





Independent Boards and Innovation

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My objectives for today's talk:

- Discuss how pressures for better governance since SOX and scandals have influenced innovation
 - I'm not a finance guy (that's Gustavo) so am curious for your input
- Cause you to ponder how we conceptualize and measure innovation
 - Patent and cite counts are inadequate and potentially misleading
 - Highly cited patents correlate with value (Trajtenberg; Harhoff and colleagues; Hall and colleagues) but the relationship is very noisy and the mechanisms remain poorly explained
 - We propose more extensive measures that differentiate effort/ productivity vs. creativity/novelty/search





Managers must be monitored...

- High-profile scandals of the 1990s (Enron, WorldCom) transformed corporate governance landscape
- "...the Enron Board of Directors failed to safeguard Enron shareholders and contributed to the collapse of the seventh largest public company in the United States..." Forbes 2001
- Since 2002, Sarbanes-Oxley requires majority of independent directors
- Consensus: board oversight has increased











...but monitoring imposes costs

- Manager's career concerns increase (Aghion et al. 2013)
- Manager's don't like to share information (Adams and Ferreira 2007)
- Managing becomes less appealing (Aghion and Tirole, 1997)
- Directors themselves "...want to move beyond their 'compliance' (monitoring) role to a more 'valueadded' (strategic) role." (Leblanc and Gillies, 2005)
- 84% of directors agree that they are spending more time on monitoring than on strategy (Heidrick & Struggles, 2007)
- 75% of directors want to devote more time to strategy discussions (PricewaterhouseCoopers, 2012)





RQ: What's the influence of independent boards on innovation?

H1: Firms that transition to independent boards will invent more patents.

H2: Firms that transition to independent boards will invent less creative and less novel patents.





H1: Firms that transition to independent boards will invent more patents

- Independent boards more likely to fire a manager for poor performance
 - so managers (and assumedly their underlings) work harder
- Increased monitoring alleviates agency problems

- less shirking

- Managers take actions that are and appear to be more in the interests of shareholders
 - patents can be counted and adduced as evidence for superior performance





H2: Firms that transition to independent boards will invent less creative and less novel patents

- Independent boards more likely to fire a manager for poor performance
 - so managers become concerned about career and risk averse
- Increased monitoring focuses manager on immediate gain
 - rather than embark on risky new exploration, will harvest currently successful approaches
- Independent boards constrain future flexibility
 - options created by exploration become more difficult to pursue
- Risk aversion flattens distribution of citation outcomes – completely failed and breakthrough inventions less likely





Related literatures

- Exploration/exploitation and incentives (Arrow, 1969; Weitzman, 1979; March, 1991; Manso, 2011)
- Managerial discretion and agency (Aghion and Tirole, 1997; Burkart, Gromb, and Panunzi, 1997; Adams and Ferreira, 2007)
- Corporate governance and innovation (almost all use patent data):
 - –Managerial compensation (Ederer and Manso, 2013; Baranchuk, Kieschnick, and Moussawi, 2014), firm's going public decision (Bernstein, 2012)
 - -Private equity/venture capital involvement (Lerner, Sorensen, and Stromberg, 2011; Tian and Wang, 2014; Chemmanur, Loutskina, and Tian, 2014)
 - -Anti-takeover provisions (Atanassov, 2013; Chemmanur and Tian, 2014)
 - –Institutional ownership (Aghion, Van Reenen, and Zingales, 2013)
 - -Financial market development (Hsu, Tian, and Xu, 2014)
 - -Conglomerate structure (Seru, 2014)
 - -Analyst coverage (He and Tian, 2013)
 - -Stock market liquidity (Fang, Tian, and Tice, 2013)







Identification from regulatory change

- No random shock, but exogenous pressures on board composition (→ increase independent directors)
- 1999: Blue Ribbon committee
- 2001: Enron scandal
- 2002: Sarbanes Oxley Act
- 2003: Change in NYSE and Nasdaq



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- Focus on switch from minority to majority of independent directors after regulatory changes became effective

 – empirically: 1{board composition > 50% independent}
- Control group: All firms in compliance before change







Identification from regulatory change (source IRRC)







Data

- Public U.S. based firms from 1996 to 2006
- Granted patents applied for 1996-2006
- •NBER data ends 2006, causing truncation of application dates
- Start with USPTO standardized names in 2012
- Use NBER assignment of patents to standardized names
 1975-2006
- Applied this training set to Fung Institute April 2014 dataset
- Board data from Investor Responsibility Research Center (IRRC)
- Compustat data merged in
- 337,465 patents for 6,676 observations of 932 firms





Summary stats

Variable	Ν	mean	median	sd	min	max
Patents	6107	53.78	3	243.36	0	5261
Citations	6107	573.70	5	3329.21	0	108496
Top 1%	6107	0.53	0	2.42	0	44
Top 10%	6107	5.06	0	25.18	0	660
Cited patents	6107	30.62	1	149.93	0	3512
Uncited patents	6107	18.13	1	98.77	0	4033
Back-citations	6107	1157.22	26	4851.25	0	101943
Self-citations	6107	176.60	0	990.85	0	22415
New classes	6107	1.28	0	3.88	0	227
Old classes	6107	52.50	2	242.47	0	5259
Tech. prox.	6107	0.54	0.68	0.41	0	1
Indep. Board	6107	0.77	1	0.42	0	1
Board size	6107	9.23	9	2.52	3	21
log(total assets)	6107	7.41	7.22	1.51	3.09	13.53
R&D /assets	6107	0.05	0.02	0.07	0	1.12
Age	6107	17.78	15	10.98	1	37
Cap. exp. /assets	6107	0.05	0.04	0.04	0	0.43
Leverage	6107	0.18	0.17	0.16	0	1.35
log(Q)	6107	1.23	1.04	0.85	-2.46	6.72





Diffs in diffs OLS models

- Patents, cites, backward cites, self-cites, new and old classes, technological distance:
 - a) Industry FE
 - b) Firm FE
 - c) Firm FE and Coarsened Exact Matching (CEM)
 - d) Firm FE, CEM, and firm specific trend controls
 - e) Firm FE, CEM, trend, change in control variable influence
- •Controls: Boardsize, total assets, R&D, long term debt/ assets, age, cap ex,Tobin's Q, CEO tenure, age
- Robust to Poisson QMLE

 $log(1 + patents_{i,t+1}) = \beta_0 + \beta_1 \cdot independent \ board_{it} \cdot post_t + \gamma \cdot Z_{it}$

 $+ \delta \cdot firm_i \cdot pre2002_t \cdot t + \zeta \cdot Z_{it} \cdot post_t + \theta_t + \alpha_i + \epsilon_{it}$





Variable	no. of firms	mean
Panel A: Treate	d firms before matc	hing
log(total assets)	125	7.02
R&D / assets	125	0.04
Age	125	2.45
Leverage	125	0.18
Cap. exp.	125	0.06
log(Q)	125	1.34
Board size	125	8.45
Panel B: Non-trea	ted firms before ma	tching
log(total assets)	588	7.33**
R&D / assets	588	0.05*
Age	588	2.43
Leverage	588	0.20
Cap. exp.	588	0.05
log(Q)	588	1.25
Board size	588	8.99**
Panel C: Non-tre	ated firms after mat	ching
log(total assets)	430	6.99
R&D / assets	430	0.04
Age	430	2.37
Leverage	430	0.20
Cap. exp.	430	0.05
log(Q)	430	1.21
Board size	430	8.56





No impact of board independence on R&D spending

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.822***	0.564***	0.601***	0.609***	0.602***
	(0.017)	(0.044)	(0.040)	(0.049)	(0.049)
log(age)	-0.153***	0.002	-0.006	-0.017	-0.013
	(0.021)	(0.029)	(0.038)	(0.056)	(0.054)
Leverage	-0.562***	0.040	-0.085	-0.211	-0.462**
-	(0.113)	(0.107)	(0.124)	(0.152)	(0.212)
Cap. exp.	0.753	0.562	0.542	0.378	0.820
	(0.616)	(0.351)	(0.391)	(0.431)	(0.518)
log(Q)	0.366***	-0.016	-0.015	-0.014	0.022
0.1	(0.025)	(0.024)	(0.029)	(0.032)	(0.035)
Boardsize	0.024**	0.007	0.004	0.006	-0.004
	(0.009)	(0.008)	(0.011)	(0.013)	(0.014)
Independent board	0.071	-0.052	-0.057	-0.059	-0.043
-	(0.090)	(0.055)	(0.056)	(0.064)	(0.061)
Observations	6107	6107	4414	4414	4414
R^2	0.733	0.256	0.254	0.450	0.508
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes



Berkeley Haas

20-30% increase in number of patent grants to firms whose boards go independent

	(a)	(b)	(c)	(d)	(e)		
	b/se	b/se	b/se	b/se	b/se		
log(total assets)	0.767***	0.273***	0.284***	0.369***	0.425***		
	(0.017)	(0.060)	(0.064)	(0.067)	(0.079)		
R&D	5.561***	0.941*	0.842	0.711	0.835		no. patents
	(0.568)	(0.517)	(0.668)	(0.713)	(0.896)	- 1.5	
log(age)	0.105***	0.068	0.000	0.004	-0.019		
	(0.023)	(0.044)	(0.039)	(0.048)	(0.058)	 8	/
Leverage	-0.468***	-0.112	-0.094	-0.253	-0.250	ut si	
	(0.123)	(0.176)	(0.196)	(0.188)	(0.212)	fficie	
Cap. exp.	1.635***	0.147	0.127	0.321	0.325		
	(0.490)	(0.484)	(0.518)	(0.522)	(0.561)		
log(Q)	0.199***	0.057*	0.057	0.081**	0.066	بن _	
	(0.027)	(0.034)	(0.037)	(0.040)	(0.041)	-5 -4 -3	-2 -1 0 1 2 3 4
Boardsize	0.015	0.017	-0.003	-0.016	-0.012		timeline
	(0.010)	(0.014)	(0.016)	(0.015)	(0.017)		
Independent board	0.308***	0.272***	0.215***	0.208**	0.198**	bco	efficients — — – 95%-confidence-inte
	(0.083)	(0.079)	(0.080)	(0.087)	(0.087)		
Observations	6107	6107	4414	4414	4414		
R ²	0.571	0.207	0.176	0.410	0.414		
Year fixed effects	Yes	Yes	Yes	Yes	Yes		
Firm fixed effects	No	Yes	Yes	Yes	Yes		
Trend control	No	No	No	Yes	Yes		
Controls * post-SOX	No	No	No	No	Yes		





35-50% increase in number of claims within patents to firms whose boards go independent

	(a)	(b)	(c)	(d)	(e)	-
	b/se	b/se	b/se	b/se	b/se	
log(total assets)	1.013***	0.380***	0.362***	0.512***	0.477***	
	(0.030)	(0.099)	(0.114)	(0.132)	(0.146)	
R&D	8.685***	1.326	1.362	1.486	0.580	
	(0.981)	(0.950)	(1.182)	(1.300)	(1.368)	
log(age)	0.146***	0.030	-0.002	-0.001	-0.097	
	(0.043)	(0.059)	(0.067)	(0.083)	(0.094)	
Leverage	-0.291	0.188	0.230	-0.099	0.084	10101
	(0.228)	(0.282)	(0.322)	(0.330)	(0.414)	1000
Cap. exp.	1.448	-0.023	0.012	0.447	0.338	
	(0.881)	(0.934)	(0.989)	(1.059)	(1.183)	
log(Q)	0.280***	0.110*	0.152**	0.184**	0.172**	
	(0.051)	(0.062)	(0.068)	(0.078)	(0.087)	
Boardsize	0.000	0.002	-0.014	-0.037	-0.036	
	(0.017)	(0.022)	(0.027)	(0.028)	(0.033)	
Independent board	0.501***	0.488***	0.476***	0.365**	0.359**	Т
	(0.153)	(0.137)	(0.142)	(0.178)	(0.178)	
Observations	6107	6107	4414	4414	4414	
R ²	0.466	0.133	0.119	0.304	0.307	
Year fixed effects	Yes	Yes	Yes	Yes	Yes	
Firm fixed effects	No	Yes	Yes	Yes	Yes	
Trend control	No	No	No	Yes	Yes	
Controls * post-SOX	No	No	No	No	Yes	_





This is a relatively unused variable in the lit to date

Berkeley Haas



						_
	(a)	(b)	(c)	(d)	(e)	_
	b/se	b/se	b/se	b/se	b/se	
log(total assets)	0.917***	0.320***	0.276***	0.321***	0.523***	-
	(0.027)	(0.089)	(0.098)	(0.115)	(0.126)	
R&D	7.700***	2.464***	2.706***	3.292***	4.767***	
	(0.868)	(0.836)	(1.036)	(1.159)	(1.402)	
log(age)	0.142***	0.065	0.006	0.024	-0.056	
	(0.038)	(0.056)	(0.058)	(0.080)	(0.089)	
Leverage	-0.369*	0.124	0.337	0.203	0.146	
-	(0.200)	(0.262)	(0.301)	(0.304)	(0.388)	
Cap. exp.	2.623***	0.118	0.184	0.551	0.524	
	(0.805)	(0.817)	(0.852)	(0.980)	(1.117)	
log(Q)	0.355***	0.221***	0.240***	0.244***	0.275***	
	(0.046)	(0.055)	(0.061)	(0.076)	(0.085)	
Boardsize	0.000	-0.004	-0.029	-0.045*	-0.049	
	(0.015)	(0.021)	(0.026)	(0.027)	(0.032)	
Independent board	0.594***	0.635***	0.536***	0.423***	0.411***	
	(0.128)	(0.116)	(0.119)	(0.137)	(0.139)	
Observations	6107	6107	4414	4414	4414	
R ²	0.506	0.318	0.286	0.446	0.454	
Year fixed effects	Yes	Yes	Yes	Yes	Yes	
Firm fixed effects	No	Yes	Yes	Yes	Yes	
Trend control	No	No	No	Yes	Yes	
Controls * post-SOX	No	No	No	No	Yes	_
						_



This is where most of the literature has stopped to date.



Finfet transistor structures having a double gate ... (Degree 3)



Raw citation counts are widely used and shown to correlate with value, but distribution and type of citation less commonly used.

We will break citation distribution into separate estimations with number of patents in each area of the distribution (quantile regressions don't always converge but are consistent).





No consistent signal for number of top 1% cited patents (* p<.10)

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.166***	0.037**	0.056***	0.054***	0.037*
	(0.008)	(0.016)	(0.015)	(0.019)	(0.020)
R&D	0.724***	-0.092	-0.060	-0.045	-0.102
	(0.097)	(0.136)	(0.223)	(0.290)	(0.364)
log(age)	0.036***	0.013	0.004	-0.002	-0.008
	(0.007)	(0.010)	(0.008)	(0.011)	(0.013)
Leverage	-0.198***	-0.049	-0.113***	-0.145**	-0.110
	(0.035)	(0.042)	(0.043)	(0.058)	(0.070)
Cap. exp.	0.489***	-0.109	-0.094	-0.110	-0.049
	(0.150)	(0.118)	(0.107)	(0.130)	(0.152)
log(Q)	0.031***	-0.000	-0.015	-0.021	-0.023
	(0.009)	(0.011)	(0.012)	(0.015)	(0.015)
Boardsize	0.000	0.004	0.000	-0.002	0.002
	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)
Independent board	0.027	0.043*	0.030	0.045*	0.041
	(0.027)	(0.024)	(0.025)	(0.027)	(0.026)
Observations	6107	6107	4414	4414	4414
R^2	0.312	0.009	0.014	0.179	0.182
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes





No consistent signal for number of top 2% to 10% patents

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.389***	0.103***	0.113***	0.109***	0.058
	(0.014)	(0.030)	(0.032)	(0.035)	(0.038)
R&D	2.283***	0.218	-0.072	-0.120	-0.232
	(0.265)	(0.222)	(0.344)	(0.420)	(0.553)
log(age)	0.072***	0.040**	0.027*	0.030	0.035
	(0.015)	(0.017)	(0.014)	(0.019)	(0.022)
Leverage	-0.300***	0.049	-0.046	-0.079	-0.064
0	(0.076)	(0.072)	(0.083)	(0.095)	(0.110)
Cap. exp.	0.997***	-0.236	-0.196	-0.228	-0.068
	(0.330)	(0.207)	(0.219)	(0.228)	(0.277)
log(Q)	0.101***	0.030	0.026	0.034	0.028
	(0.018)	(0.019)	(0.022)	(0.030)	(0.028)
Boardsize	0.003	0.004	-0.004	-0.007	-0.001
	(0.007)	(0.006)	(0.007)	(0.008)	(0.009)
Independent board	0.069	0.064*	0.051	0.062	0.061
•	(0.054)	(0.039)	(0.040)	(0.055)	(0.054)
Observations	6107	6107	4414	4414	4414
R ²	0.407	0.017	0.021	0.208	0.214
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes





22-35% increase in number of cited but not top 10% patents

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.678***	0.268***	0.227***	0.251***	0.316***
	(0.018)	(0.055)	(0.057)	(0.062)	(0.069)
R&D	4.879***	1.123**	0.820	0.857	1.210
	(0.497)	(0.459)	(0.566)	(0.615)	(0.755)
log(age)	0.097***	0.045	0.001	0.004	-0.024
	(0.023)	(0.034)	(0.032)	(0.041)	(0.048)
Leverage	-0.433***	-0.045	-0.031	-0.103	-0.064
	(0.116)	(0.148)	(0.157)	(0.162)	(0.189)
Cap. exp.	2.093***	0.284	0.407	0.553	0.544
	(0.481)	(0.401)	(0.419)	(0.455)	(0.519)
log(Q)	0.183***	0.091***	0.103***	0.097***	0.090**
	(0.027)	(0.031)	(0.032)	(0.037)	(0.039)
Boardsize	0.004	0.009	-0.003	-0.016	-0.014
	(0.009)	(0.012)	(0.014)	(0.014)	(0.016)
Independent board	0.348***	0.339***	0.260***	0.229***	0.220***
	(0.076)	(0.067)	(0.067)	(0.073)	(0.074)
Observations	6107	6107	4414	4414	4414
R^2	0.536	0.248	0.207	0.416	0.421
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes





No strong signal for uncited patents

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.635***	0.223***	0.278***	0.390***	0.299***
	(0.015)	(0.068)	(0.075)	(0.081)	(0.095)
R&D	3.953***	0.184	-0.206	-0.677	-1.452
	(0.433)	(0.557)	(0.868)	(0.990)	(1.322)
log(age)	0.085***	0.071	-0.011	-0.004	-0.025
	(0.019)	(0.047)	(0.039)	(0.051)	(0.066)
Leverage	-0.418***	-0.233	-0.299	-0.492**	-0.273
-	(0.103)	(0.175)	(0.209)	(0.217)	(0.244)
Cap. exp.	1.043***	-0.264	-0.304	-0.338	-0.343
	(0.400)	(0.472)	(0.513)	(0.532)	(0.568)
log(Q)	0.114***	0.003	-0.012	0.006	-0.025
	(0.023)	(0.035)	(0.040)	(0.044)	(0.043)
Boardsize	0.019**	0.028*	0.010	-0.000	0.003
	(0.008)	(0.015)	(0.015)	(0.015)	(0.018)
Independent board	0.167**	0.106	0.077	0.099	0.098
	(0.071)	(0.089)	(0.090)	(0.094)	(0.091)
Observations	6107	6107	4414	4414	4414
R ²	0.510	0.045	0.040	0.323	0.332
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes





Quantile regression of board change on future cites



See very similar results for quantile regression at the patent level



patents



40-50% increase in backward cites of firm's

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	1.030***	0.399***	0.383***	0.556***	0.535***
	(0.031)	(0.106)	(0.119)	(0.134)	(0.148)
R&D	8.023***	1.155	1.117	1.342	0.465
	(0.932)	(1.032)	(1.211)	(1.394)	(1.359)
log(age)	0.133***	0.017	-0.022	0.009	-0.102
	(0.045)	(0.064)	(0.076)	(0.094)	(0.106)
Leverage	-0.231	0.213	0.251	-0.137	-0.052
-	(0.238)	(0.304)	(0.356)	(0.363)	(0.439)
Cap. exp.	2.028**	0.085	0.044	0.382	0.515
	(0.915)	(0.958)	(1.007)	(1.099)	(1.225)
log(Q)	0.305***	0.127**	0.160**	0.188**	0.183**
	(0.052)	(0.063)	(0.070)	(0.083)	(0.091)
Boardsize	0.002	-0.002	-0.021	-0.041	-0.044
	(0.018)	(0.023)	(0.028)	(0.030)	(0.035)
Independent board	0.498***	0.479***	0.482***	0.389**	0.388**
-	(0.159)	(0.133)	(0.139)	(0.173)	(0.174)
Observations	6107	6107	4414	4414	4414
R^2	0.450	0.115	0.106	0.295	0.298
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes



Firms move into areas where patents cite more prior art (think econ vs. management) – what does that imply for total citations – and assumed value of innovations?





Pardon the endogeneity: quantile regression of board change on cites in future years w/ backward cites (in year of application) as control



Similar mediation by including number of patents or claims





25-40% increase in self cites

	(a)	(b)	(c)	(d)	(e)	_
	b/se	b/se	b/se	b/se	b/se	
log(total assets)	0.833***	0.204***	0.160**	0.244***	0.244**	-
0.	(0.024)	(0.071)	(0.072)	(0.085)	(0.099)	self-cites
R&D	5.728***	0.234	-0.104	-0.233	-0.585	رز –
	(0.636)	(0.671)	(0.835)	(1.056)	(1.106)	
log(age)	0.158***	0.075	0.013	0.030	0.000	size
	(0.031)	(0.047)	(0.045)	(0.060)	(0.071)	
Leverage	-0.321*	0.004	-0.014	-0.275	-0.154	oeffic
Ū	(0.170)	(0.228)	(0.257)	(0.264)	(0.346)	° •
Cap. exp.	3.488***	0.853	0.761	1.017	1.240	u
	(0.672)	(0.580)	(0.595)	(0.703)	(0.829)	
log(Q)	0.269***	0.035	0.038	0.059	0.075	timeline
	(0.038)	(0.042)	(0.043)	(0.047)	(0.053)	b coefficients 05% confidence interval
Boardsize	0.018	0.023	0.010	-0.013	-0.017	
	(0.013)	(0.015)	(0.018)	(0.018)	(0.022)	
Independent board	0.389***	0.359***	0.284***	0.260***	0.262***	
	(0.109)	(0.080)	(0.081)	(0.096)	(0.096)	
Observations	6107	6107	4414	4414	4414	Firms with independent boards
R ²	0.469	0.088	0.061	0.285	0.286	focus on their extant
Year fixed effects	Yes	Yes	Yes	Yes	Yes	technologies
Firm fixed effects	No	Yes	Yes	Yes	Yes	
Trend control	No	No	No	Yes	Yes	
Controls * post-SOX	No	No	No	No	Yes	





20-30% increase in number of patents in previously patented classes

	(a)	(b)	(c)	(d)	(e)	
	b/se	b/se	b/se	b/se	b/se	_
log(total assets)	0.779***	0.275***	0.290***	0.368***	0.431***	-
	(0.018)	(0.059)	(0.063)	(0.066)	(0.078)	no. of patents in known classes
R&D	5.718***	0.989*	0.743	0.534	0.649	
	(0.572)	(0.527)	(0.678)	(0.732)	(0.943)	
log(age)	0.107***	0.061	-0.018	-0.020	-0.038	e e
	(0.023)	(0.046)	(0.040)	(0.050)	(0.059)	
Leverage	-0.521***	-0.206	-0.217	-0.383**	-0.390*	Hicie
	(0.124)	(0.179)	(0.200)	(0.191)	(0.221)	
Cap. exp.	1.622***	-0.009	0.056	0.122	0.167	
	(0.500)	(0.471)	(0.510)	(0.501)	(0.553)	``
log(Q)	0.214***	0.059*	0.064*	0.091**	0.080*	-5 -4 -3 -2 -1 0 1 2 3 4 5
	(0.028)	(0.034)	(0.037)	(0.040)	(0.042)	timeline
Boardsize	0.018*	0.023	0.006	-0.005	-0.001	
	(0.010)	(0.014)	(0.016)	(0.015)	(0.017)	b-coefficients 95%-confidence-interva
Independent board	0.323***	0.289***	0.231***	0.209**	0.198**	
	(0.082)	(0.079)	(0.079)	(0.083)	(0.083)	Firme with independent board
Observations	6107	6107	4414	4414	4414	- Finns with independent boards
R^2	0.572	0.184	0.153	0.401	0.406	focus on their extan
Year fixed effects	Yes	Yes	Yes	Yes	Yes	technologies
Firm fixed effects	No	Yes	Yes	Yes	Yes	Ũ
Trend control	No	No	No	Yes	Yes	
Controls * post-SOX	No	No	No	No	Yes	_





No clear signal in number of patents in new-tofirm classes

	(4)			(4)	(0)	
	b/se	b/se	b/se	b/se	b/se	
log(total assets)	0.171***	0.096***	0.103***	0.101**	0.177***	-
	(0.008)	(0.032)	(0.037)	(0.042)	(0.045)	no. of patents in new classes
R&D	0.994***	0.329	0.508	0.516	1.039**	
	(0.175)	(0.270)	(0.379)	(0.472)	(0.494)	0
log(age)	-0.002	0.018	0.025	0.032	0.021	2
	(0.010)	(0.019)	(0.021)	(0.025)	(0.029)	Lician de la companya
Leverage	-0.091*	0.099	0.104	0.099	-0.011	0
	(0.055)	(0.086)	(0.098)	(0.115)	(0.134)	
Cap. exp.	0.958***	0.916***	0.802**	0.866**	0.975**	بن [–]
	(0.239)	(0.303)	(0.322)	(0.389)	(0.443)	-5 -4 -3 -2 -1 0 1 2 3 4 5
log(Q)	0.062***	0.064***	0.053***	0.026	0.012	timeline
	(0.012)	(0.019)	(0.020)	(0.025)	(0.027)	b coefficiente 05% coefficience interval
Boardsize	0.002	0.004	-0.004	-0.009	-0.012	
	(0.005)	(0.008)	(0.011)	(0.012)	(0.012)	
Independent board	0.088**	0.055	0.023	0.037	0.036	
	(0.036)	(0.045)	(0.044)	(0.053)	(0.052)	- Etherican Million and a state of the second state
Observations	6107	6107	4414	4414	4414	Firms with independent boards do
R ²	0.319	0.134	0.115	0.284	0.291	not explore new technologies.
Year fixed effects	Yes	Yes	Yes	Yes	Yes	
Firm fixed effects	No	Yes	Yes	Yes	Yes	
Trend control	No	No	No	Yes	Yes	
Controls * post-SOX	No	No	No	No	Yes	





Sometimes significant 25% increase in Jaffe measure year to year

	(a)	(b)	(c)	(d)	(e)
	b/se	b/se	b/se	b/se	b/se
log(total assets)	0.451***	0.187**	0.224**	0.363***	0.306**
	(0.020)	(0.085)	(0.100)	(0.117)	(0.124)
R&D	5.353***	0.859	0.976	0.820	0.033
	(0.710)	(0.835)	(1.018)	(1.104)	(1.132)
log(age)	0.085***	-0.005	-0.024	-0.021	-0.049
	(0.030)	(0.052)	(0.063)	(0.077)	(0.081)
Leverage	-0.020	-0.138	-0.075	-0.448	-0.472
	(0.172)	(0.263)	(0.313)	(0.344)	(0.428)
Cap. exp.	-0.280	-0.179	-0.362	-0.228	-0.161
	(0.663)	(0.856)	(0.937)	(0.944)	(1.055)
log(Q)	0.177***	0.038	0.061	0.100	0.097
	(0.036)	(0.048)	(0.057)	(0.066)	(0.074)
Boardsize	0.014	0.023	0.011	0.010	0.022
	(0.012)	(0.018)	(0.022)	(0.025)	(0.030)
Independent board	0.247**	0.255**	0.289**	0.177	0.169
	(0.115)	(0.120)	(0.126)	(0.138)	(0.140)
Observations	6107	6107	4414	4414	4414
R^2	0.369	0.118	0.112	0.292	0.294
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Trend control	No	No	No	Yes	Yes
Controls * post-SOX	No	No	No	No	Yes



Firms whose boards go independent tend to stay closer to last year's position in technology "space" (working on visualizing this)





Robustness checks

- See same firm level effects at patent level
 - citation distribution
 - proportion of back and self cites
- Coefficient of variation down for IB transitions
- Alternate mechanisms:
 - lazy manager
 - explains productivity increase nicely but no implications for explore/exploit tradeoff
 - career concerns -> risk aversion
 - split sample by entrenchment index (Bebchuk, Cohen, and Ferrell 2009)
 - greater impact on more highly entrenched managers











Research needs to be more subtle in conceptualizing and measuring innovation

- "Innovation" is usually synonymous with patent counts/citations/novelty/search/exploration
 - yet our results demonstrate an inverse correlation between counts and cites with novelty and search
- Many papers adduce increased patent counts and cites as evidence for "risky" innovation
 - cannot directly speak to risk, but can show how safer exploitation strategies lead to greater counts and cites





Contributions

- Simple model and consistent evidence for how independent boards influence innovation
 - Firms whose boards go independent exploit current technologies at expense of exploring new technologies
- Metrics for innovative productivity vs. creativity
 - Reliance on citation counts no solution and possibly misleading
- •Next paper: exploration/exploitation => firm value?





Correlation Matrix

	variable	1	2	3	4	5	6	7	8	9
1	patents	1								
2	all future cites	0.8643	1							
3	no. new classes entered	0.7073	0.6012	1						
4	patents in new classes	0.7106	0.6073	0.987	1					
5	patents in old classes	0.968	0.8344	0.5561	0.5533	1				
6	tech proximity	0.2695	0.2709	-0.0492	-0.0464	0.3578	1			
7	av. back cite year	-0.0028	-0.0504	-0.0771	-0.0745	0.0193	0.0234	1		
8	av. inventor age	0.1749	0.1591	-0.0556	-0.0498	0.2288	0.1378	0.2773	1	
9	all back cites	0.9146	0.8405	0.6189	0.6259	0.8885	0.2783	0.1134	0.2349	1
10	all self cites	0.8774	0.7672	0.4728	0.4725	0.8949	0.3021	0.0777	0.2798	0.8528







PCA – Varimax rotation

Variable	Comp1 (Exploit)	Comp2 (Explore)
no. new classes entered		0.5667
patents in new classes		0.5644
patents in old classes	0.4600	
tech proximity	0.3587	-0.2526
av. back cite year	0.2522	-0.3081
av. inventor age	0.3957	-0.3547
all back cites	0.4441	
all self cites	0.4768	

Rotated components, abs(loading)<0.2 blank



Exploit

College of Engineering | UC Berkeley



A typology of technology search



strategies

Next step is to connect these strategies with performance