Publications, Patents or Secrecy: Contracting Over the Disclosure of Scientific Knowledge

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- Increasing interest in the foundations of economic growth (Romer, Aghion etc.)
- Central role of knowledge accumulation in step-by-step growth models
- What are the factors shaping the rate & direction of knowledge accumulation?
- Disclosure as one *key feature* of effective accumulation

“If I have seen further it is by standing on the shoulders of giants.” (Isaac Newton)

Key insight: you have to know about the giant and not be eaten by the giant.

Key policy issue: how do we encourage cumulative knowledge accumulation?

Why is disclosure central to knowledge accumulation?

- The mere production of knowledge does not guarantee that others will be able to exploit it (Mokyr, 2002)
- Without mechanisms ensuring access to knowledge (at reasonable cost) researchers must "reinvent" the wheel (Rosenberg; Mokyr)
- Disclosure is a necessary (but not sufficient) condition for access (Furman and Stern 2006; Aghion et al. 2007)

Economic foundations of disclosure strategy

- In a world where cumulative knowledge accumulation is efficient, what are the incentives for scientists and firms to disclose knowledge through publication?
- How do disclosure incentives interact with intellectual property protection, scientific rewards and conditions of public funding?

- Sociology of science
  - Merton (1963)
  - Stokes (1996)
- Economics of innovation
  - Rosenberg
  - Dasgupta & David
  - Romer (1990)
- Recent work
  - Aghion, Dewatripont and Stein (2005)

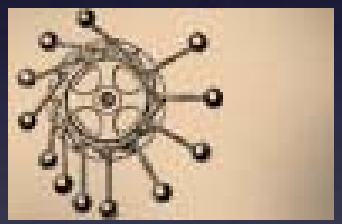
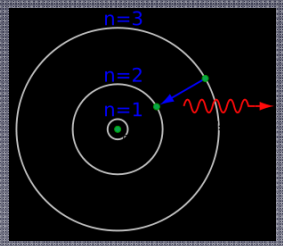
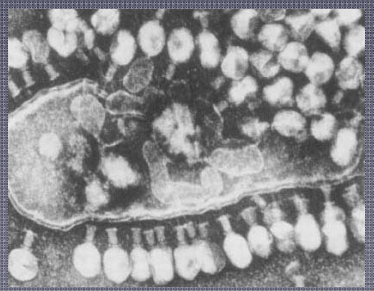
Outline

- Introduce our framework
- Explore model with patenting and short-term research funders
- Demonstrate mechanisms for internalizing cumulative knowledge
- Extensions and conclusions

Key elements …

- Many ideas have *both* scientific merit and commercial application
- Disclosure is a strategic choice of scientists and funders/firms
- Scientists are motivated towards openness
- Funder's preferences are driven by their time horizon
  - Determines ability to consider and appropriate the returns from cumulative knowledge acquisition.

From Stokes (1996)

Scientific Merit \ Immediate usefulness	Low	High
Low		
High		

From Stokes (1996)

Scientific Merit \ Immediate usefulness	Low	High
Low	Steorn	Edison
High	Bohr	Pasteur

- Disclosure mechanisms
  - Publication
  - Patenting
- Four strategies
  - Secrecy
  - Commercial Science (patent only)
  - Open Science (publish only)
  - Patent-paper pairs (both but with publication after idea generation and managed so as to not create prior art claim; less than 12 months)

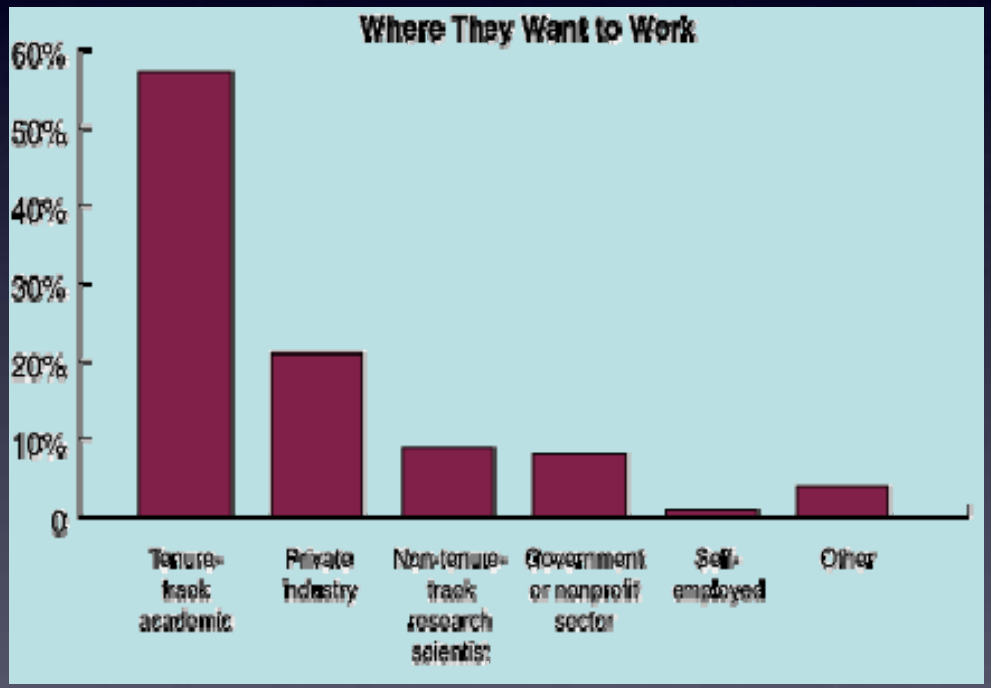
Patent-paper pairs …

- Arise in Pasteur's Quadrant
- Important phenomenon in the life sciences (& beyond) – many of the major breakthroughs are disclosed as patent-paper pairs including:
    - recombinant DNA techniques (Cohen et al., 1973),
    - transgenic mouse prone to cancer – the Oncomouse (Stewart et al. 1984),
    - RNA interference (Zamore et al. 2000),
    - human embryonic stem cells (Thomson et al. 1998).
- They are prevalent among most "normal science" as well as breakthroughs
    - For example, of 340 articles published 1997-1999 in the leading academic journal *Nature Biotechnology* 50% were associated with patents (Murray and Stern, 2007)

- Disclosure strategy arises as the result of the *interaction* between the researcher and the research funder
  - Traditionally the "gentleman scholar" funded his own work, was "disinterested" as a result of his gentleman's status and disregard for the pursuit of financial returns from science (Shapin, 1994).
  - Today's scientists & in the past those (e.g. Galileo) funded by patrons (e.g. Medici) have to match their disclosure requirements with those of their funder (patron)
- Outcome depends on preferences for disclosure

Disclosure preferences of scientists:

Scientists prefer disclosure over secrecy– they are willing to trade off salary in return for opportunities to control & disclose their work



Median 2006 Salaries

	Academic	Industry
Medicine	$140,000	$145,500
Pharmacology	$99,000	$116,000
Toxicology	$78,000	$105,000
Environmental	$85,000	$88,000
Genetics	$73,458	$83,750
Agricultural	$74,000	$99,500
Biochemistry	$63,300	$98,000
Physiology	$65,000	$88,010
Neuroscience	$66,150	$100,000
Biotechnology	$63,000	$105,000
Microbiology	$62,000	$89,000
Bioinformatics	$65,000	$103,000
Ecology	$61,474	$75,000
Zoology	$59,300	$47,000
Virology	$57,500	$89,000
Molecular biology	$52,750	$84,000
Immunology	$54,000	$96,525
Cell biology	$52,050	$84,300
Cancer biology	$50,000	$62,000
Developmental biology	$45,000	$65,130
Other	$71,000	$92,000

Note: Survey respondents are AAAS members and free registrants on the *Science* magazine Web site. Kelly Scientific Resources also participated in the survey by polling some 12,000 of their employees, whose responses were combined with the rest of the survey data.

Source: http://sciencecareers.sciencemag.org/

- Preferences not simply related to greater control over research agenda provided in academic vs. industry (Aghion, Dewatrapoint & Stein, 2007) but also opportunity to publish.
- Estimates from a study of multiple job offers for PhD scientists (Stern, 2006) imply that individuals will accept 20% less, on average, if they are given the opportunity to and incentives to publish in the public scientific literature.
- Disclosure in the form of patents does not provide a similar "preference" effect for researchers (assuming they are not participating in the rents from patent licensing) giving the following disclosure preference ordering

=> publication > patents > secrecy

Do scientists have a preference for papers or patent-paper pairs?

- Evidence that, in the absence of rent sharing from patent licensing, scientist preference is:

$\Rightarrow$ publications > **patent-paper pairs** > patents > secrecy

- Patent-paper pairs have ~10% lower citations post patent grant (Murray and Stern, 2007) & can be associated with greater complexity of research collaboration, knowledge diffusion etc. (Murray, 2007)

Oncomouse – potential costs associated with disclosure in patent-paper pairs

Leder & Stewart, Harvard develop the "Oncomouse" in 1984

- Revolution" in the use of genetically engineered research mice as a tool for life sciences progress
- First mouse with genes inserted to predispose mouse to cancer

Oncomouse is a "dual" discovery & serves as foundation for both:

- On-going scientific discovery AND
- Invention & economic growth

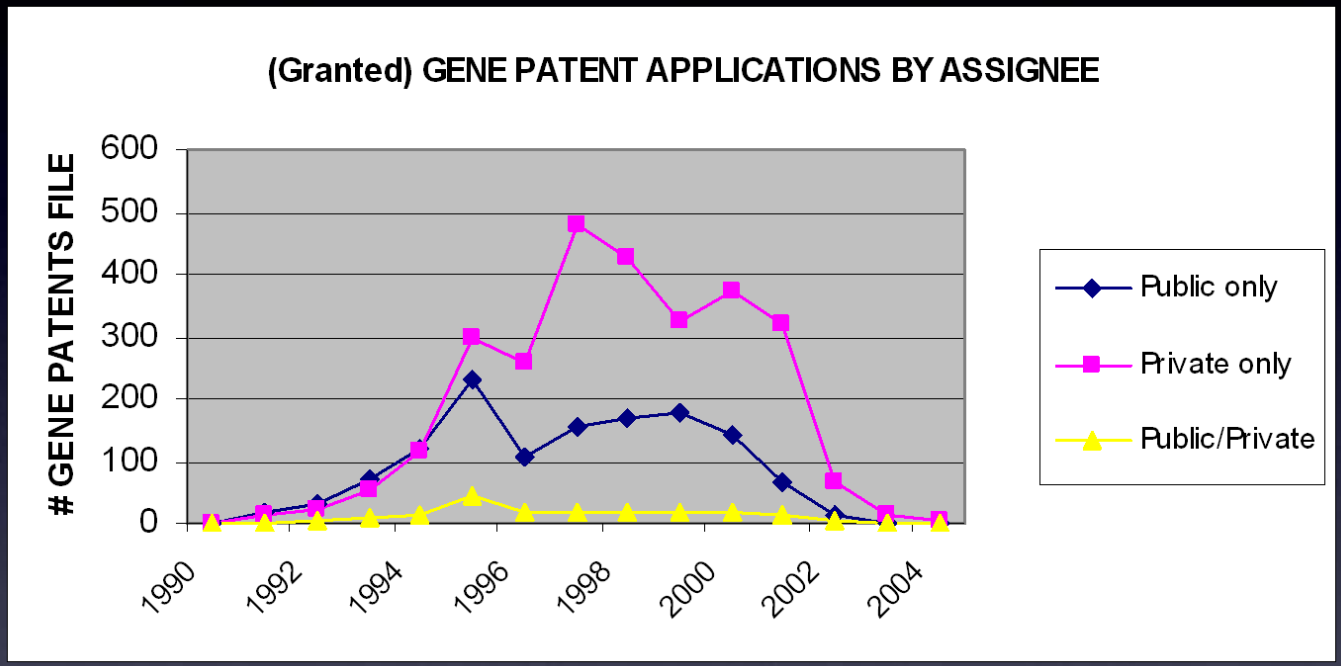
Oncomouse disclosed as a "patent-paper pair"

- four years after publishing in *Cell (1984)*
- Harvard is granted US patent which is licensed to Du Pont who distribute the mouse with controversial restrictions

Oncomouse patent enforcement by DuPont

- Inhibits researchers from using the mouse in follow-on research
- Inhibits the informal peer-to-peer exchange of research materials
- **Costly** to the reputation of scientists who developed the Oncomouse

In spite of costs of patent-paper pairs increasing prevalence in academia:



- 1990-2005: > 4000 patents granted on gene sequences with ~30% filed by public sector researchers who also publish papers (Jensen & Murray, 2005).
- Specific instance of rise in academic patenting in the wake of the 1980 *Bayh-Dole Act.*
- WHY? Partly result of increased participation of researchers in patent benefits & requirements of RESEARCH FUNDERS
- Is this because there are more patents, more papers or both?

Disclosure preferences of (private) research funders

- Patents & secrecy provide alternative mechanisms thru which firms can capture the value of their ideas – depends on the dynamics of the market for ideas (Gans & Stern, 2003)
- How does publication impact these alternatives?
  - When the research funder chooses secrecy, papers *undermine* the opportunity for value capture
  - When the research funder chooses patents, papers may *reduce* the opportunity for value capture due to the additional disclosure required in papers (& the requirements to provide material access etc.)

$\Rightarrow$ secrecy >> publication

$\Rightarrow$ patents > patent-paper pairs >> publication

Disclosure preferences of (public) research funders

- Disclosure preferences only shift when research funders have non-monetary preferences; e.g., NIH, Howard Hughes
- In cases where research funders want to maximize knowledge accumulation & disclosure in future generations their current preference ordering is:

$\Rightarrow$ publication > patent-paper pairs > patents >> secrecy

- Preference ordering between papers & patent-paper pairs is *ambiguous* & lies at the core of the *anti-commons debate* (Heller and Eisenberg, 1998) – do patent-paper pairs provide less accumulation?
- Raises question of dynamics – not simply monetary or reputational rents in one period *but* over time

Preference summary

- Current time period …
  - Patents provide funder with returns through product market protection
  - Publications provide scientists with career benefits
- Future time periods …
  - Patents provide opportunities for future returns through reach-through rights.
  - Publications provider opportunities for future kudos through citation and awards.
  - Both require others to build on their research
- Sharing
  - What if scientist can share in commercial returns through equity?
  - What if funder can share in the returns to publication through reputation or kudos?

Modeling choices …

Patenting	Private funder time-horizon: Short	Private funder time-horizon: Long
Clear cut	This talk	Other welfare criteria along with openness
Difficult	Potential for full secrecy	Complex

- Impact of strong intellectual property
  - Current appropriability
  - Claims on future innovation
- Should scientists share in commercial returns? (Lachs & Schankerman)
  - Consultant fees
  - Equity
  - Patent ownership
- What is the role of public funding?

This talk: Focus on openness (sole welfare criteria) and leave IP choice exogenous

- Dynamic, overlapping generations model
- Gen t: scientist and a firm (lives 2 periods)
  - Period 1: negotiate over disclosures or openness through publication (o_t); earn current payoff
  - Period 2: earn future payoff (discounted by δ)
- No uncertainty over research outcomes
- Requires cooperation of both the scientist (labour) and the firm (capital)
- Capital costs of research ($c_t \equiv c(o_{t-1})$) are borne by the firm; decreasing in past openness

Commercial returns:

$$\pi_c(o_t;\lambda)+\delta\pi_f(o_t;\lambda)$$
$$-w_t-c_t$$

- Non-increasing and convex in o_t
- λ: IP strength

Academic/scientific rewards:

$$z_c(o_t)+\delta z_f(o_t)+w_t$$

- Non-decreasing and concave in o_t

$$w_t \geq 0$$

$$\exists o \text{ st } \pi_c(o;\lambda) + \delta\pi_f(o;\lambda) \geq c(o)$$

$$\frac{\partial \pi_c}{\partial o_t}, \frac{\partial \pi_f}{\partial o_t} \text{ increasing in } \lambda$$

- Scientist and firm negotiate over wage and openness using the Nash bargaining solution

$$\max_{w_t, o_t} \left(z_c(o_t) + \delta z_f(o_t) + w_t \right) \left(\pi_c(o_t; \lambda) + \delta \pi_f(o_t; \lambda) - w_t - c_t \right)$$

- Negotiated wage:

$$w_t = \tfrac{1}{2} \max \left\{ \pi_c(o_t; \lambda) + \delta \pi_f(o_t; \lambda) - c_t - \left(z_c(o_t) + \delta z_f(o_t) \right), 0 \right\}$$

"Do scientists pay to be scientists" effect (Stern, 2004)

Stronger IP protection (λ) increases openness

- Cases:

$$w_t > 0 \qquad \hat{o}_t : \frac{\partial z_c(o_t)}{\partial o_t} + \delta \frac{\partial z_f(o_t)}{\partial o_t} + \frac{\partial \pi_c(o_t;\lambda)}{\partial o_t} + \delta \frac{\partial \pi_f(o_t;\lambda)}{\partial o_t}$$

$$w_t = 0 \qquad \hat{o}_t : \left(\frac{\partial z_c(o_t)}{\partial o_t} + \delta \frac{\partial z_f(o_t)}{\partial o_t}\right)\left(\pi_c(o_t;\lambda) + \delta \pi_f(o_t;\lambda) - c_t\right) + \left(\frac{\partial \pi_c(o_t;\lambda)}{\partial o_t} + \delta \frac{\partial \pi_f(o_t;\lambda)}{\partial o_t}\right)\left(z_c(o_t) + \delta z_f(o_t)\right)$$

- Both increasing in λ

Banning wage payments increases openness

- Some substitution shows that banning wages will improve openness if:

$$\left(\frac{\partial z_c(o_t)}{\partial o_t}+\delta\frac{\partial z_f(o_t)}{\partial o_t}\right)\left(\pi_c(o_t;\lambda)+\delta\pi_f(o_t;\lambda)-c_t-\left(z_c(o_t)+\delta z_f(o_t)\right)\right)>0$$

- Holds in ‘positive wage’ range so removing wages causes (weakly) greater openness
- Note: greater past openness encourages greater openness today
  - Independent with positive wages

- Greater openness today reduces capital costs tomorrow
- Intertemporal externality not internalised in baseline model
- Two methods by which this could be internalised
  - System of scientific rewards
  - Licensing of intellectual property

- System of scientific rewards
  - Scientist future reward depends on citation in future publication
  - Requires initial publication ($o_t > 0$), future publication ($o_{t+1} > 0$) and a citation …
- Incentives to build on prior research:
  - Researching scientist at t+1 must expend effort (e_{t+1}) to 'understand' t's publication
  - Probability of *understanding* is $p(e_{t+1})$
  - If understands, then the capital cost of future research is $c(o_t)$; otherwise it is $c(0)$
  - If understands, then scientist at t is cited and receives $z_f(o_t)$

- Next generation choice:

$$\max_{e_{t+1}} \; p(e_{t+1})\left(s_{t+1}(o_t) - s_{t+1}(0)\right) - e_{t+1}$$

  - Where s_{t+1} is (t+1)'s expected payoff for a given level of o_t 'absorbed'
  - Note that $s_{t+1}(0)$ may equal zero if next generation project does not proceed.
  - Effort in understanding is increasing in openness as this makes it more likely project will proceed and also increases the share of the surplus the scientist receives

- Current generation has an incentive to take into account future research costs as this increases expected scientific rewards.

- Intertemporal complementarity
  - If expect future scientist to publish, then more likely to publish today in order to realise future scientific kudos
  - If do not expect future scientist to publish, then will not receive future scientific kudos and so have less incentive to publish today
  - Expected openness drives openness
- Possibility of multiple equilibria
  - Unique equilibrium with $o_t > 0$ for all t if: $\frac{\partial z_c(0)}{\partial o_t} + \delta \frac{\partial \pi_f(0;\lambda)}{\partial o_t} > 0$
  - Exists another equilibrium with $o_t = 0$ for all t if: $\frac{\partial z_c(0)}{\partial o_t} + \delta \frac{\partial \pi_f(0;\lambda)}{\partial o_t} \leq 0$
  - Openness equilibrium is Pareto superior

- Research generates a patent owned by the firm
- Next generation researchers need to license the patent in order to proceed commercially
  - License fee: once off payment of τ_t
- Two modeling extensions:
  - Openness may allow next generation researchers to 'work around' patented technology
  - Negotiations include license payment: three parties – scientist, firm and patent holder
  - No system of scientific rewards (later …)

- Work-around possibility:
  - Suppose that $o_t > 0$ (there is a publication)
  - Then the probability that a license fee, τ_{t+1} must be paid falls to ϕ
  - ϕ is a measure of the strength of future IP
- Tension in future impact of openness
  - Increased past openness reduces future research costs and increases surplus from license negotiations
  - Past openness makes it more likely a work-around will be found that avoids license payments

- Multi-agent Nash bargaining solution:

$$\max_{w_{t+1},\tau_{t+1},o_{t+1}} s_{t+1}\Pi_{t+1}\tau_{t+1}$$

  - where Π_{t+1} is the firm's payoff
- If wages and license fees are positive, outcome corresponds to the Shapley value solution
  - Openness chosen to maximise scientist and firm surplus
  - So long as commercial return is positive, license fee is positive

- Dynamic structure ($w_{t+1} > 0$)

$$\tau_{t+1} = \tfrac{1}{3}\left(s(\hat{o}_{t+1}) + \pi_c(\hat{o}_{t+1};\lambda) + \delta\phi\tau_{t+2}(\hat{o}_{t+1};\lambda) - c(o_t)\right)$$

$$\hat{o}_{t+1} = \arg\max_{o_{t+1}} \; s(o_{t+1}) + \pi_c(o_{t+1};\lambda) + \delta\phi\tau_{t+2}(o_{t+1};\lambda)$$

- Openness may enhance future returns …

$$\frac{\partial \tau_{t+2}}{\partial o_{t+1}} = -\frac{\partial c}{\partial o_{t+1}} > 0 \Rightarrow \frac{\partial \pi_f}{\partial o_{t+1}} > 0$$

- Symmetric dynamic equilibrium with positive openness ($\tau_t = \tau$ for all t)

$$\tau = \frac{1}{3-\delta\phi}\left(z_c(\hat{o}) + \delta z_f(\hat{o}) + \pi_c(\hat{o};\lambda) - c(\hat{o})\right)$$

$$w = \frac{1}{3-\delta\phi}\left(\pi_c(\ddot{o};\lambda) - (2-\delta\phi)\left(z_c(\ddot{o}) + \delta z_f(\ddot{o})\right) - c(\ddot{o})\right)$$

- License fees 'reach through' all future generations (both commercial and scientific returns)
  - Share of current surplus appropriated by scientist and patent holder exceeds 2/3
  - Scientific kudos reduces a scientist's wage (from their own kudos) and boosts it from appropriation of future scientific kudos through expected license revenue
  - Happens without an actual 'reach through' contract
  - License fees only positive if *current* profits exceed research costs

- Dynamic structure ($w_{t+1} = 0$)

$$\tau_{t+1} = \tfrac{1}{2}\left(\pi_c(\hat{o}_{t+1};\lambda) + \delta\phi\tau_{t+2}(\hat{o}_{t+1};\lambda) - c(o_t)\right)$$

$$\hat{o}_{t+1} = \arg\max_{o_{t+1}} s(o_{t+1})\left(\pi_c(o_{t+1};\lambda) + \delta\phi\tau_{t+2}(o_{t+1};\lambda) - c(o_t)\right)^2$$

- Symmetric dynamic equilibrium license fee:

$$\tau = \frac{1}{2-\delta\phi}\left(\pi_c(\hat{o};\lambda) - c(\hat{o})\right)$$

- With zero wages, there is always openness unless it is commercially infeasible.
- Openness equilibrium does not exist if:

$$\delta(1-\phi)\left(\pi_c(0;\lambda)-c(\hat{o})\right) > (3-\delta)\left(z_c(\hat{o})+\delta z_f(\hat{o})\right)$$

- Equilibrium with no openness

$$\frac{3+\delta}{3-\delta}\left(\pi_c(0;\lambda)-c(0)\right)$$

$$\geq \max_{o_t}\ s(o_t)+\pi_c(o_t;\lambda)+\delta\phi\tfrac{1}{3}\left(\pi_c(0;\lambda)+\tfrac{\delta}{3-\delta}\left(\pi_c(0;\lambda)-c(0)\right)-c(o_t)\right)-c(0)$$

$$\Rightarrow \frac{3-\delta\phi}{3-\delta}\left(\pi_c(0;\lambda)-\tfrac{\delta}{3}c(0)\right) \geq s(\hat{o})+\pi_c(\hat{o};\lambda)-\delta\phi\tfrac{1}{3}c(\hat{o})$$

- Multiple equilibria possible

Policy experiments

- Strengthening IP
  - λ: causes openness to increase
  - ϕ: strengthening future IP increases openness (more weight on future cost reduction from openness)
- Banning scientist wages
  - Continues to strengthen openness

Suppose that there was a ‘system of scientific rewards’ and licensing

- Impact on firm incentives for openness
  - When choosing openness, firm will be concerned about scientist ‘understanding’ as it is only in this case that patent holder appropriates cost savings.
  - Thus, strengthens incentives towards openness.
- Impact on scientist incentives to ‘understand’
  - If don’t cite but are subject to licensing regardless, then license fee does not impact on incentives
  - If don’t cite and are not subject to license fees in this case, then license fee impacts on incentives to build but this impact is partially internalised through openness choice: consistent with Murray & Stern (2007)
  - Two systems reinforce each other
- All previous results go through (qualitatively)

Suppose that whether to patent or not was a choice and part of scientist-firm negotiations

- If secure a patent, more likely to choose a higher degree of openness
- Relinquishing patent rights might be a more effective mechanism in encouraging future citations but at a lower level of openness

Suppose that a share of the capital costs was provided by a public funder …

- In baseline model, without additional conditions, this will either have no impact on openness or will increase it (when wage payments are made)
- Of course, with either scientific rewards or licensing, internalisation of future costs is muted as the public portion is ‘free’
  - Thus, public funding may diminish openness

Suppose scientist owned a share of patent returns, α

- Does this play a different role from the wage?
  - Baseline model: same outcome
  - Scientific rewards: same outcome
  - Licensing: depends if past scientist gets a seat at the negotiating table. Push harder for openness and so makes openness equilibrium more likely.

Suppose patent rights extended through to two future generations

- A reach through right would mean that there were four parties in each future negotiation
- Would this diminish openness?
- May capture true ‘anti-commons’ argument and lead to a conclusion that license rights need to be pooled.

- Openness is part of a negotiation between the scientist and funders
- For private funders
  - Trade-off between openness and commercial returns
  - Mitigated by strength of IP – more openness
  - Restricting scientist commercial interest increases openness
- Intertemporal externalities
  - System of scientific reward: interest in openness to reduce future costs – to gain citation
  - Licensing: allows appropriation of future costs
  - Can create multiple equilibria

- Commercial & Scientific interactions
  - What drives secrecy?
  - What is the role of competition?
- Economic analysis of scientific institutions
  - What drives status amongst scientists?
  - How were reward norms established?
  - Are races for priority efficient?
  - Is science really open?