

Initial Competence, Innovation Strategies, and Firm Growth

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- Many studies investigate the determinants of firm innovation and growth
- However, what really determines firm R&D innovation performance?
 - Time-varying factors? R&D inputs?
 - R&D competence (productivity)
- What is firm R&D competence?
 - Complex harmonisation of individual technologies and production skills (Hamel and Prahalad 1990)
 - Skilled human capital, organization endowment and culture, superior technology (Drucker 2007)

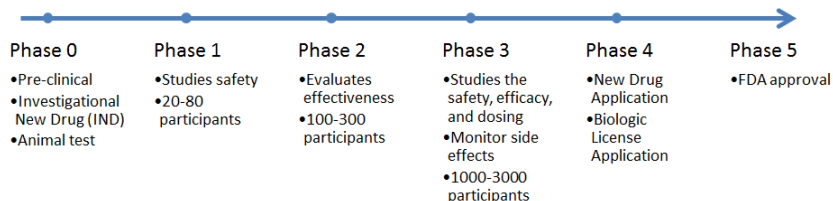
Motivation

- Firms could be *inherently* different and thus pursue different ways of innovation and growth.
- Measures in prior studies could not examine such inherent difference as they extensively use patent data
 - Patent data, by definition, registers only on innovation projects that have already succeeded and thus are patentable
 - Failed or ongoing projects which better represent the challenges of innovation are not observable
 - More matured firms are likely to patent their ideas: our own extensive name matching to patent data result in only 114 matches out of 460 firms with founding year ≤ 2006 (154 out of 799 firms for whole period)

- 1 Adds to the literature that explores firm initial conditions (Lemmon, Roberts, Zender(2008), Maksimovic, Philips, Yang (2013))
 - Create a new innovation measure based on initial R&D competence and its progress, using detailed project-level new drug development data
 - Show that firm technological competence is inherently given and highly persistent over time
- 2 Adds to the entrepreneurship literature
 - Examine how initial competence affects startup firms' success such as in IPO exit and VC funding
 - Examine how initial competence also affects diversification decision
 - Estimate direct and indirect effects (via diversification) of initial competence, using a simultaneous mediation model

New Drug Development Data: BioMedTracker

- BioMedTracker is primarily for advising investment opportunities by Pharmaceutical Intelligence
- Tracks FDA's drug review processes, news articles, press releases, medical conferences & direct communications with companies
- Both publicly and privately held companies in drug industry
- 799 private firms and 3,851 firm-year observations from 1985-2014
- BioMedTracker data provides not only successful innovations but also **failed and ongoing R&D projects**



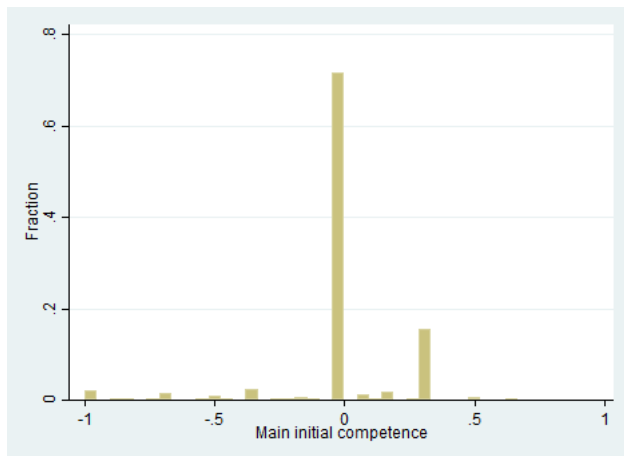
How We Measure R&D Competence?

- Each project can be suspended, stays, or advances to the next phase
 - 1 Assign +1 for an advance
 - 2 Assign -1 for a suspension
 - Regulatory agencies can order suspension due to safety risk
 - Voluntary suspension
 - 3 Assign 0 for no phase change
- R&D competence for a given firm in a given year:

$$= \frac{\# \text{ of advances} - \# \text{ of suspensions}}{\text{total } \# \text{ of projects}}$$

- Main competence: *R&D competence* of the firm's major segment
- Initial main competence: Average of the first three non-missing *Main competence*

Distribution of Initial Main Competence



206 firms (26%) out of 799 firms in our sample have non-zero initial main competence

Summary Statistics

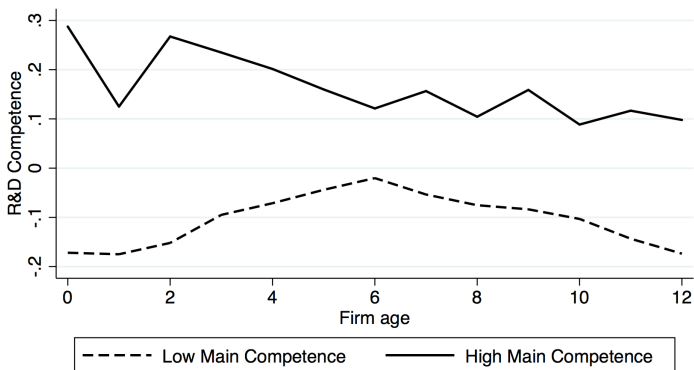
	Mean	Std. Dev	Min	Median	Max	Obs.
R&D competence	-0.064	0.381	-1.000	0.000	1.000	3851
Main competence	-0.063	0.390	-1.000	0.000	1.000	3851
Main initial competence	0.011	0.235	-1.000	0.000	0.667	3851
Going public (firm)	0.142	0.349	0.000	0.000	1.000	799
Going public (firm year)	0.032	0.177	0.000	0.000	1.000	3851
VC backed	0.522	0.500	0.000	1.000	1.000	799
VC fund (\$mi)	3.812	15.413	0.000	0.000	471.070	3851
Div. w/ project shares	0.123	0.229	0.000	0.000	0.821	3851
Div. w/ # of industries	1.380	0.874	1.000	1.000	9.000	3851
Firm age	7.318	4.447	0.000	7.000	36.000	3851
# of projects	2.218	2.144	1.000	1.000	23.000	3851
% matured projects	0.087	0.270	0.000	0.000	1.000	3851
% projects with partner	0.396	0.466	0.000	0.000	1.000	3851
# of competitors	47.294	17.253	2.000	47.000	71.000	3851
Ind failure rate	0.217	0.104	0.000	0.241	0.414	3851
Ind % matured projects	0.233	0.180	0.056	0.200	1.000	3851

Summary Statistics

Disease code	Disease group	Observations	Percent
1	Allergy	9	0.23
2	Autoimmune/Immunology	232	6.02
3	Cardiovascular	315	8.18
4	Dermatology	19	0.49
5	Ear, Nose, Throat/Dental	25	0.65
6	Endocrine	289	7.50
7	Gastroenterology	59	1.53
8	Hematology	113	2.93
9	Infectious	381	9.89
10	Metabolic	120	3.12
11	Neurology	563	14.62
12	Obstetrics/Gynecology	18	0.47
13	Oncology	1,172	30.43
14	Ophthalmology	136	3.53
15	Orthopedics	3	0.08
16	Psychiatry	119	3.09
17	Renal	30	0.78
18	Respiratory	151	3.92
19	Rheumatology	19	0.49
20	Urology	60	1.56
21	Not Specified	18	0.47
Total		3,851	100

Persistence of R&D Competence

- Evolution of firms' overall R&D competence over firm age



Persistence of R&D Competence

- Firm-year level panel regression estimations for 1985-2014
- Firm FE: time-invariant firm heterogeneity
- Model Specification

$$\text{Main R\&D competence}_{i,t} = \alpha + \beta_1 \text{Initial main competence}_{i,0} + \beta_2 \text{Firm and Industry controls}_{i,t} + \alpha_i + \gamma_t + \epsilon_{i,t}$$

Persistence of R&D Competence

	Main competence					
	(1)	(2)	(3)	(4)	(5)	(6)
Main initial competence					0.752*** (13.74)	0.736*** (14.51)
Log(# of phase 0 projects)				0.0169 (0.37)		0.0461*** (2.70)
% matured projects				0.362** (2.52)		0.147*** (4.73)
% projects with partner				-0.0883 (-0.85)		-0.0600** (-2.53)
Log(1+firm age)				0.303* (1.74)		-0.172*** (-5.55)
Log(# of competitors)				-0.0967* (-1.92)		-0.108 (-1.05)
Ind failure rate				-0.564 (-1.23)		-0.456* (-1.65)
Ind % matured projects				-0.837*** (-2.84)		-0.363* (-1.93)
Observations	3071	3071	3071	3071	3071	3071
Adjusted R^2	0.300	0.005	0.375	0.385	0.165	0.200
Fixed Effects	Firm	Year	Firm, Year	Firm, Year	Ind, Year	Ind, Year

R&D Competence and Innovation Strategies

- How does firm competence affect innovation strategies?
- Firms with relatively high (low) initial performance in their main segment are more likely to stay focused (diversify)
 - Maksimovic and Phillips (2002) : Higher opportunity costs to move into other industries
 - McGrath (2001): Innovation success depends on generating sufficient variation that at least some will prove to yield desirable results
 - Thakor (2013): Innovation has option-like payoffs of innovation where out-of-the money firms will take more risk
- Determinants of exploitative vs. explorative innovation strategies
 - Levinthal and March (1993): Managerial myopia in learning
 - Manso (2011): Tolerance for early failure
 - Ferreira, Manso, and Silva (2014): Public market listing
 - Our paper goes back to the beginning of a firm and shows initial R&D competence matters

R&D Competence and Diversification: Regression

- Diversification measures
 - Diversification w/ # of industries: total number of different disease groups where the firm has projects
 - Diversification w/ project shares

$$1 - \sum \left(\frac{\# \text{ of projects in each disease group}}{\text{total \# of Projects}} \right)^2$$

- Firm-year level panel regression estimations for 1985-2014
- Model Specification

$$\text{Diversification}_{i,t} = \alpha + \beta_1 \text{Initial main competence}_{i,0} + \beta_2 \text{Firm and Industry controls}_{i,t} + \alpha_i + \gamma_t + \epsilon_{i,t}$$

R&D Competence and Diversification: Result

	Div. # of industries		Div. project shares	
	(1)	(2)	(3)	(4)
Initial main competence	-0.206*** (0.06)		-0.040** (0.02)	
Main competence		-0.190*** (0.04)		-0.035*** (0.01)
Log(# of phase 0 projects)	0.430*** (0.06)	0.439*** (0.07)	0.116*** (0.01)	0.118*** (0.01)
c Log(1+firm age)	0.125*** (0.02)	0.108*** (0.02)	0.036*** (0.01)	0.033*** (0.01)
% matured projects	0.432*** (0.05)	0.447*** (0.05)	0.099*** (0.01)	0.101*** (0.01)
% projects with partner	0.108*** (0.02)	0.101*** (0.02)	0.026*** (0.01)	0.024*** (0.01)
Log(# of competitors)	0.604*** (0.16)	0.583*** (0.16)	0.223*** (0.05)	0.219*** (0.05)
Ind failure rate	0.463 (0.42)	0.379 (0.42)	0.174 (0.14)	0.159 (0.14)
Ind % matured projects	0.599** (0.27)	0.561** (0.27)	0.142* (0.08)	0.136* (0.08)
VC backed	0.037* (0.02)	0.035* (0.02)	0.021*** (0.01)	0.020*** (0.01)
Observations	3851	3851	3851	3851
Adjusted R ²	0.146	0.150	0.144	0.146
Fixed Effects	Ind, Year	Ind, Year	Ind, Year	Ind, Year

Destinations of Diversification

- Abernathy and Utterback (1978)'s model on industry life cycle
- Early Phase (fluid phase) industries: more competitive and riskier industries

	Percentage	p-value	t-statistics
High competence	49.5%	0.55	-0.13
High suspend rate	96.8%	0.00	39.47
High advance rate	47.3%	0.79	-0.81
More products	81.4%	0.00	11.92
More matured products	1.4%	0.00	-62.06
More phase 0 products	93.2%	0.00	25.35
High coompetition	99.5%	0.00	109.00
More incumbents	99.5%	0.00	109.00
Observations		220	

R&D Competence and Firm Growth

- We examine the effect of initial competence on firm growth:
 - Are firms with high initial competence in their main segment are more likely to go public earlier?
 - Are firms with high initial competence more likely to receive a greater amount of venture capital funding before exits?
 - Do explorative strategies by firms with low initial competence also increase the likelihood of an IPO exit or venture capital funding?

Simultaneous Analysis and Mediation Model

- Simultaneously analyze the effects of initial R&D competence and diversification on firm growth
- A system of linear equations with firm-year level panel regression for 1985-2014
- Model Specification

$$\text{Diversification}_{i,t} = \alpha + \beta_1 \text{Initial main competence}_{i,0} + \beta_2 \text{Firm and Industry controls}_{i,t} + \alpha_i + \theta_t + \epsilon_{i,t}$$

$$\text{Going Public or VC funding}_{i,t} = \alpha + \gamma_1 \text{Initial main competence}_{i,0} + \gamma_2 \text{Diversification}_{i,t} + \gamma_3 \text{Firm and Industry controls}_{i,t} + \mu_i + \kappa_t + \eta_{i,t}$$

Simultaneous Analysis and Mediation Model

	Diversification (1)	Going public (2)	Diversification (3)	VC funding (4)
Diversification		0.012** (0.01)		0.047** (0.02)
Initial main competence	-0.206*** (0.06)	0.033*** (0.01)	-0.202*** (0.06)	0.090 (0.07)
Log(# of phase 0 projects)	0.430*** (0.06)	0.005 (0.02)	0.429*** (0.06)	0.034 (0.06)
Log(1+firm age)	0.125*** (0.02)	0.000 (0.00)	0.129*** (0.02)	-0.021 (0.03)
% matured projects	0.432*** (0.05)	-0.012 (0.01)	0.427*** (0.05)	-0.397*** (0.06)
% projects with partner	0.108*** (0.02)	0.013** (0.01)	0.106*** (0.02)	-0.009 (0.04)
Log(# of competitors)	0.604*** (0.16)	0.021 (0.04)	0.605*** (0.16)	0.076 (0.21)
Ind failure rate	0.463 (0.42)	-0.387*** (0.13)	0.463 (0.42)	-0.450 (0.76)
Ind % matured projects	0.599** (0.27)	0.176* (0.10)	0.590** (0.27)	-0.294 (0.49)
VC backed	0.037* (0.02)	0.048*** (0.01)		
Observations	3851		3851	
Berndt R^2	0.206		0.186	
Fixed Effects	Ind, Year		Ind, Year	

Endogeneity and Medicare Part D

- Diversification and IPO or VC funding could be endogenous
- Thus, we instrument for diversification decisions using Passage of the Medicare Part D in 2003
 - Prior to the implementation in 2006, the Medicare program covered only prescription medicines associated with physician services
 - Medicare Part D significantly expanded drug coverage among older individuals to include prescription drugs
 - Firms increase R&D expenditures in response to the passage of Part D (Duggan and Scott Morton 2010 AER)

Firms without a project in Part D drug classes, especially those performing poorly in their original main industries, have incentives to explore the Part D related industries

Medicare Part D: The Effect of Diversification

- The differential effects of Medicare Part D on firm diversification
 - Treated: Firms without any projects in Part D classes before legislation
 - After: Equals one after the passage of the Medicare Part D in 2003
 - Low competence: Indicator for a firm with low initial main competence

$$\text{Diversification}_{i,t} = \alpha + \text{Complete combinations of } \textit{Treated}, \textit{After} \text{ \& } \textit{Low competence} \text{ are added}$$

$$\beta_2 \textit{Firm and Industry controls}_{i,t} + \alpha_i + \theta_t + \epsilon_{i,t}$$

$$\textit{Going Public or VC funding}_{i,t} = \alpha + \gamma_1 \textit{Low competence}_{i,0} + \gamma_2 \textit{Diversification}_{i,t} + \gamma_3 \textit{Firm and Industry controls}_{i,t} + \mu_i + \kappa_t + \eta_{i,t}$$

Medicare Part D: The Effect of Diversification

	Diversification (1)	Going public (2)	Diversification (3)	VC funding (4)
Diversification		0.011** (0.00)		0.044** (0.02)
Treated * Post * Low competence	1.132*** (0.38)		1.125*** (0.38)	
Treated * Post	-0.401 (0.27)		-0.390 (0.27)	
Treated * Low competence	-1.171*** (0.38)		-1.170*** (0.38)	
Post * Low competence	-0.388 (0.31)		-0.389 (0.31)	
Treated	0.784** (0.31)		0.775** (0.31)	
Low competence	0.347 (0.30)	-0.019** (0.01)	0.348 (0.30)	-0.130*** (0.05)
Controls		Yes		Yes
Observations		3851		3851
Berndt R^2		0.213		0.195
Fixed Effects		Ind, Year		Ind, Year

Conclusion

- 1 Firm R&D competence is inherently given and highly persistent over long periods of time
- 2 Firm's initial competence (time-invariant) drives firm innovation strategies
 - Firms with high initial competence are more likely to be exploitive by focusing on their best segment
 - Firms with low initial competence tend to be explorative by operating in multiple segments
- 3 Firm's initial competence (time-invariant) drives firm growth patterns
 - Firms with high initial competence exit through an IPO earlier and receive a greater amount of VC funding
 - Firms with low initial competence tend to diversify, thereby increasing IPO likelihood and VC funding