



The Foundations of Knowledge Markets

Evidence from the life sciences

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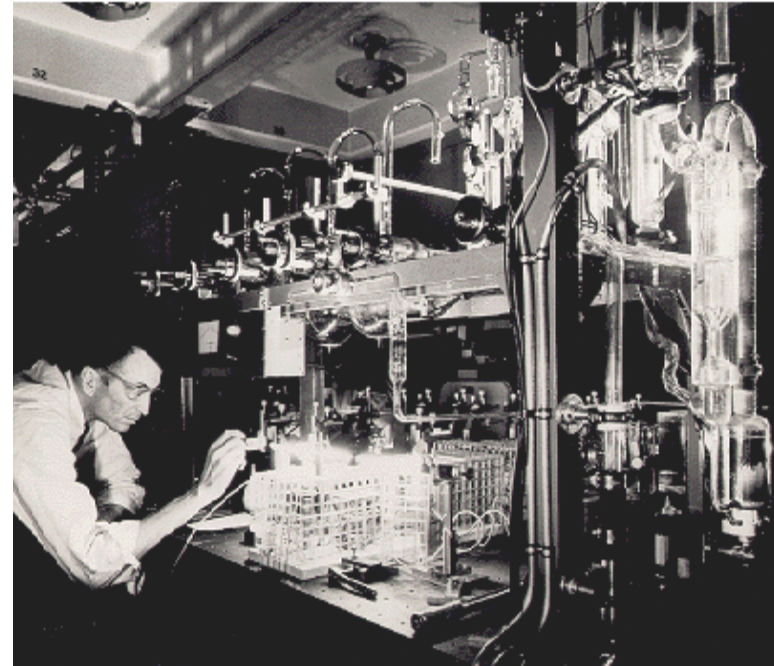
AGENDA

- Define key characteristics of knowledge & knowledge markets
- Map knowledge markets– from old world of informal institutions to the new world of formal institutions
- Analyze knowledge markets– what do we know?
- Conclusions & questions

Four Key Characteristics of Knowledge

- Knowledge production is a step-by-step process
 - Outputs from one step are inputs into the next (Aghion & Howitt 2000)
- Knowledge production is multi-faceted
 - Key outputs include information, materials, know-how, methods (Collins 1974)
- Knowledge is non-rival in use
 - One idea can be an input into many follow-on experiments (Arrow 1952, Rosenberg 1986)
- Follow-on experiments can be uncertain
 - Wide ranging perspectives on what the most interesting possible direction (Shane 2001)

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Implications for knowledge markets

- Need to ensure that knowledge outputs are available for exchange i.e. *we need a market!*
 - Need to exchange multiple facets of a given knowledge output
 - Need to be widely available to many follow-on innovators
 - Need to limited how prescriptive the market is for follow-on innovation i.e. allow follow-on innovators to select their chosen line

Not a simple single product market

Not a simple buyer-seller market

Not a simple contract for a single use



Knowledge markets require institutions

Mere production of knowledge does not guarantee its use by the next generation (Rosenberg 1984; Mokyr 2002; David & Dasgupta 1994):

- Secrecy limits available knowledge
- Even with disclosure, access is critical
- Markets require incentives – rewards to participation

“...impact of new technology, no matter how ingenious, can be realized only if the institutional environment is conducive and allows for the exploitation of inventions in an effective manner” [and EXPLORATION]

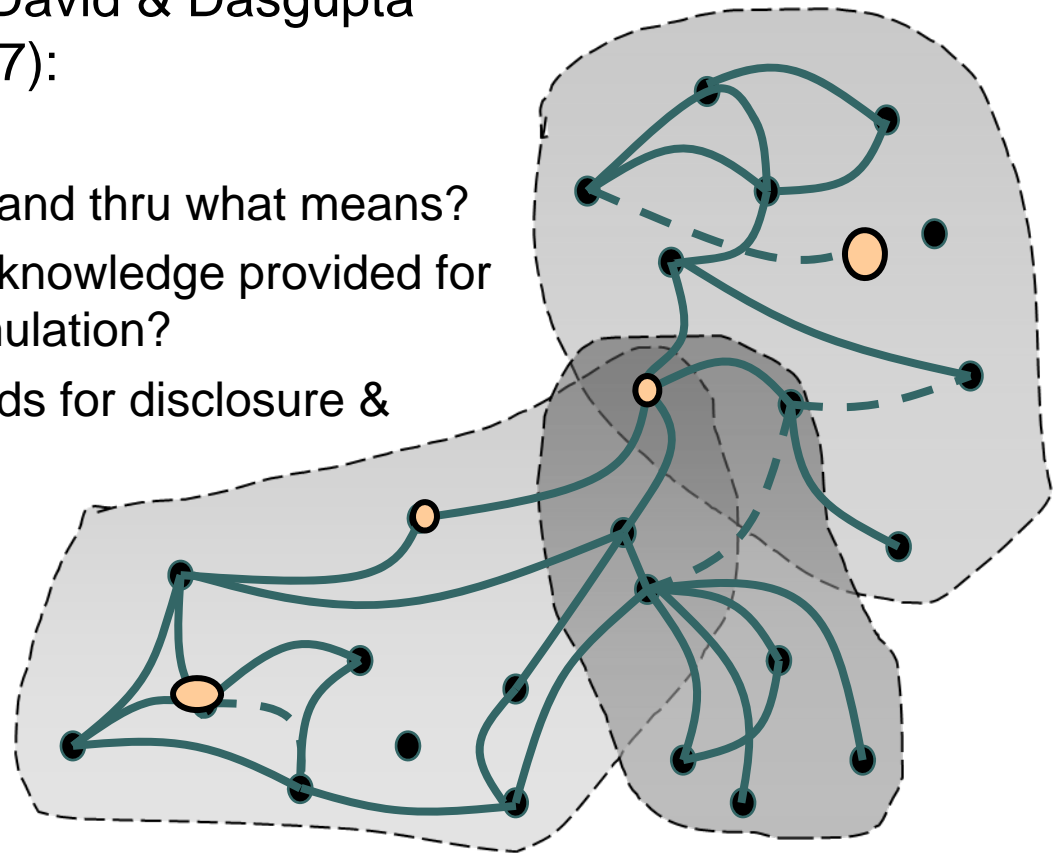
In J. Mokyr Market for Ideas, 2004 p. 1

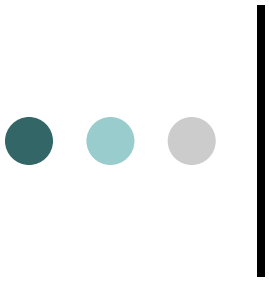
Defining the knowledge complex

Complex of informal & formal institutions that support knowledge markets.

Define the terms of exchange (David & Dasgupta 1994; Murray & O'Mahony 2007):

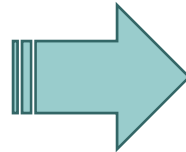
- Disclosure – what is disclosed and thru what means?
- Access – under what terms is knowledge provided for replication, validation & accumulation?
- Rewards – what are the rewards for disclosure & access



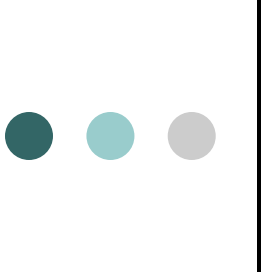


Map of the informal knowledge complex supporting traditional knowledge markets

- Small elite communities
- Close personal relationships
e.g. Erdos
- Exchanged and accumulated peer-to-peer under shared norms & culture
- Informal means to deal with competition, lack of reciprocity etc.

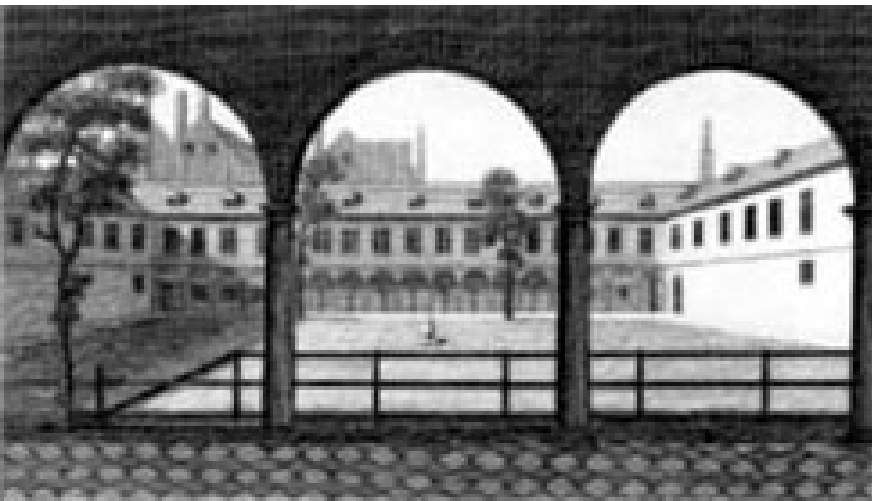


Old World
***Informal peer-to-peer
institutional complex with only
a few formal institutions***



Clubs & societies played a central role in the traditional knowledge markets

“The origins of the Royal Society lie in an “invisible college” of natural philosophers who began meeting in the mid-1640s to discuss the ideas of Bacon”.



While democratic on some levels, as Shapin (1984) has vividly described participation was closely guarded & tied to being a “gentleman”

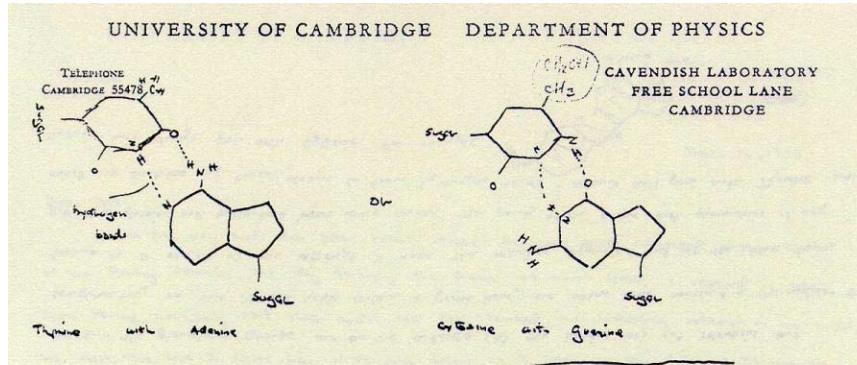
Scientific materials in private collections were accessible to those in the informal market



FLIES gathered,
bred & shared under
the watchful eye of
Thomas Hunt
Morgan (“Lord of the
Flies” (Kohler 1988)
& his former post-
doc Sturtevant

A.H. Sturtevant in the *Drosophila* stock room.
Courtesy of the Caltech Archives ©

Letters were another critical form of exchange that operated in the informal knowledge market



While my diagram is crude, in fact these pairs form 2 very nice hydrogen bonds in which all of the angles are exactly right. This pairing is based on the effective presence of only one out of the two possible tautomeric forms - in all cases we prefer the keto form over the enol and the amino over the imino. This is a definitive or assumption but Jerry Donohue and

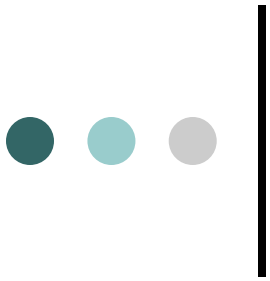
Bill Cochran tell us that, for all organic molecules so far examined, ~~more~~ the keto and amino forms are present in preference to the enol and imino possibilities.

The model has been derived ^{almost} entirely from stereochemical considerations with the only know consideration being the spacing ^{between} of the pair of bases 3.4A which was originally found by Astbury. It tends to build itself with approximately 10 residues per turn in 34A. The arrow is right handed.

The X-ray pattern approximately agrees with the model, but since the photographs available to us are poor and we have no photographs of our own and like really must use Astbury's photographs, this agreement is in no way constitutes a proof of our model. We are certainly a long way from proving its correctness. To do this we must obtain collaboration ^{the} even group at King's College London who possess very excellent photographs of a crystalline phase if attention to interference spots photographs of a paracrystalline phase. Our model has been made in reference to the paracrystalline form, but we get no sense unless we try to find these interference spots

Multiple letters exchanged between Watson & Crick, Max Delbruck, Linus Pauling in the race to the structure of DNA

Letter from Watson & Crick to Delbruck, March 12 1953



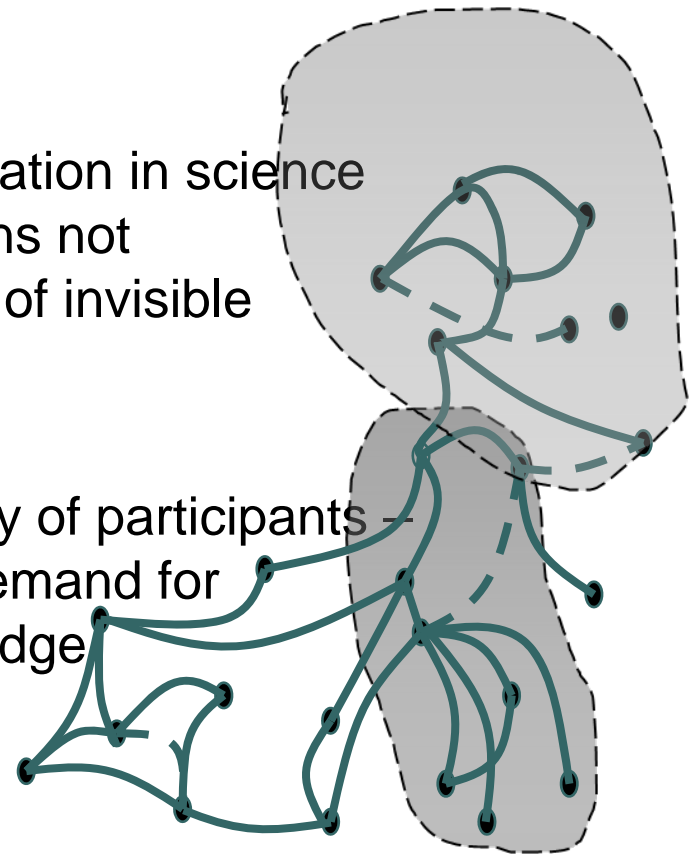
Informal knowledge complex supporting knowledge markets under increasing strain

SUPPLY-SIDE

DEMAND-SIDE

- Knowledge growing in complexity
- Knowledge inputs increasingly costly to maintain; hard to standardize & validate
- New rules e.g. Bayh-Dole requires suppliers to triage the terms of access

- Increase in size of the scientific community
- Growing participation in science from other nations not traditionally part of invisible college
- Growing diversity of participants - more industry demand for scientific knowledge



Informal exchange of scientific knowledge & materials could be costly & time consuming

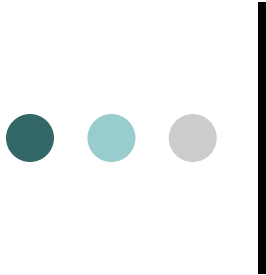
Exchange of mice among the “Mouse Club of America” became costly. One participant recalled:

*“When possible, a breeding pair was sent to anyone requesting them. Memorably, one of the first such pairs was a gift to Marie Curie. **Keeping up with the demand, however, was far beyond the capabilities of my small laboratory.** When it was impossible to fill requests for the mice, there were grumblings that Strong was uncooperative. ...**I was glad to share the mice, but I had no intention of abandoning my career in cancer research to become a supplier of laboratory animals for others.**”*

Leonell Strong quoted in Murray 2007

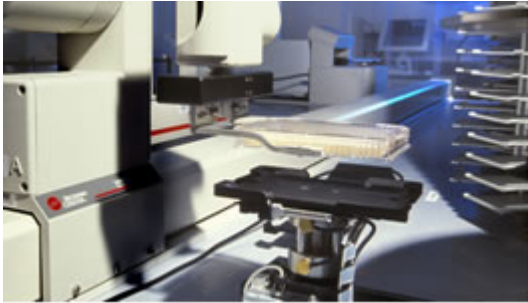
Today over 15,000 unique research mice documented in academic publications



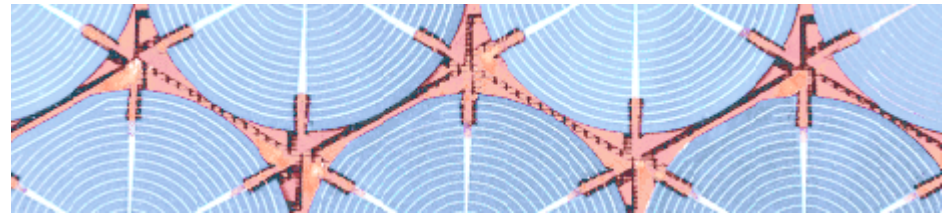


Response:

Emergence of complex of formal institutions to increase efficiency of knowledge market



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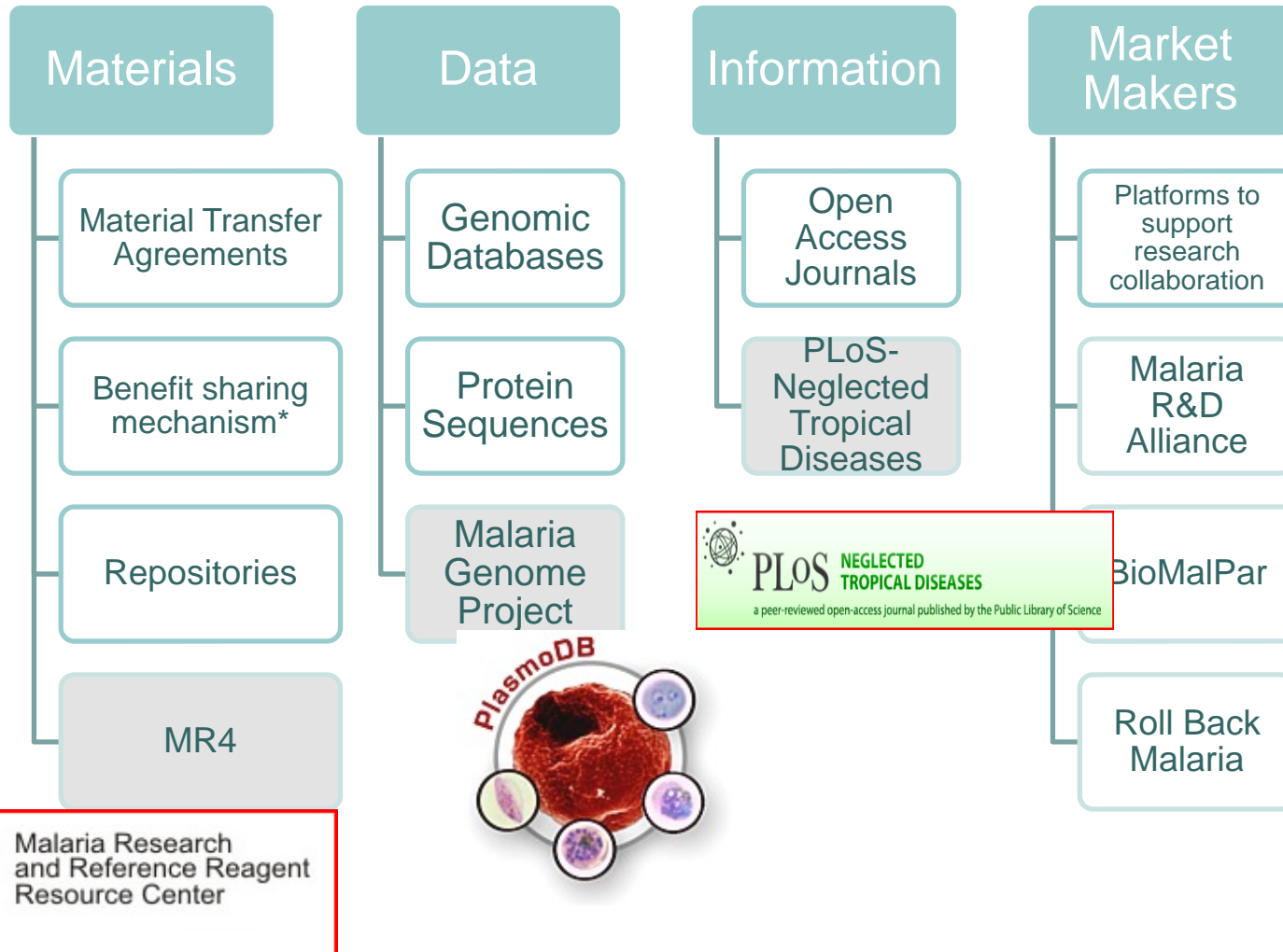
The most important source of new data for GenBank[®] is direct submissions from scientists. GenBank depends on its contributors to help keep the database as comprehensive, current, and accurate as possible.

celebrating over
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1929 1936 1947 1949 1950 1956 1960 1968 1978 1983 1996 2001 2004 >

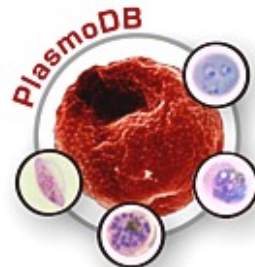


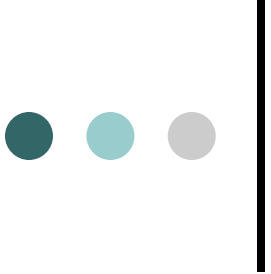
Over 16,000 researchers in more than 60 countries rely upon JAX[®] Mice. They are the most published and well characterized models in the world

Formal institutions supporting knowledge market in Malaria



Malaria Research and Reference Reagent Resource Center

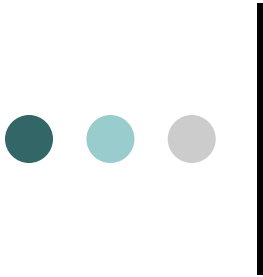




Formal institutions do not create effective knowledge markets alone

Key Issues of Disclosure, Access & Rewards

- Access to knowledge means:
 - Making it possible to actually read articles
 - Giving follow-on innovators the opportunity to replicate & build upon the ideas (can be limited by IP)
 - Providing access to key materials (can be limited by MTAs)
- IP issues are part of the access/rewards challenge
 - Balance incentives for follow-on exploitation with access for a wide range researchers engaging in exploration
 - Not a public-private issue (e.g. WARF with hESC)
 - IP & materials often entangled (e.g. Cre-lox) – can limit materials use without IP but IP limits many attempts to “work around” or independent replication



Rewards for participation in the Knowledge Market can be hard to provide e.g. competition in SARS

"China had patient #1, death #1...publications? Zero."

In a well-equipped lab in southern Beijing, a group of virologists had already discovered a new virus in samples from some of the earliest patients... By the first week of March, the group had tentative evidence that the new virus might indeed be linked to the epidemic. There was just one problem. **They didn't dare tell the world...** A call or an e-mail to Stöhr [coordinator of the WHO network] might also have ensured Yang and his colleagues a more prominent place in the history of the disease.....**That failure, many note, stems in part from systemic problems in Chinese science: a lack of coordination and collaboration, stifling political influence, hesitation to challenge authorities, and isolation from the rest of the world.**

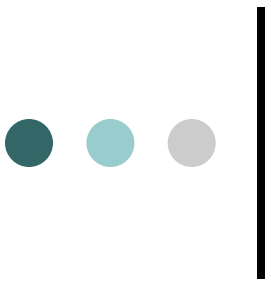
Teams in Stöhr's network, which at the time didn't include any from mainland China, started holding daily teleconferences, posting their findings on a secure Web site, and sending each other samples and reagents by overnight delivery....

(Science, 18 July 2003)

"Li [Director of the Chinese Centre for Disease Control and Prevention] admitted there are still some problems with the management of specimens of the SARS virus. Many laboratories hold their own specimens and need to co-ordinate their research into SARS to make their work safer and more efficient.

(China People's Daily 10-23-2003)

Analyzing Knowledge Markets

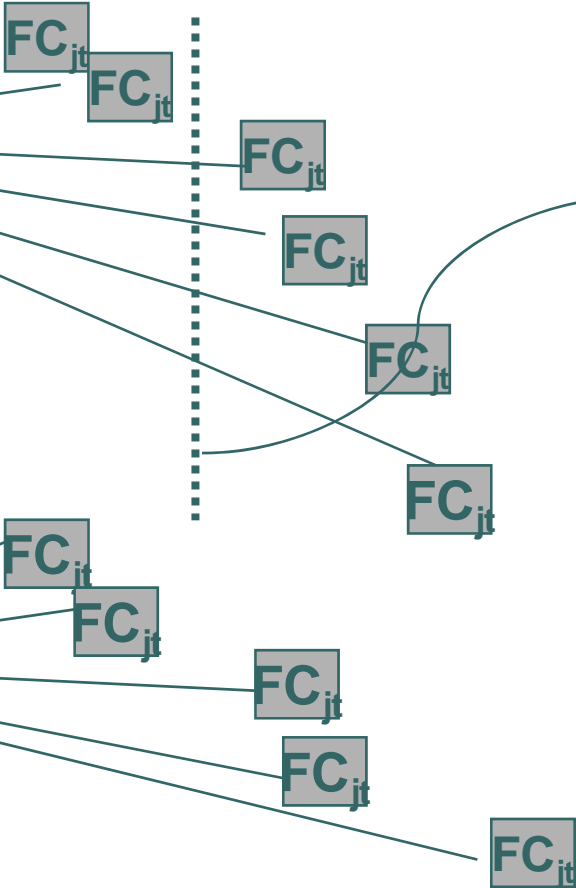


← Pre-period institutional setting Post-period institutional setting →

Treatment group



Control group



Exogenous SHIFT in market arrangements

Measure citations before & after to estimate impact of SHIFT

Plot forward citations over time as a measure of scientific knowledge accumulation building on a "piece of knowledge"



Analyzing Knowledge Markets

Results for Biological Resource Center Deposit

Negative Binomial Models	Dep. Var. Annual Forward Citations
BRC-Article, Post-Deposit	2.35
Article FE	Y
Age FE	Y
Calendar Year FE	Y

**135%
Boost
After
Deposit**

- Evidence for the positive impact of material deposit and lower cost open access on scientific accumulation

Analyzing Knowledge Markets

Granting IP rights over gene sequences cited in publications

	Annual Citations to Gene Papers	Annual Citations to Gene Papers	Annual Citations to Gene Papers	Annual Citations to Gene Papers
PATENTED, Post Grant	0.95			0.95
PATENTED, Private Sector		0.91		
PATENTED, Public Sector		0.99		
PATENTED, Cancer Gene			0.89	
PATENTED, Other Gene			0.97	
PATENTED * Fragmentation				0.97
Article FE	Y			Y
Age FE	Y			Y
Citation-Year FE	Y			Y

**11 %
Decline in
citations
after
patent grant**

- Evidence for negative impact of patent grant on knowledge markets (measured by publications) esp. with patent thickets
- Does not account for the positive benefits of patents on commercialization etc.



Analyzing Knowledge Markets

Results for Changing Access to Research Mice

**20-30%
Boost in citations
after Open Access
agreements**

Negative Binomial Models	Cre-lox (IP + Access)	Onco (IP only)
Overall impact on Annual Forward Citations	1.32	1.21
Impact on Diversity of Annual Forward Citations (new key words)	1.36	1.20
Impact on Diversity of Annual Forward Citations (new people)	1.44	1.22
Impact on Basic Research	2.07	<i>1.03</i>
Impact on Applied Research	<i>0.92</i>	1.56
<i>Article Effects</i>	Fixed	
<i>Age FE, Calendar Year FE, Transition Window Effects</i>	Y	



Unanswered Questions

Global Access to Knowledge Markets

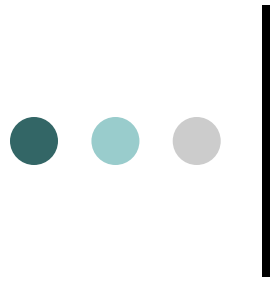
Does the shift from informal to the new mixed formal & informal complex really bring global equity in participation in scientific knowledge markets?

Effectiveness of Markets

While we can encourage more knowledge exchange and better functioning markets, what about failure? Are the new efficiencies created in these formal institutions dwarfed by inefficiencies that arise from secrecy & failure?

Matching the Market to the Problem

Do all scientific areas need this complex of formal arrangements? How could/should market arrangements be contoured to fit the underlying problems?



Thank you!

Questions or comments?

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