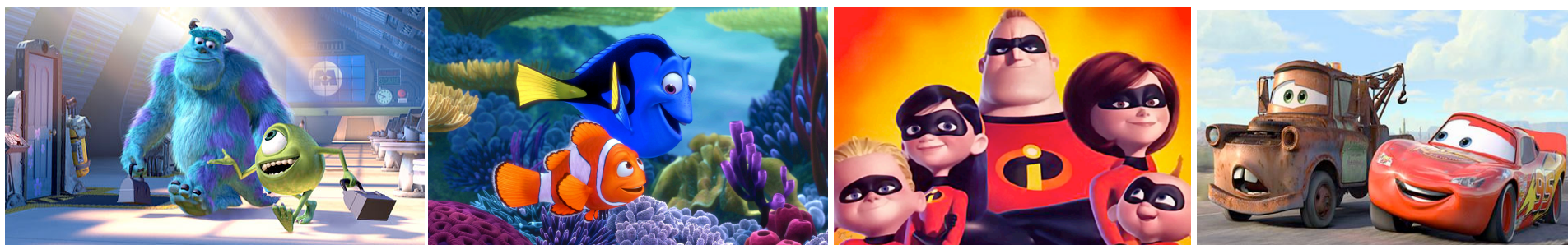
- **Research question:**

What is the relationship between the mode of entrepreneurial exit (IPO / M&A) and start-up innovation outcomes?

Pixar anecdote

- Steve Jobs almost sells Pixar to MSFT in 1994 (pre-*Toy Story*)
 - ▶ Nathan Myhrvold, on behalf of MSFT:

“I was interested in them initially because we were interested in graphics, and we had the idea that maybe there’s some technology that we could invest in early on that would be relevant to PCs later” (The Pixar Touch, 2008)
- Jobs has a change of heart and instead licenses patents related to motion blur and realistic depth of field to MSFT for \$6.5M
- Pixar goes public in 1995, raising \$140M, beating out NSCP for largest IPO of the year (acquired 2006 by Disney, \$7.4B)



What is the endogeneity problem?

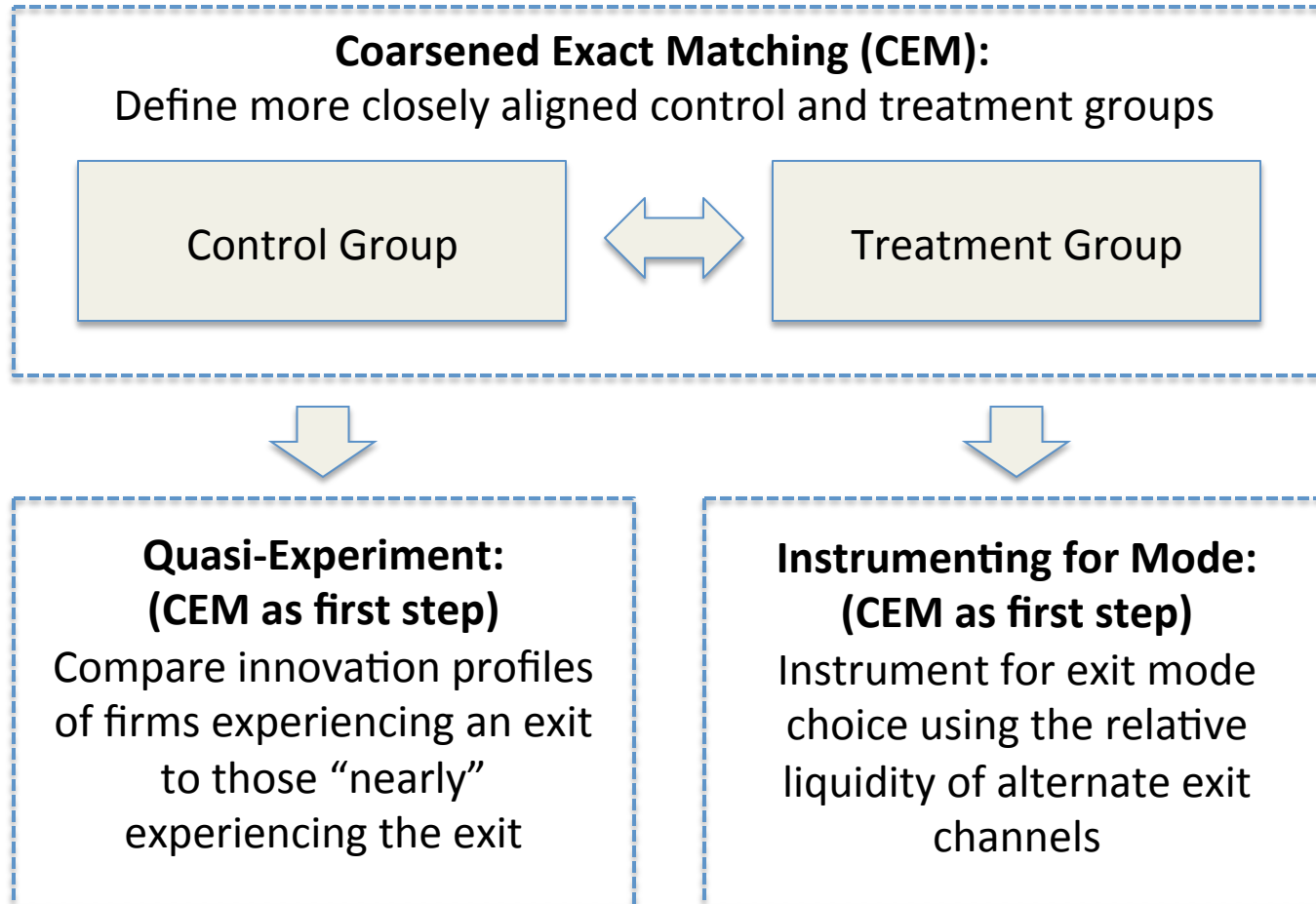
- Key difficulty: Investigating the innovation consequences of entrepreneurial exit mode raises the issue of possible self-selection into mode based on unobserved factors
 - ▶ “Gold standard” of random assignment into mode not possible
 - ▶ Being in a position to consider a liquidity event (of any sort) is not a random occurrence



- Goal: Disentangle the comingling of exit mode selection and treatment effects to estimate the causal effect of mode choice on innovation outcomes

What is our empirical strategy?

Three approaches using a panel dataset of VC-backed start-ups



CEM methodology

- **Goal: pre-process data by “pruning” observations to balance treated and control groups**
 - ▶ Creates similar distributions of covariates across groups
 - ▶ Reduces statistical bias and model dependence
- **Process for CEM**
 1. Coarsen each covariate into groups of substantively similar values (histogram)
 2. Group into “strata,” each of which contains exactly matched observations
 3. Retain strata that contain at least one control and at least one treatment
 4. Discard remaining strata and perform analyses on un-coarsened data; weight control units to equal number of treated units in strata
- **Benefits of CEM**
 - ▶ Works in sample, requires no assumptions about the data generation process
 - ▶ Statistical properties dominate methods such as propensity score matching
 - ▶ Easier to use than other matching methods and faster in computational time

Quasi-experiment

■ Our approach:

- ▶ Identify IPO and M&A events that were “withdrawn”
- ▶ Exit process started, but not taken to completion
- ▶ Try to verify that reasons for non-completion are exogenous
- ▶ Compare effects of “actual” treatment vs. “near” (withdrawn) control

■ IPOs:

- ▶ Firm filed for an IPO, subsequently did not go public
- ▶ Search news articles to ensure the IPO withdrawal was due to unstable or volatile market conditions

■ M&As:

- ▶ Deal announced, but never consummated
- ▶ Search news articles to ensure that withdrawals are due to shareholder objections or to regulatory oversight

Instrumenting for exit mode choice

- **Confine sample to firms experiencing either an IPO or M&A, using the IPO-treatment CEM-balanced sample**
- **Instrument for IPO event using the relative IPO vs. M&A biotechnology industry liquidity**
 - ▶ Relative “heat” in one market vs. other (within biotech)
 - ▶ Volume-based measures commonly employed in prior literature
 - ▶ Step 1: Number of quarters where four-quarter moving average of biotech IPO (or M&A) volume >25% last 5-year quarterly average
 - ▶ Step 2: IV is the ratio of the IPO measure to the M&A measure
 - ▶ All else equal, higher the IV, more likely firm will IPO
- **Instrument: positively related to IPO occurrence, unrelated to innovation**
 - ▶ Significant (1%) predictor of IPO year indicator
 - ▶ Industry-level measure of liquidity (outcomes at firm-level)
 - ▶ Not a measure of differences in factor inputs that would correlate with innovation
 - ▶ Prior literature suggests that it is very difficult to predict “hot” markets; thus unlikely that entrepreneurs can anticipate

Sample and dataset

- **Universe of VC-backed biotech firms founded 1980-2000**
 - ▶ VC involvement as a quality screen, desirable homogeneity as liquidity needs create pressures to pursue exits
 - ▶ Importance of patenting as a measure of innovation
 - ▶ 476 firms in human biotechnology
- **Unbalanced firm-year panel, observed from founding to 2006**
 - ▶ Final year chosen in accordance with forward citation measure
 - ▶ Include years following exit event (IPO, M&A, not dissolution)
- **Also assemble an inventor-year panel to sharpen our understanding of the underlying theoretical mechanisms**
- **Sources**: USPTO, IQSS, VentureXpert, Recap RDNA, PharmaProjects, Inteleos, IBES Factiva, Thomson One, Zephyr, SEC

Variable construction

■ Dependent variables

- ▶ Patent applications, forward citations (4-year window) (USPTO; IQSS)
- ▶ Challenge of identifying patents associated with the M&A subsample
 - Use pre-acquisition acquired firm inventors to identify post-acquisition patents for acquired firms
 - Include patents applied for directly by focal firm, as well as those applied for by pre-M&A firm inventors patenting post-M&A in the parent firm

■ Events and time windows

- ▶ Post-event (+1,+3); other windows for robustness
- ▶ Dummies for focal IPO sample and focal M&A sample

■ Time-varying biotechnology characteristics

- ▶ Firm age; VC inflow stock; strategic alliances stock; product portfolios

Variable construction

- **Withdrawn IPOs and M&As (quasi-experiment)**
- **Instrument for relative IPO market heat (IV strategy)**
- **Within-mode analyses to sharpen theoretical understanding**
 - ▶ **IPOs:**
 - Level of analyst coverage
 - ▶ **M&As:**
 - Public acquirer?
 - Technology overlap: measure of dyadic patent class overlap between acquirer and target (Jaffe 1986)

Summary statistics

Variable	Definition	Mean	Std. dev.
Dependent variables			
<i>Patent applications stock</i>	Stock of patent applications to firm i in year t	17.17	57.04
<i>Forward patent citations four years stock</i>	Forward patent citations to firm i 's stock of patents within four years of patents granted in year t	55.01	156.45
Independent variables			
Event and time variables			
<i>Focal IPO sample</i>	Dummy = 1 only for all firm-years (pre- and postevent) associated with a firm undergoing an IPO	0.48	0.50
<i>Focal, post-IPO window</i>	Dummy = 1 for the time window one to three years (inclusive) after the IPO event	0.08	0.27
<i>IPO year indicator</i>	Dummy = 1 only for the year in which a firm undertook an IPO	0.04	0.20
<i>Focal M&A sample</i>	Dummy = 1 only for all firm-years (pre- and postevent) associated with a firm undergoing an M&A	0.40	0.49
<i>Focal, post-M&A window</i>	Dummy = 1 for the time window one to three years (inclusive) after the M&A event	0.07	0.26
<i>Focal, post-M&A window, private acquirer</i>	Interaction term for the time window one to three years (inclusive) after the M&A event if acquired by a privately held entity (indicator variable)	0.04	0.20
<i>Focal, post-M&A window, technology overlap</i>	Interaction term for the time window one to three years (inclusive) after the M&A event with a normalized angular separation between vectors of primary patent classes of acquired and acquiring firms (see text; formula follows Jaffe 1986)	0.10	0.26
Biotechnology firm characteristics			
<i>Age</i>	Age in years of the focal firm as of year t	8.42	6.12
<i>VC inflows stock</i>	Cumulative VC inflows invested in the focal firm to year t (in \$M)	16.39	27.87
<i>Strategic alliance stock</i>	Cumulative number of strategic alliances the focal firm had entered into as of year t as reported by Deloitte Recap RDNA	10.39	17.91
<i>Weighted products^a</i>	Aggregate measure of focal firm's product portfolio in year t created by weighting the number of products along the FDA approval process: preclinical (weighted 1), stage 1 (2), stage 2 (5), and stage 3 (10)	75.54	143.38
<i>Preclinical products^a</i>	Number of preclinical products in a firm-year	1.05	3.39
<i>Analyst reports</i>	For firms going public, number of analyst reports issued on focal firm in year t	61.25	128.94
Instrumental variable			
<i>IPO vs. M&A biotechnology industry liquidity</i>	Ratio of number of quarters in a focal year in which the deal volume of IPOs in the biotechnology industry exceeded by 25% the rolling average over the prior five-year window to the same count for M&As	0.56	0.63

Results pre-CEM matching

- Simple post- vs. pre-event regressions (no matching, etc.)
- Key variable is *focal, post-event (1,3)* for IPO, M&A
- IPO: Decline in patent applications, increase in citations
- M&A: Increase in patent applications, decrease in citations

Dependent variable:	Post- vs. pre-IPO innovation comparisons				Post- vs. pre-M&A innovation comparisons			
	L Patent applications stock		L Forward patent citations four years stock		L Patent applications stock		L Forward patent citations four years stock	
	(3-1)	(3-2)	(3-3)	(3-4)	(3-5)	(3-6)	(3-7)	(3-8)
<i>Focal, postevent (1, 3)</i>	−1.069*** (0.054)	−0.361*** (0.032)	0.022 (0.022)	0.049** (0.023)	0.508*** (0.051)	0.223*** (0.032)	−0.066*** (0.020)	−0.073*** (0.021)
<i>Firm-level controls</i>	No	Yes	No	Yes	No	Yes	No	Yes
<i>Event year FE</i>	No	Yes	No	Yes	No	Yes	No	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.339*** (0.021)	−0.308*** (0.034)	0.276*** (0.018)	0.219*** (0.024)	1.759*** (0.021)	−0.320*** (0.033)	0.278*** (0.015)	0.264*** (0.022)
No. of observations (firms)	3,498 (202)	3,498 (202)	3,498 (202)	3,498 (202)	2,934 (180)	2,934 (180)	2,934 (180)	2,934 (180)

Pre- and post-CEM balancing

- CEM procedure: match on *age*, *VC inflow stock*, *strategic alliance stock*, and *weighted products*
- Separate control and treatment samples for IPO and M&A treatments

IPO Treatment

	<i>Pre-CEM</i>		<i>Post-CEM</i>	
	IPO sample	Control sample	IPO	Control sample
L <i>Age</i>	2.04 (0.83)	1.90** (0.83)	2.19 (0.60)	2.20 (0.68)
L <i>VC inflow stock</i>	2.10 (1.53)	1.55** (1.40)	2.16 (1.55)	2.00 (1.49)
L <i>Strategic alliance stock</i>	2.11 (1.18)	1.10** (1.03)	2.10 (0.79)	2.25 (0.77)
L <i>Weighted products</i>	1.22 (2.15)	0.91** (1.68)	0.59 (1.61)	0.44 (1.40)

M&A Treatment

	<i>Pre-CEM</i>		<i>Post-CEM</i>	
	M&A sample	Control sample	M&A	Control sample
	2.00 (0.83)	1.94** (0.83)	2.47 (0.47)	2.50 (0.43)
	2.05 (1.48)	1.66** (1.48)	2.44 (1.34)	2.37 (1.33)
	1.81 (1.23)	1.58** (1.21)	2.23 (0.96)	2.25 (0.77)
	1.12 (1.86)	1.02** (1.97)	1.03 (1.76)	0.99 (1.93)

Post-CEM (IPO treatment)

- Post-event reduction in patent applications and citations
 - ▶ Patent applications result in line with pre-CEM analysis (decrease)
 - ▶ Citations result reverses: 19% decrease in patent citations post-IPO (vs. 5% increase)
- Robust to: removing private-only firms; only firms undergoing both IPO *and* M&A

Dependent variable:	L Patent applications stock			L Forward patent citations four years stock		
Sample:	All	Removing firms remaining private	Firms experiencing both an IPO and M&A	All	Removing firms remaining private	Firms experiencing both an IPO and M&A
	(4-1)	(4-2)	(4-3)	(4-4)	(4-5)	(4-6)
<i>Focal, post-IPO (1, 3)</i>	−0.399*** (0.038)	−0.352*** (0.039)	−0.279*** (0.050)	−0.190*** (0.027)	−0.155*** (0.029)	−0.243*** (0.038)
<i>Focal IPO sample</i>	1.076 (2.257)	−1.391 (1.872)		1.710 (1.588)	0.112 (1.356)	
<i>Focal, post-M&A (1, 3)</i>			0.035 (0.055)			−0.119*** (0.041)
<i>Firm controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Event year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.778 (2.207)	−1.190 (0.540)	−1.762*** (0.585)	0.063 (1.555)	0.066 (1.308)	−0.437 (0.443)
No. of observations (firms)	2,702 (328)	1,872 (200)	817 (79)	2,702 (328)	1,872 (200)	817 (79)

Post-CEM (M&A treatment)

- Post-event increase in patent applications, reduction in forward citations
 - ▶ Applications effect: 25-50% the economic size of the pre-CEM analysis
 - ▶ Reduction in forward citations consistent with pre-CEM analysis
- Robust to: removing private-only firms; only firms undergoing both M&A *and* IPO

Dependent variable:	L Patent applications stock			L Forward patent citations four years stock		
Sample:	All	Removing firms remaining private	Firms experiencing both an M&A and IPO	All	Removing firms remaining private	Firms experiencing both an M&A and IPO
	(5-1)	(5-2)	(5-3)	(5-4)	(5-5)	(5-6)
<i>Focal, post-M&A</i> (1, 3)	0.171*** (0.022)	0.177*** (0.022)	0.106*** (0.027)	-0.037*** (0.013)	-0.036*** (0.014)	-0.078*** (0.018)
<i>Focal M&A sample</i>	0.693 (3.198)	0.522 (3.222)	0.011 (0.189)	1.431 (1.932)	1.430 (1.956)	-1.432 (2.082)
<i>Focal, post-IPO</i> (1, 3)			-0.504*** (0.047)			-0.083*** (0.033)
<i>Firm controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Event year FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.290 (2.262)	0.372 (2.280)	-0.188 (2.235)	0.009 (1.366)	0.361 (1.383)	0.153 (1.472)
No. of observations (firms)	4,711 (396)	3,681 (260)	1,369 (96)	4,711 (396)	3,681 (260)	1,369 (96)

Quasi-experiment (withdrawals)

- CEM matching as a first step (IPO and M&A treatments respectively)
- Results consistent with the two post-CEM analysis (IPO and M&A)
- Note: likelihood of withdrawal is unrelated to innovation and firm covariates

Estimation method and sample:	OLS analysis of “near” vs. actual IPOs, post-CEM		OLS analysis of “near” vs. actual M&As, post-CEM	
Dependent variable:	L Patent applications stock	L Forward patent citations four years stock	L Patent applications stock	L Forward patent citations four years stock
	(6-1)	(6-2)	(6-3)	(6-4)
<i>Focal, post-IPO</i> (1, 3)	-0.320*** (0.041)	-0.151*** (0.030)		
<i>Focal, post-M&A</i> (1, 3)			0.180*** (0.021)	-0.050** (0.014)
<i>Focal event sample</i>	-0.429 (0.910)	0.045 (0.457)	0.457 (2.182)	-0.985 (1.449)
<i>IPO year indicator</i> (instrumented)				
<i>Firm-level controls</i>	Yes	Yes	Yes	Yes
<i>Event year FE</i>	Yes	Yes	Yes	Yes
<i>Firm FE</i>	Yes	Yes	Yes	Yes
Constant	-2.373*** (0.749)	0.807* (0.435)	-0.457*** (0.124)	0.985*** (0.169)
No. of observations (firms)	1,612 (168)	1,612 (168)	2,154 (175)	2,154 (175)

Instrumenting for IPO exit mode

- Sub-sample of firms that experienced either an IPO or M&A
- First stage regression: *IPO year indicator* on *IPO vs. M&A biotech relative liquidity*, along with the slate of firm controls
- Results consistent with CEM matching alone, CEM + quasi-experiment

Estimation method and sample:	2SLS IV analysis on firms undergoing either an IPO or M&A, post-CEM balancing (IPO treatment)	
Dependent variable:	L Patent applications stock (2SLS)	L Forward patent citations four years stock (2SLS)
	(6-5)	(6-6)
<i>Focal, post-IPO</i> (1, 3)	−0.409*** (0.058)	−0.150*** (0.043)
<i>Focal event sample</i>	−0.145 (1.033)	0.152 (0.751)
<i>IPO year indicator</i> (instrumented)	1.157** (0.527)	−0.069 (0.384)
<i>Firm-level controls</i>	Yes	Yes
<i>Event year FE</i>	Yes	Yes
<i>Firm FE</i>	Yes	Yes
Constant	−1.000 (0.700)	0.809 (0.510)
No. of observations (firms)	1,049 (179)	1,049 (179)

Theoretical mechanisms

■ Prior literature

- ▶ Drivers of exit mode choice
 - VC contract design, industry and market characteristics, firm and product market characteristics, founder preferences
- ▶ No empirical study linking choice among multiple exit modes to innovation

■ Information confidentiality as a key mechanism

- ▶ Routine disclosure to meet shareholder expectations under public ownership
- ▶ Possible information leakage to competitors
- ▶ Differences in project selection and managerial ability to take risk

■ Key prediction: Private > M&A > Public (with respect to innovation)

■ Alternate explanation: HR turnover (inventor-level dataset)

Testing mechanisms and robustness

■ Tests using within-IPO sample

- ▶ Joint condition of high preclinical products and high analyst coverage reduces patent citations

■ Tests using within-M&A sample


- ▶ Private acquirer increases citations
- ▶ Higher technology overlap with acquiring firm increases applications and reduces citations



Within-mode results → information confidentiality mechanism

- Results robust to different post-event windows
- Inventor-level dataset:
 - ▶ Productivity: post-exit, post-joining, post-leaving
 - ▶ Inventor-level turnover not driving firm-level patterns

Summary

- **Main findings: private > M&A > IPO, for innovation quality**
 - ▶ **Evidence for causal effects of mode choice on innovation**
 - CEM to preprocess data and create matched samples (IPO, M&A treatments)
 - Quasi-experiment focusing on “near” vs. “realized” exit outcomes
 - Instrument for IPO choice using the IPO + M&A sub-sample
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- Together, these approaches help overcome endogeneity associated with the lack of random selection to exit mode
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- ▶ **Evidence for firm-level information confidentiality mechanism**
 - Within-mode analyses at the IPO and M&A-levels
 - Inventor-level analyses suggesting that effects arise due to firm-level factors
 - Robustness checks on different exit windows suggest a “regime shift” explanation

CEM method references

- **Technical references:**

- ▶ Iacus, King & Porro (Political Analysis, 2012)
- ▶ Iacus, King & Porro (JASA, 2011)

- **Stata programming reference:**

- ▶ Blackwell, Iacus, King & Porro (Stata Journal, 2009)

- **Some examples of CEM application:**

- ▶ Aggarwal & Hsu (MS, 2014)
- ▶ Azoulay, Graff Zivin & Wang (QJE, 2010)
- ▶ Singh & Agrawal (MS, 2011)

Thank you!

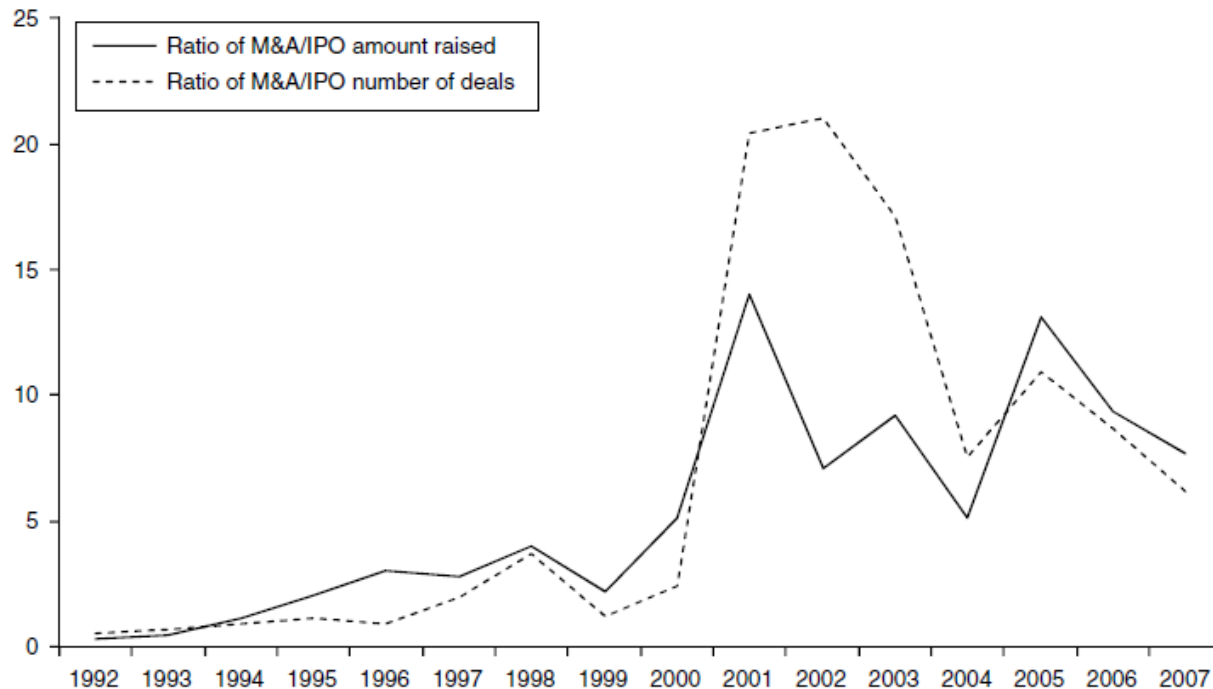
Questions?

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Balance of IPO vs. M&A exits

- M&A outstrips IPO as the modal form of entrepreneurial exit; increasingly dominant in recent years (public policy implications...)
- Modes are correlated, but not perfectly so (implications for IV analysis)

M&A to IPO ratio (value and number of deals)
All venture capital-backed firms



CEM benefits

- **Statistical benefits to using CEM (e.g., Iacus et al, 2011)**
 - ▶ Bounds the degree of imbalance (chosen by the user)
 - ▶ Bounds level of model dependence and average treatment effect estimation error
 - ▶ Produces reasonable number of matches on real data sets (correlated covariates)
- **Comparison with propensity score matching (e.g., King et al, 2011)**
 - ▶ PSM: collapse vectors of pre-treatment covariates to $P(\text{treatment})$, then match each treated unit to the “nearest neighbor” control unit; apply some method to remove treated units that are too distant from the controls
 - ▶ Iteratively aim to maximize treated-control balance and sample size
 - ▶ PSM: choose fixed number of observations ex ante, hope for imbalance reduction as a result of the procedure
 - ▶ In CEM, fixed level of balance is chosen ex ante, and the number of observations is simply an outcome of this process
 - ▶ PSM tends to approximate random matching in many situations