An Empirical Test for General Purpose Technology:

An examination of the Cohen-Boyer's rDNA technology

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Why is GPT interesting?

- General Purpose Technology as a source of long-run economic growth
  - Schumpeter (1911)
    - Technological breakthrough based on entrepreneurial activities and follow-up innovations create a long wave of economic growth
  - Various names used but always important
    - Radical Innovation (Freeman & Perez, 1988)
    - Platform Technologies (Nelson & Winter, 1982)
    - General Purpose Technology (Bresnahan & Trajtenberg,1982 Helpman, 1998; Lipsey, et al.1998; 2005, etc)
  - Incremental Innovations are extensively studied but GPT have the greatest potential for growth

Our Motivation

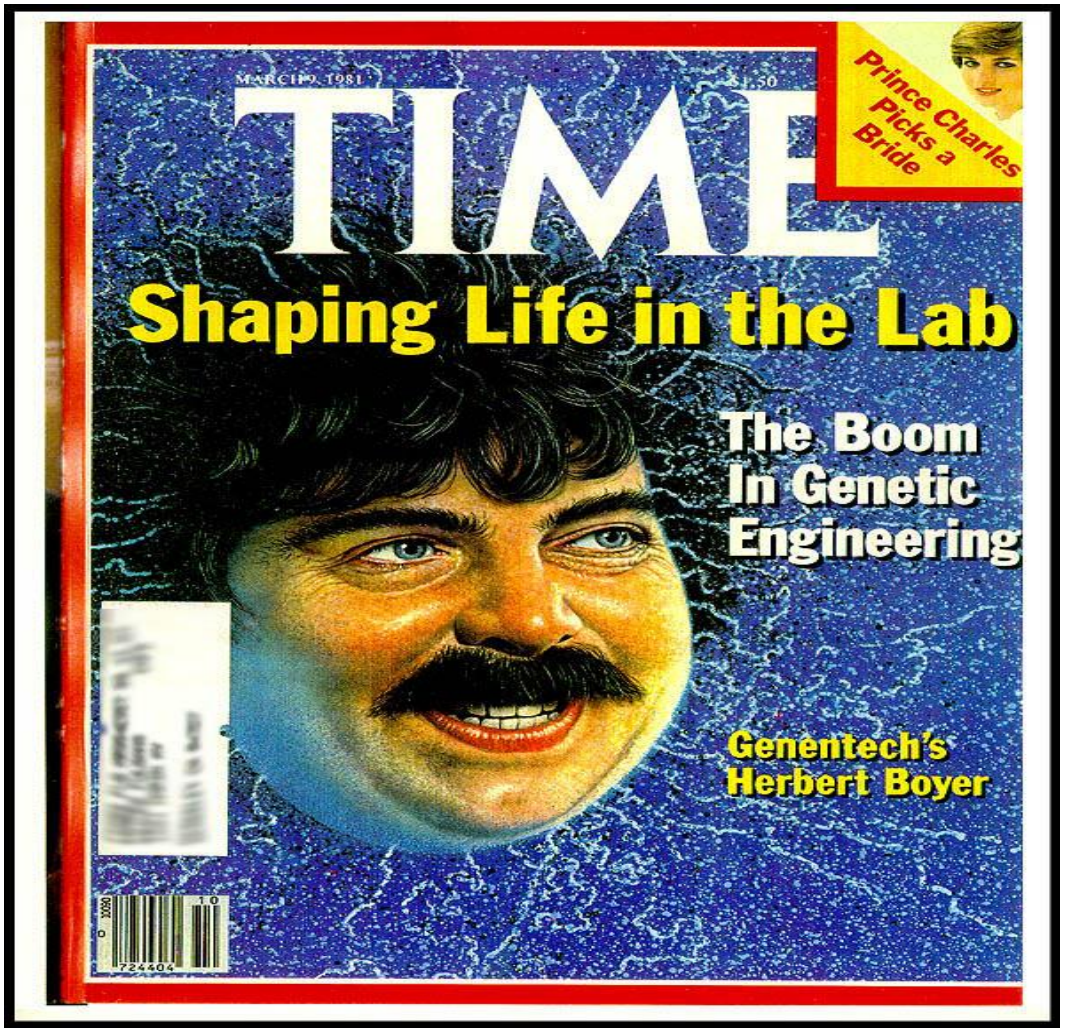
- Nations, industries, firms, regions and places are searching for the *next big thing*
  - Can we examine a technology to discern its potential?
- Let's take an invention that is believed to be a potential GPT and test its characteristics!
  - Literature is rather prosaic about characteristics
  - Hence, we attempt to define theoretically based empirical measures
- Empirical Papers
  - Moser & Nicholas (2004) - Electricity is not a GPT!
  - Hall and Trajtenberg (2004) - just a few GPTs
- Can patents identify a GPT?

Biotechnology Background

- Cohen-Boyer Collaboration
  - Important discovery to biotechnology
- What is the impact?
  - 1 Scientific paper
    - *Construction of Biologically Functional Bacterial Plasmids In Vitro* - Proc. Nat. Acad. Sci. USA, 1973
    - 299 citations
  - 1 patent application; 3 issued patents (1 key process)
    - 362 citing patents
- Stanford University
  - 468 Licenses issued to companies
    - $250M in licensing revenue
    - $35B in new product sales

Is Cohen-Boyer a General Purpose Technology?

Biotech is a GPT Candidate: rDNA is a key technology



United States Patent [19]

Cohen et al.

[11] 4,237,224

[45] Dec. 2, 1980

[54] PROCESS FOR PRODUCING BIOLOGICALLY FUNCTIONAL MOLECULAR CHIMERAS

[75] Inventors: Stanley N. Cohen, Portola Valley; Herbert W. Boyer, Mill Valley, both of Calif.

[73] Assignee: Board of Trustees of the Leland Stanford Jr. University, Stanford, Calif.

[21] Appl. No.: 1,021

[22] Filed: Jan. 4, 1979

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 959,288, Nov. 9, 1978, which is a continuation-in-part of Ser. No. 687,430, May 17, 1976, abandoned, which is a continuation-in-part of Ser. No. 520,691, Nov. 4, 1974.

[51] Int. Cl.³ C12P 21/00

[52] U.S. Cl. ..... 435/68; 435/172; 435/231; 435/183; 435/317; 435/849; 435/820; 435/91; 435/207; 260/112.5 S; 260/27R; 435/212

[58] Field of Search ..... 195/1, 28 N, 28 R, 112, 195/78, 79; 435/68, 172, 231, 183

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Primary Examiner—Alvin E. Tanenholtz

Attorney, Agent, or Firm—Bertram I. Rowland

[57] ABSTRACT

Method and compositions are provided for replication and expression of exogenous genes in microorganisms. Plasmids or virus DNA are cleaved to provide linear DNA having ligatable termini to which is inserted a gene having complementary termini, to provide a biologically functional replicon with a desired phenotypical property. The replicon is inserted into a microorganism cell by transformation. Isolation of the transformants provides cells for replication and expression of the DNA molecules present in the modified plasmid. The method provides a convenient and efficient way to introduce genetic capability into microorganisms for the production of nucleic acids and proteins, such as medically or commercially useful enzymes, which may have direct usefulness, or may find expression in the production of drugs, such as hormones, antibiotics, or the like, fixation of nitrogen, fermentation, utilization of specific feedstocks, or the like.

14 Claims, No Drawings

Best personal Regards

Herb Boyer

Stan Cohen

Presentation Outline

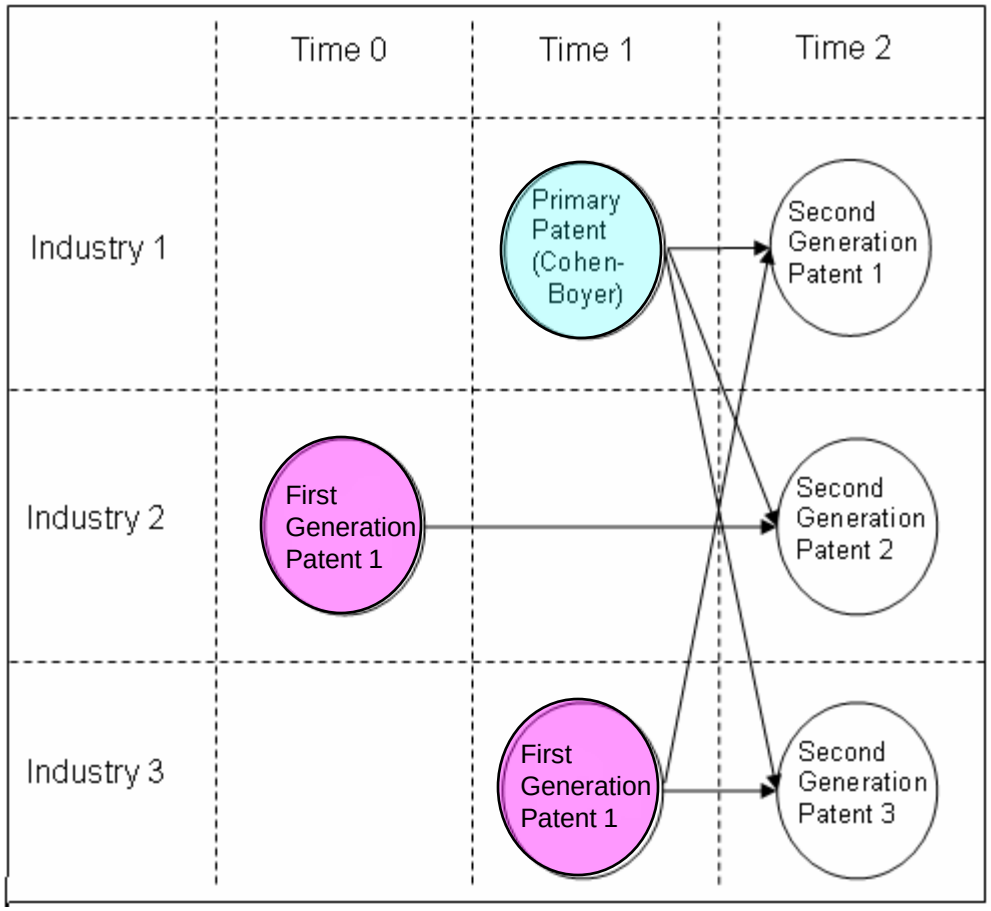
- Define attributes of GPTs
  - Synthesis of the literature
- Develop empirically testable propositions
  - Common attributes of GPT
- Construct Data and Sample
  - USPTO Patent Data
  - Cohen-Boyer & Control Patents
- Provide empirical results
- Conclusion

Proposition 1: Technological Complementarity

- Pervasive use - as an input in many sectors throughout the economy
  - Stream engine, Electricity, Information technology
  - adaptability across industrial sectors
- GPT is able to be combined with a large number of complementary components
- P1: A GPT will be combined with a broader range of complementary application sectors than an incremental technology

Technological Complementarity

N of different industries from other 1st generation patents



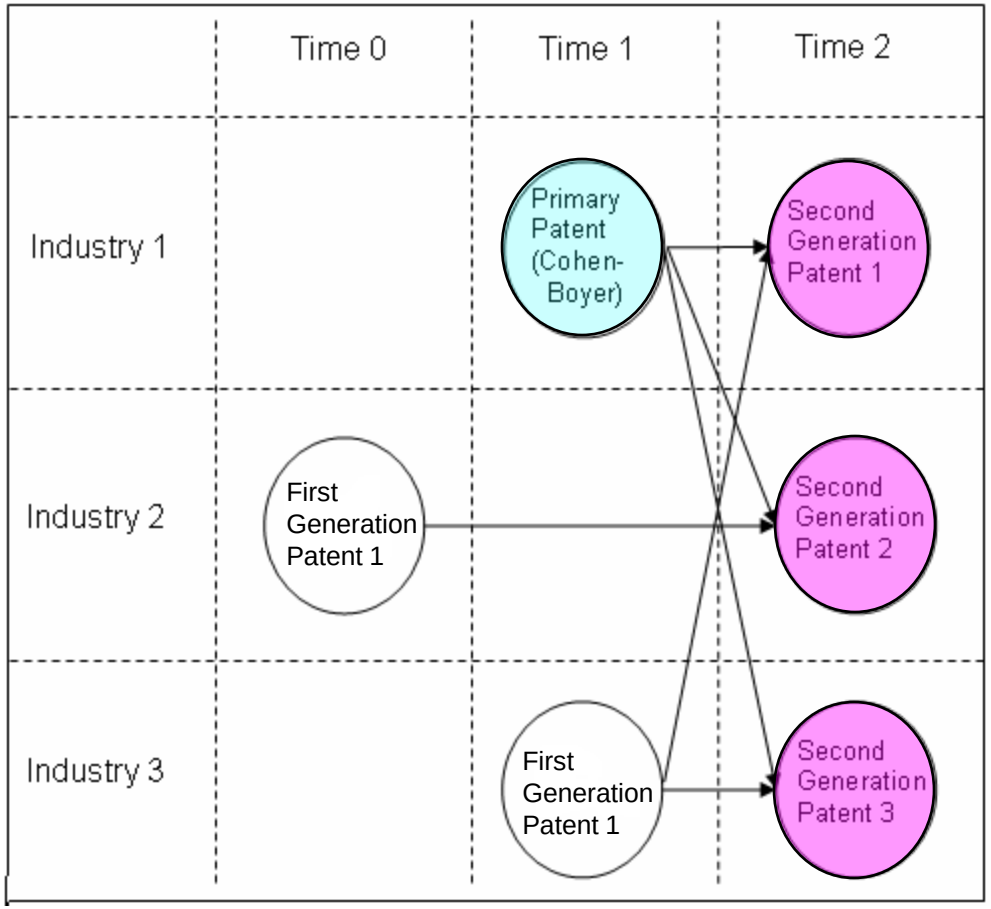
Proposition 2: Technological Applicability

- Fosters complementary investment and technological change in the user sectors
  - Bresnahan and Trajtenberg (1995)

- The patents that use a GPT are applicable to wide range of industries
  - Bresnahan and Gambardella (1998), Helpman and Trajtenberg (1998), and Lipsey et al. (2003)
  - Lerner (1994) Patent Scope
- P2: Follow-on inventions using the GPT will be applied to a wide range of industries than incremental technologies.

Technological Applicability

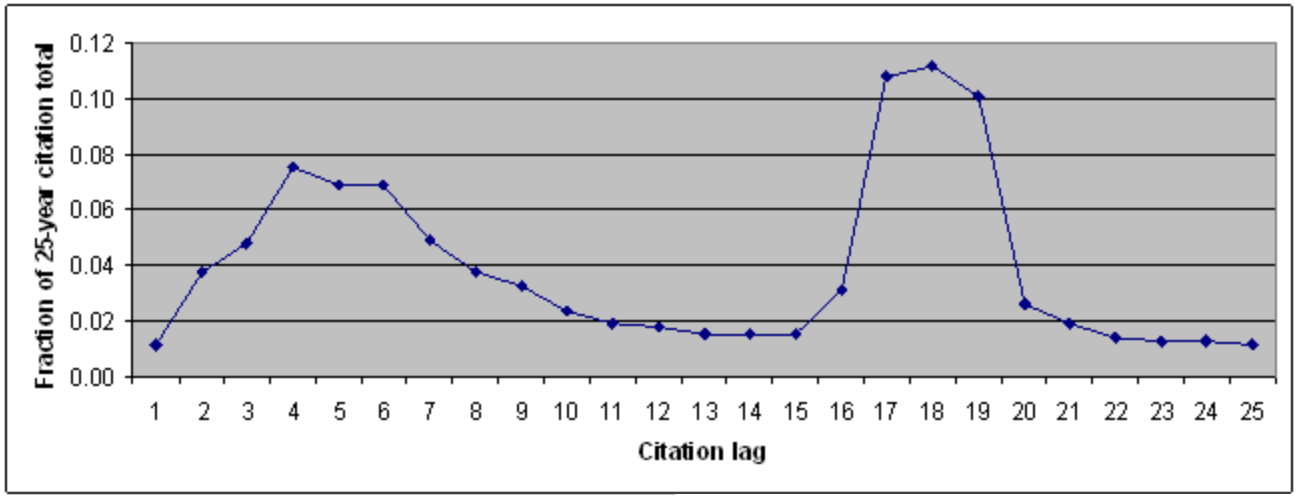
N of different industries from 2nd generation patents



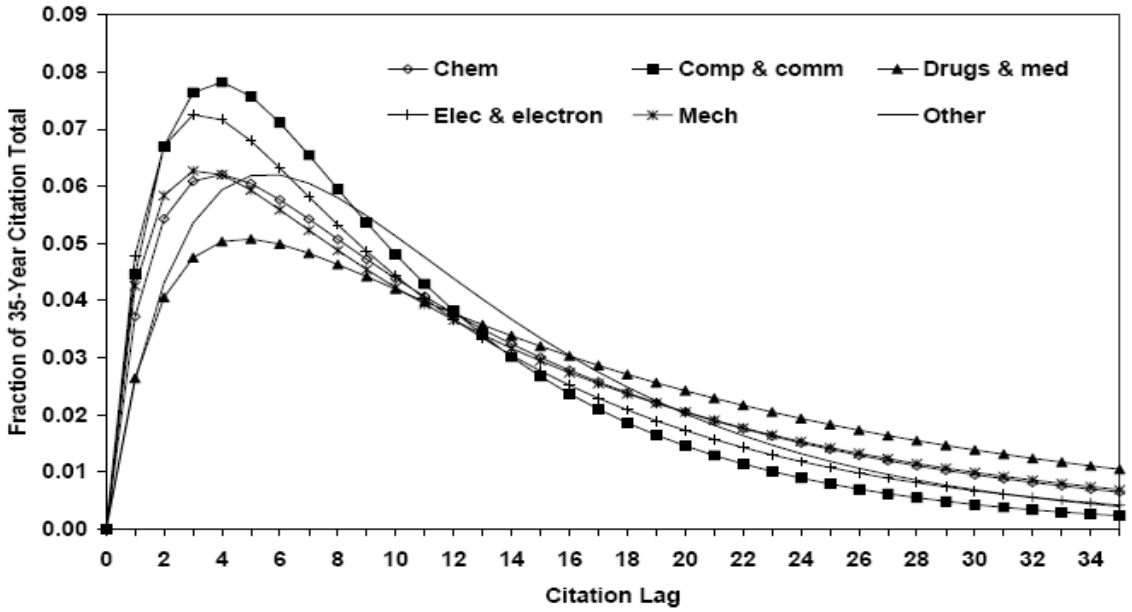
Proposition 3: Technological Discontinuity

- GPT creates disequilibrium
  - Schumpeter's winds of creative destruction
  - More difficult to model
- Longer time lags for the application development
  - Computers and the productivity paradox example
  - Time needed for diffusion & development of capabilities
- P3a: GPT will have a longer time lag
- Geographic proximity matters to realize potential of discovery
  - For greater technology complementarity
  - For greater technological applicability
- P3b: GPT will be more geographically concentrated

Time Lag Forward Citation



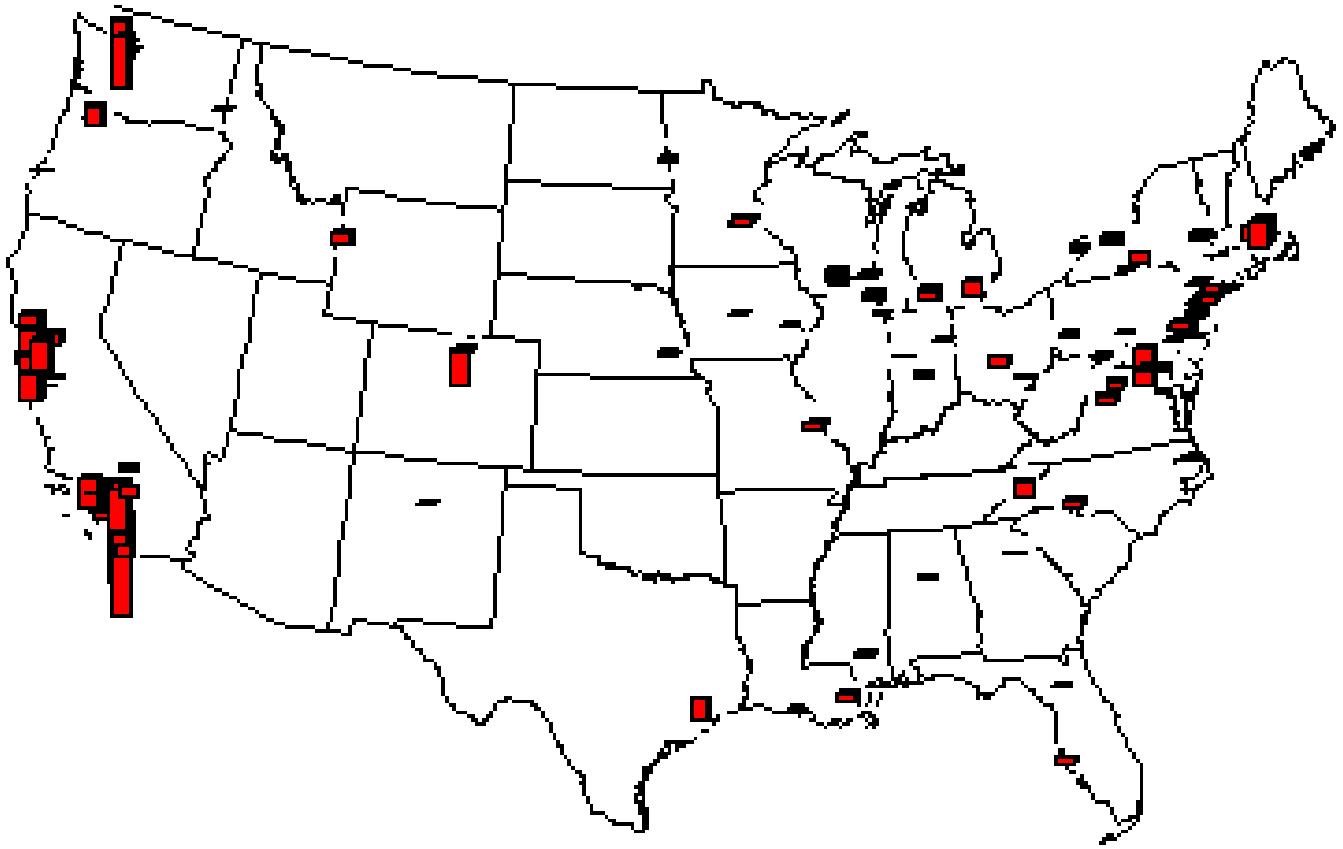
Cohen-Boyer



All patents 76-99
Hall et al., 2001

Distribution of Patents Citing C-B

by city



Research Strategy

- Compare Cohen-Boyer rDNA Patents to control group of similar patents
- Criteria Used to construct control group
  - Applied/Issued at the similar time period (1976-1980)
  - Bio-medical technology domain (Patel 2003)
  - Radical – having 0 backward citation
  - Important – having more at least 50 forward citations
  - Assigned to University – basic research
- Only 2 patents are comparable
  - Assigned to Cornell and OSU
- Process Patent assigned to Stanford

Matched Control Patents

Patent	Title	Number of Forward Citations
US4164559	Collagen drug delivery device -- Chemically-modified collagen membrane prepared at physiologic pH and soluble thereat provides a carrier for ophthalmic medication leaving no removable material after drug release.	50
US4201770	Antigenic modification of polypeptides- Modified hormones or fragments of hormones are useful in producing antibodies when administered to an animal. These modified hormone or fragment may be administered to animals for the purpose of contraception, abortion, or treatment of hormone related disease states and disorders.	55
US3949073	Process for augmenting connective mammalian tissue with in situ polymerizable native collagen solution - A method for augmenting hard or soft connective tissue, such as skin, tendon, cartilage, bone or interstitium, in a living mammal	127

Simple Econometric Model

- Dependent Variable
  - Technological Complementarity
  - Technological Applicability
- Focal Variables
  - Cohen-Boyer Dummy
  - Location of Inventors
    - Co-located
    - San Francisco Bay Area
- Control Variables
  - Organization Type
  - Number of Claims
  - Number of Assignees
  - Year
  - Number of Inventors
  - Location of Inventors
  - Number of Backward Domestic References

Descriptive Statistics

(N=594)

Variable	Mean	Std. Dev.	Min	Max
# of different SICs of prior art combined (NDIC)	2.33	3.55	0.00	17.00
# of different SICs assigned (NDIA)	1.03	0.79	0.00	4.00
Whether citing Cohen-Boyer (CCB)	0.73	0.45	0.00	1.00
# of claims (CLM)	19.75	19.93	1.00	140.00
# of domestic backward references (DOM)	16.02	22.87	2.00	187.00
Number of assignees (NASS)	1.06	0.27	1.00	4.00
Number of inventors (NINV)	2.56	1.49	1.00	11.00
Organization type				
Biotechnology firms (BIO)	0.48	0.50	0.00	1.00
Old pharmaceutical firms (PHA)	0.15	0.36	0.00	1.00
University (UNIV)	0.18	0.39	0.00	1.00
Public & non-profit organizations (PUB)	0.07	0.26	0.00	1.00
Inventor locations				
All inventors being co-located (COLO)	0.62	0.49	0.00	1.00
Having international inventors (INT)	0.26	0.44	0.00	1.00
Some inventors in the bay area (SBAY)	0.09	0.28	0.00	1.00
All inventors in the bay area (BAY)	0.12	0.33	0.00	1.00

Empirical Results: Complementarity

Dependent variable: # of different industries in the backward citations		Model (1)			Model (2)			Model (3)			Model (4)			Model (5)	
Variables	Parameter	Coef.	Sig.		Coef.	Sig.		Coef.	Sig.		Coef.	Sig.		Coef.	Sig.
Logged (Claim count)	b_1	0.00 (0.13)			0.10 (0.04)	***		-0.02 (0.13)			0.09 (0.13)			0.12 (0.12)	
Logged (Backward reference count)	b_2	2.06 (0.20)	***		0.16 (0.05)	***		2.07 (0.20)	***		1.96 (0.19)	***		2.09 (0.18)	***
Number of inventors	b_3	-0.03 (0.09)			0.01 (0.03)			-0.04 (0.09)			-0.06 (0.09)			0.02 (0.09)	
Number of assignees	b_4	0.33 (0.50)			-0.12 (0.14)			0.34 (0.50)			0.46 (0.48)			0.33 (0.46)	
Biotechnology firm assignee	b_5	0.02 (0.35)			0.07 (0.10)			0.05 (0.35)			-0.56 (0.35)			-0.74 (0.34)	**
University assignee	b_6	0.01 (0.42)			0.08 (0.12)			0.00 (0.42)			-0.13 (0.40)			0.01 (0.39)	
Cohen-Boyer patent	b_7	3.36 (0.43)	***		0.20 (0.12)	*		3.38 (0.43)	***		3.64 (0.41)	***		2.79 (0.43)	***
All inventors co-located	b_8				0.01 (0.28)			-0.17 (1.22)							
Cohen-Boyer & inventors co-located	b_9							-1.58 (2.21)							
All inventors in the Bay area	b_{10}										2.69 (0.47)	***		-0.13 (0.70)	
Cohen-Boyer & inventors co-located in Bay area	b_{11}													3.90 (0.75)	***
Year Dummy Variables		included			included			included			included			included	
Constant	b_0	-5.67 (0.94)	***		0.23 (0.26)			-5.66 (0.94)	***		-6.11 (0.90)	***		-5.75 (0.87)	***
Adj. R-square		0.51			0.51			0.50			0.55			0.58	
Sig.: *** 1%, ** 5%, * 10%															

Empirical Results: Technological Complementarity

- Cohen-Boyer patent is associated with greater technological complementarity
  - Compared to similar patents
  - After controlling for other factors
- Being in the Bay Area is associated with greater complementarity
  - Suggests that being at the locus of inventive activity permits greater understanding of technological potential
- Dedicated biotech firms are more focused
  - Not associated with greater complementarity

Empirical Results: Applicability

Dependent variable: # of different industries used for a second generation patent		Model (6)		Model (7)		Model (8)		Model (9)		Model (10)	
Variables	Parameter	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.	Coef.	Sig.
Logged (Claim count)	α_1	0.10 (0.04)	***	-0.01 (0.13)		-0.02 (0.13)		0.09 (0.13)		0.10 (0.04)	***
Logged (Backward reference count)	α_2	0.16 (0.05)	***	2.06 (0.20)	***	2.07 (0.20)	***	1.96 (0.19)	***	0.12 (0.05)	**
Number of inventors	α_3	0.01 (0.03)		-0.04 (0.09)		-0.04 (0.09)		-0.06 (0.09)		-0.01 (0.03)	
Number of assignees	α_4	-0.12 (0.14)		0.34 (0.50)		0.34 (0.50)		0.46 (0.48)		-0.08 (0.14)	
Biotechnology firm assignee	α_5	0.07 (0.10)		0.04 (0.35)		0.05 (0.35)		-0.56 (0.35)		0.06 (0.10)	
University assignee	α_6	0.08 (0.11)		-0.02 (0.42)		0.00 (0.42)		-0.13 (0.40)		0.04 (0.11)	
Cohen-Boyer patent	α_7	0.20 (0.12)	*	3.36 (0.43)	***	3.38 (0.43)	***	3.64 (0.41)	***	0.40 (0.13)	***
All inventors co-located	α_8			-0.67 (1.02)		-0.17 (1.22)					
Cohen-Boyer & inventors co-located	α_9					-1.67 (6.08)					
All inventors in the Bay area	α_{10}							2.69 (0.47)	***	0.79 (0.21)	***
Cohen-Boyer & inventors co-located in Bay area	α_{11}									-0.75 (0.22)	***
Year Dummy Variables		Included		Included		included		included		included	
Constant	α_0	0.23 (0.26)		-5.65 (0.94)	***	-5.66 (0.94)	***	-6.11 (0.90)	***	0.12 (0.25)	
Adj. R-square		0.25		0.25		0.25		0.26		0.28	
Sig.: *** 1%, ** 5%, * 10%											

Empirical Results: Technological Applicability

- Cohen-Boyer patent is associated with greater technological applicability
  - Compared to similar patents

- General Bay Area Effect
  - Positive and significant
  - Location in Bay Area facilitated application of biomedical inventions
  - Right time, right place

Discussion and Implications

- rDNA appears to have characteristics of GPT
  - Theoretically-defined characteristics
    - Complementarity
    - Applicability
    - Discontinuity
  - Confirmed using patent data
    - Compared to control incremental patents

- Policy Implications
  - Can we predict GPT?
  - Indicative but so much depends on larger context for real economic effects

- Geography matters
  - Application of GPT is geographically concentrated
    - LQ in Paper
    - Compared to distribution of biotech firms
  - Further research needed to disentangle geographical specialization
    - Why combinations vary between places

Thank You