What drives scientific disclosure?

Joshua Gans (Melbourne), Fiona Murray (MIT)
& Scott Stern (Northwestern)

UQ Seminar, 23rd May, 2008

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?

Literature

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

Outline

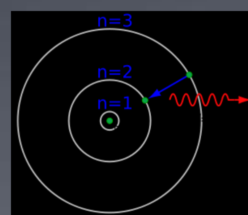
- When does scientific disclosure occur in commercial situations?
- Baseline model of firm/scientist negotiations
  - When does publication occur?
  - How does this interact with IP protection?
- Public funding
  - Which projects are funded when there is public and private funding?
  - Impact of restrictions on the commercialisation of public research?
- Races for priority
  - Does competition encourage disclosure?
- Future directions

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.

Taxonomy of Projects

From Stokes (1996)

		Immediate usefulness: Low	Immediate usefulness: High
Scientific Merit	High		
	Low		

Taxonomy of Projects

From Stokes (1996)

Immediate usefulness

Scientific Merit		Low	High
	High	Bohr	Pasteur
	Low	Steorn	Edison

Disclosure

- 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

- Patenting and publication are *not* mutually exclusive.
- 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).

PPP Examples I

	# papers	# paired with patents	% paired publications
Publications by public sector funded researchers	235	106	45%
Publications by public and private sector funded researchers	70	41	59%
Publications by private sector funded researchers	36	24	67%

Starting with publications: From a sample of 341 research publications (all the research articles from the leading life science journal *Nature Biotechnology* between 1997 and 1999). Examine which publications are also disclosed in patents. (Murray and Stern 2007)

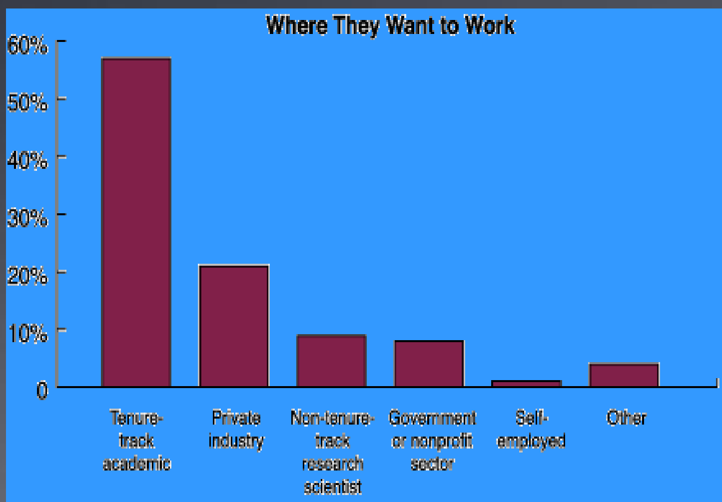
PPP Examples II

	# patents	# paired with publications	% paired patents
Patents by public sector funded researchers	1308	1099	84%
Patents by public and private sector funded researchers	187	164	88%
Patents by private sector funded researchers	2775	1347	49%

Starting with patents: From the full population of human gene patents (US patents identified using bioinformatics methods that disclose and claim a human gene sequence or fragment (Jensen and Murray 2005), we examine which patents are also disclosed in publications (Huang and Murray 2008).

Scientist Preferences

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/

Scientist Preferences

- 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

Baseline Model

What are the primary interactions between choices of disclosure strategy?

Disclosure Paths

- Can choose the degree of disclosure through publication:

$$d \in [0, D]$$

- In order to obtain a patent, a minimum level of disclosure is required:

$$d_{PAT}$$

- Baseline Assumption 1: publication and patent information are distinct (from a commercial perspective)

- Baseline Assumption 2: A patent increases the costs of a work-around by the entrant (λ)

Preferences

- Scientist

$$U = \underbrace{w}_{\text{wage}} + \underbrace{b_S d}_{\text{kudos}}$$

- Firm/Private Funder
  - Monopoly profit: $\Pi - w$
  - Competitive profit: $\pi - w$
  - Entrant's expected profit: $\pi - i\lambda + b_E(d + id_{PAT}) - \theta$
    - where θ is distributed uniformly on [0,1]
    - $\pi + b_E D < 1$ (entry always uncertain)
  - Expected profit:

$$\Pi - \underbrace{k}_{\text{capital cost}} - w - \underbrace{(\pi - i\lambda + b_E(d + id_{PAT}))}_{\text{probability of entry}}(\Pi - \pi)$$

Disclosure Regimes

		Publication disclosure (d)	
		0	D
Patent (i)	1	Commercial Science	Patent-Paper Pairs
	0	Secrecy	Open Science

Negotiations

- Scientist and firm negotiations over disclosure regime:

$$\max_{w,i,d} \left(w + b_S d \right) \left(\Pi - k - w - (\pi - i\lambda + b_E (d + id_{PAT}))(\Pi - \pi) \right)$$

$$w^* = \max \left[0, \tfrac{1}{2} \left(\Pi - k - (\pi - i\lambda + b_E (d + id_{PAT}))(\Pi - \pi) - b_S d \right) \right]$$

Unconstrained wage: $w > 0$
•Relative commercial return high
•Choose (i, d) to maximise joint surplus
•So long as

$$d^* \leq \underline{d} = \frac{\Pi - k - (\pi - i\lambda + b_E d_{PAT})(\Pi - \pi)}{b_S + b_E (\Pi - \pi)}$$

Constrained wage: $w = 0$
•Relative commercial return low
•Use d to transfer utility between firm and scientist ($d > \underline{d}$)
•Choose (i, d) to maximise NTU Nash objective

$$d_i^* = \frac{\Pi - k - (\pi - i\lambda + b_E id_{PAT})(\Pi - \pi)}{2 b_E (\Pi - \pi)}$$

Surplus Maximisation

- Consider the choices that maximise surplus

$$b_S d + \Pi - k - (\pi - i\lambda + b_E(d + id_{PAT}))(\Pi - \pi)$$

- Disclosure … choose no disclosure if

$$\Delta_d \equiv \frac{b_S}{b_E(\Pi - \pi)} \leq 1$$

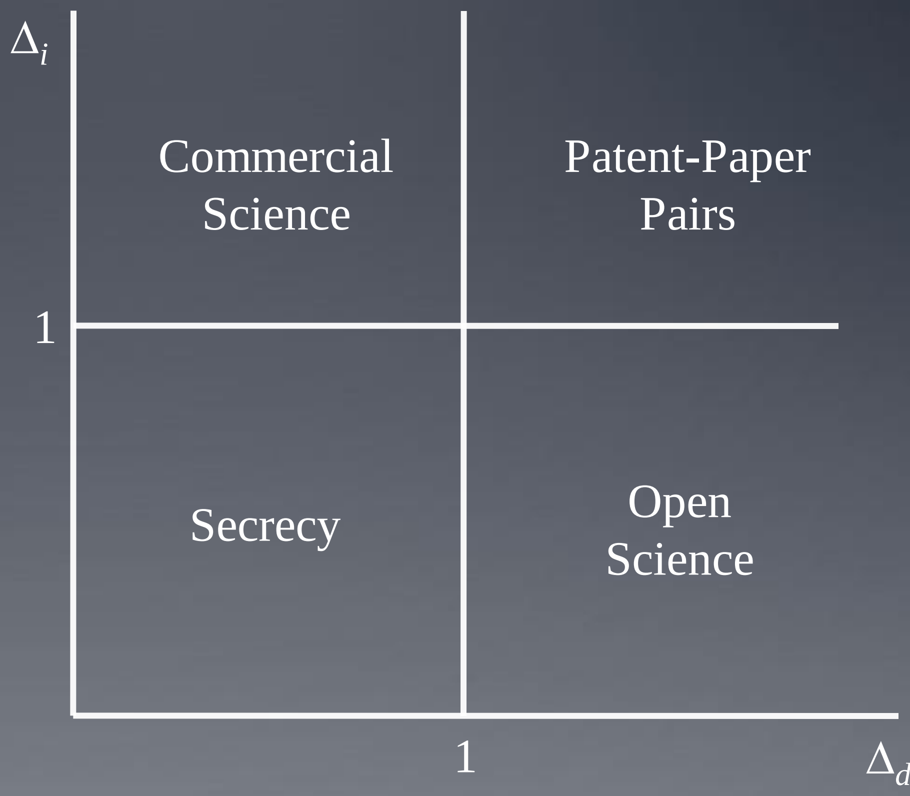
- Patent … choose no patent if

$$\Delta_i \equiv \frac{\Pi - k - (\pi - \lambda + b_E d_{PAT})(\Pi - \pi)}{\Pi - k - \pi(\Pi - \pi)} \leq 1$$

$$\Leftrightarrow \lambda \leq b_E d_{PAT}$$

Equilibrium Outcomes

- When $\Delta_d > 1$, surplus maximisation would involve $D > \underline{d}$
- Wages always zero when there is publication
- Thus, level of disclosure is less than full disclosure
- *Decisions do not interact*.



Stronger IP Protection

$$d_i^* = \frac{\Pi - k - (\pi - i\lambda + b_E i d_{PAT})(\Pi - \pi)}{2 b_E (\Pi - \pi)}$$

- Increasing λ
  - More likely to take out a patent
  - If there is publication, negotiate more disclosure
- Increasing d_{PAT}
  - Less likely to take out a patent
  - If there is a publication, reduces disclosure

Stronger IP protection (higher λ and lower d_{PAT}) stimulates openness in science

Overlapping Disclosures

- Suppose that there was full overlap between patent and publication disclosures.
  - No cost to same disclosures as in patent, so Commercial Science does not arise.
  - If choose to publish and patent disclosure requirements are low, then worthwhile patenting even if it would otherwise encourage entry; so no Open Science

$$\Delta_d < \min\left[1 - \frac{\lambda}{b_E d_{PAT}}, 1\right] \Rightarrow \text{Secrecy,}$$

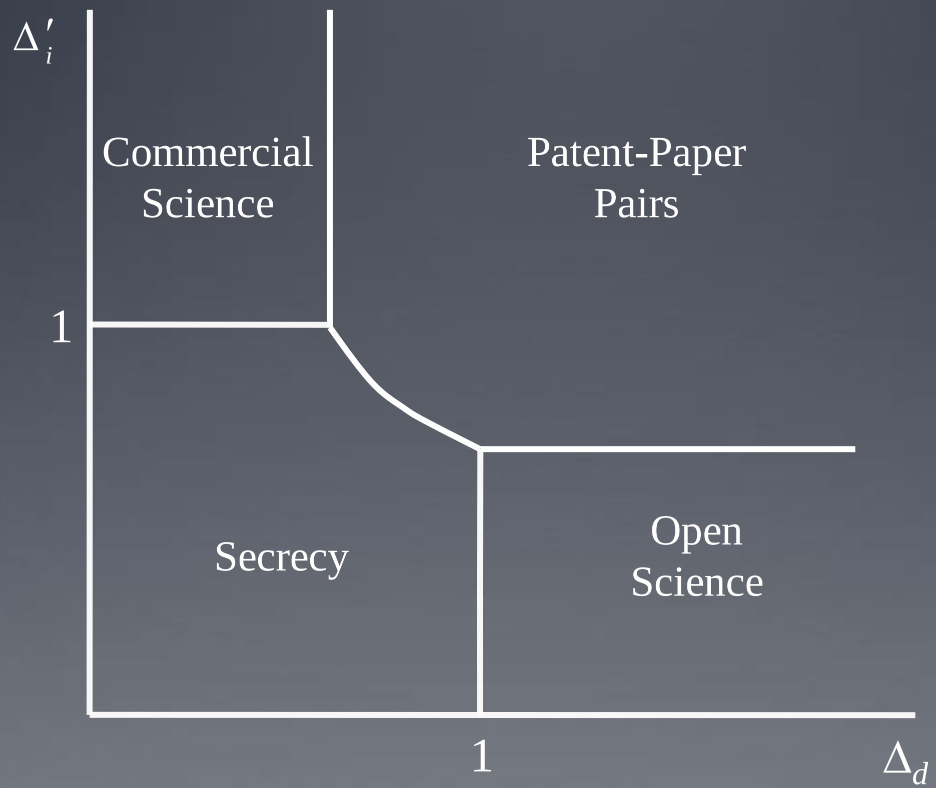
otherwise Patent-Paper Pairs

IP Protection Through Disclosures

- Baseline model: IP protection increases entry costs
- Suppose workaround not guaranteed to 'work'
  - Entrant sinks costs, λ, and generates probability, $1 - \rho$, that will still be excluded.
  - Expected entrant profit: $(1-i\rho)\pi - i\lambda + b_E d + ib_E d_{PAT} - \theta$
  - Expected firm profit: $\Pi - k - w + (1-i\rho)\left((1-i\rho)\pi - i\lambda + b_E d + b_E i d_{PAT}\right)(\Pi - \pi)$
- Marginal cost of publication falls when you have a patent

$$(1-i\rho)b_E(\Pi - \pi)$$

Complementarity



$$\Delta_i' \equiv \frac{\Pi - k - (1-\rho)((1-\rho)\pi - \lambda + b_E d_{PAT}}{\Pi - k - \pi(\Pi - \pi)}$$

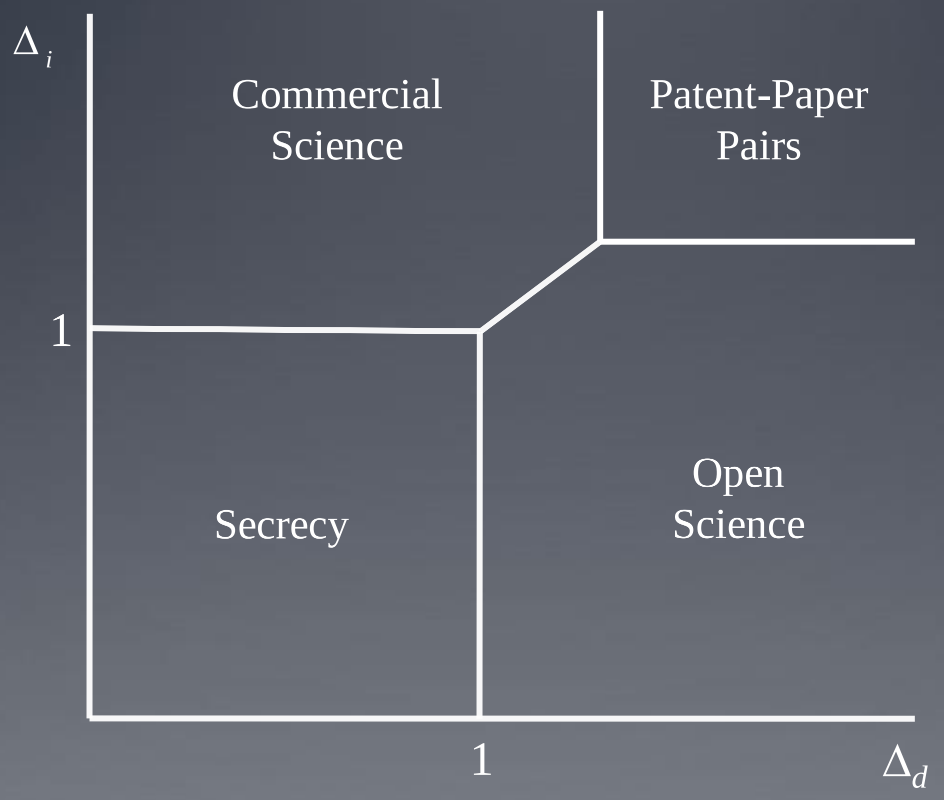
The Anti-Commons Effect

- Fear that patent thickets will deter scientific research
  - Murray and Stern (2006) found that papers with patents attached attracted fewer citations
- Assume that patent protection alters scientific kudos:

$$b_s(1 - ic)d$$

- where c (< 1) parameterises the anti-commons effect.
- Only impacts on disclosures under Patent-Paper Pairs

Substitutability



Funding

How do the mix and terms of public and private funding drive disclosure choices?

Public Funding

- Suppose there existed a liquidity constrained public funder who cared about immediate use and cumulative knowledge
- When will public funds encourage disclosure and increase the degree of innovation?
- Should publicly funded projects be permitted to obtain IP protection (e.g., the Bayh-Dole Act)?
- Do the answers to these questions hinge on the project-specific information available to the public funder?

Model Amendments

- Introduce heterogeneity amongst projects:
  - Future benefit (internalised by kudos): b_E distributed uniformly on [0,1]
  - Immediate use: let v be the immediate social value of a project; distributed uniformly on [0,1]
- Let K be the total level of public funds with $k < K < 1$
- Impact of competition:
  - $\Pi = \mu v$, $\pi = \beta v$ $(1 > \mu > 2\beta)$
  - Monopoly creates deadweight loss of $\delta > \beta$
- Simplifying assumption: $d_{PAT} = 0$ (patenting always profitable).

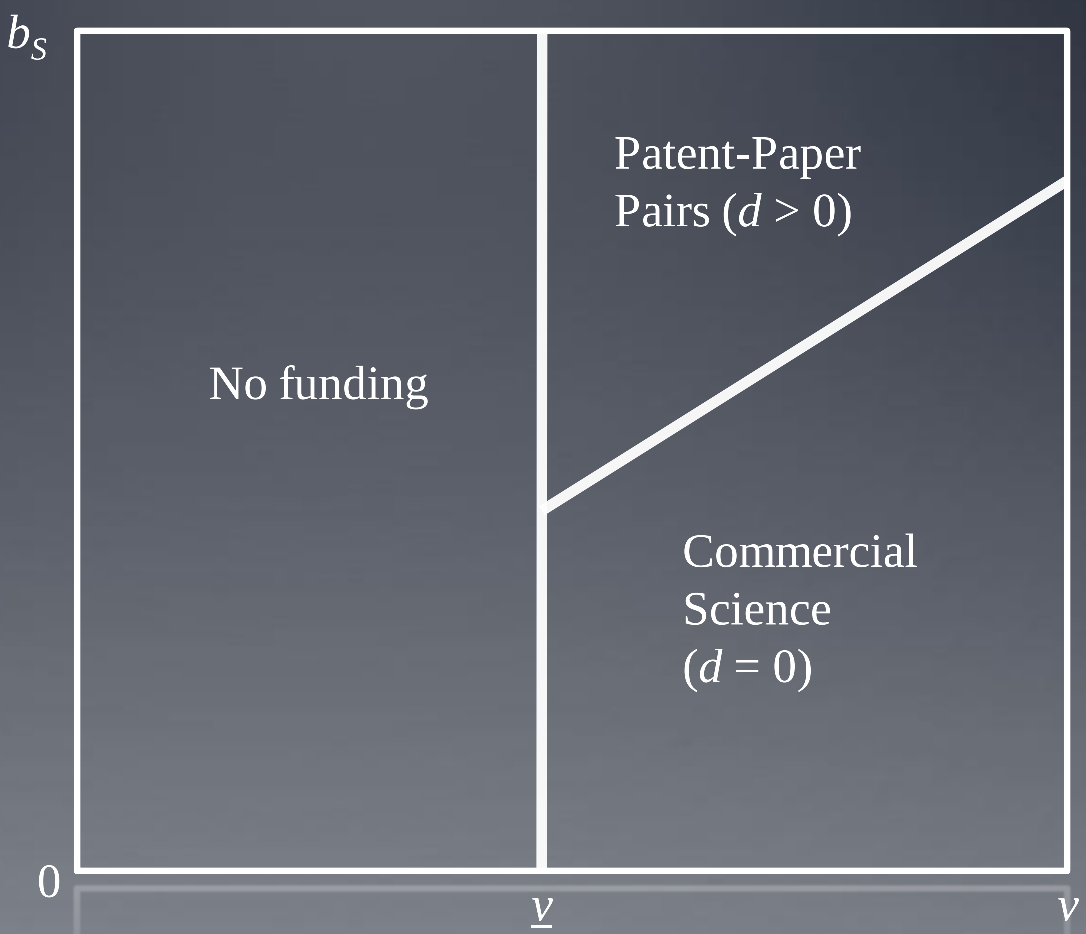
No public funding

Projects with positive commercial return are funded; i.e., $v > \underline{v}$ as defined by:

$$\mu \underline{v} - (\beta \underline{v} - \lambda)(\mu - \beta)\underline{v} = k$$

Funded projects with high enough scientific kudos permit publication; i.e., where:

$$b_S \geq b_E(\mu - \beta)v$$

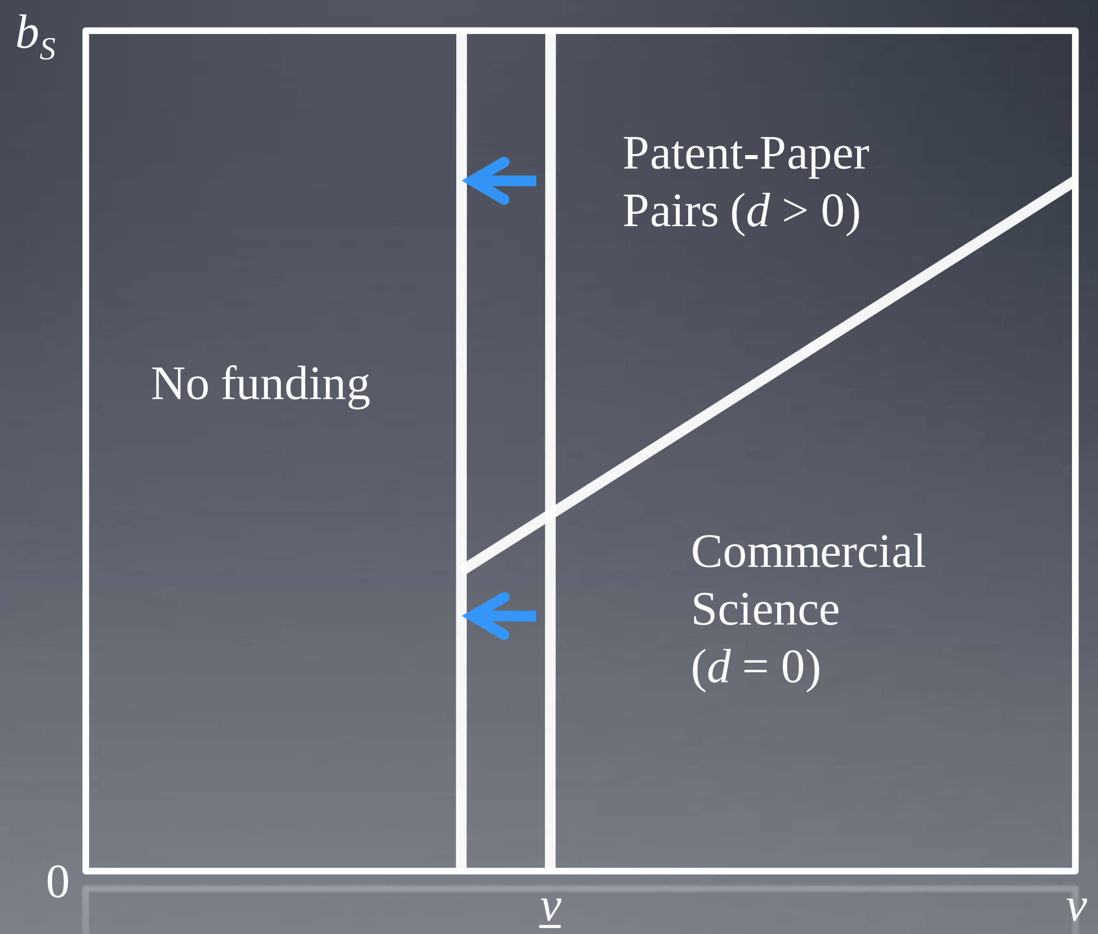


Public subsidy

A public subsidy to private firms *may* increase the number of funded projects but there is a large degree of crowding out.

However, it does increase disclosure.

Need to select on the basis of project type.



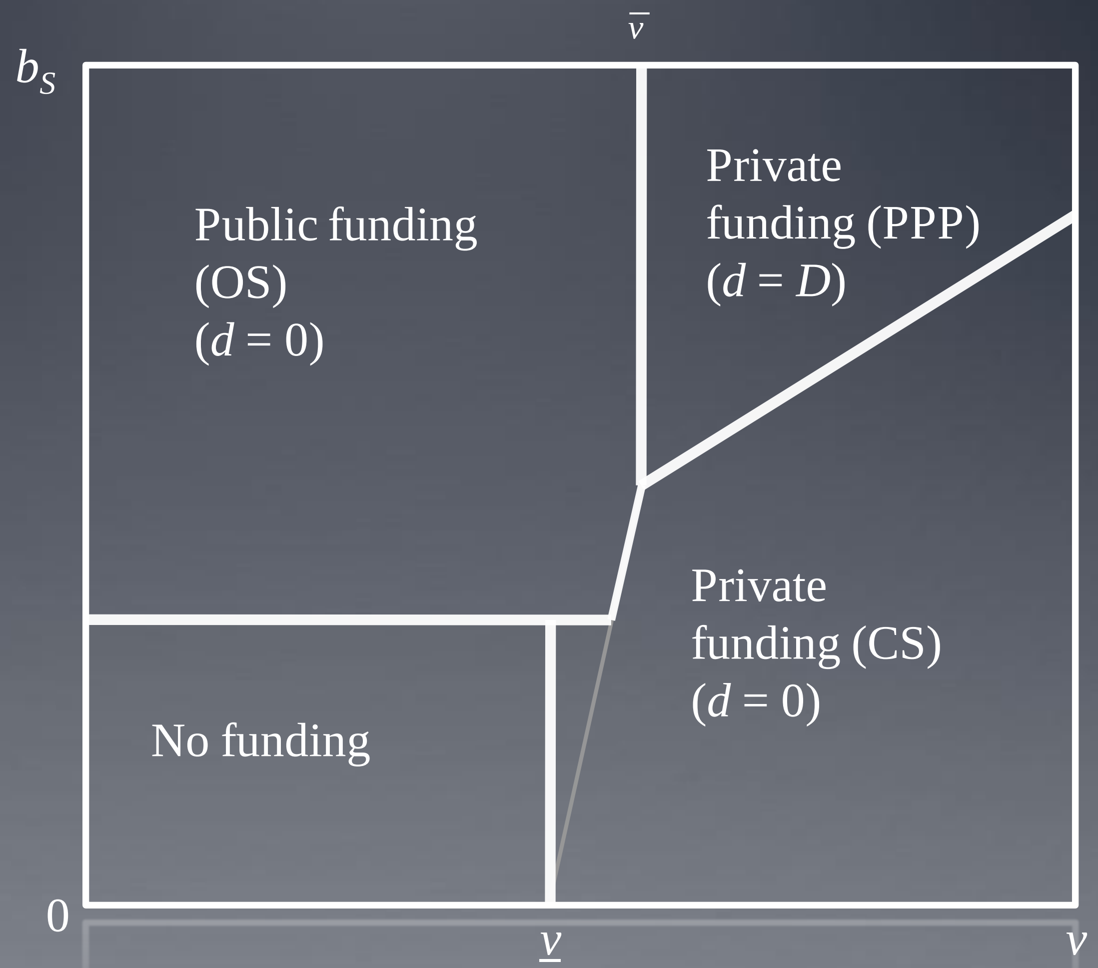
Pre-Bayh-Dole (high K)

Restricted public funding:
(i) no commercial returns to scientist; and
(ii) full disclosure

Select on basis of scientific merit (b_S)

Relatively high K

'Opt out' to secure commercial returns

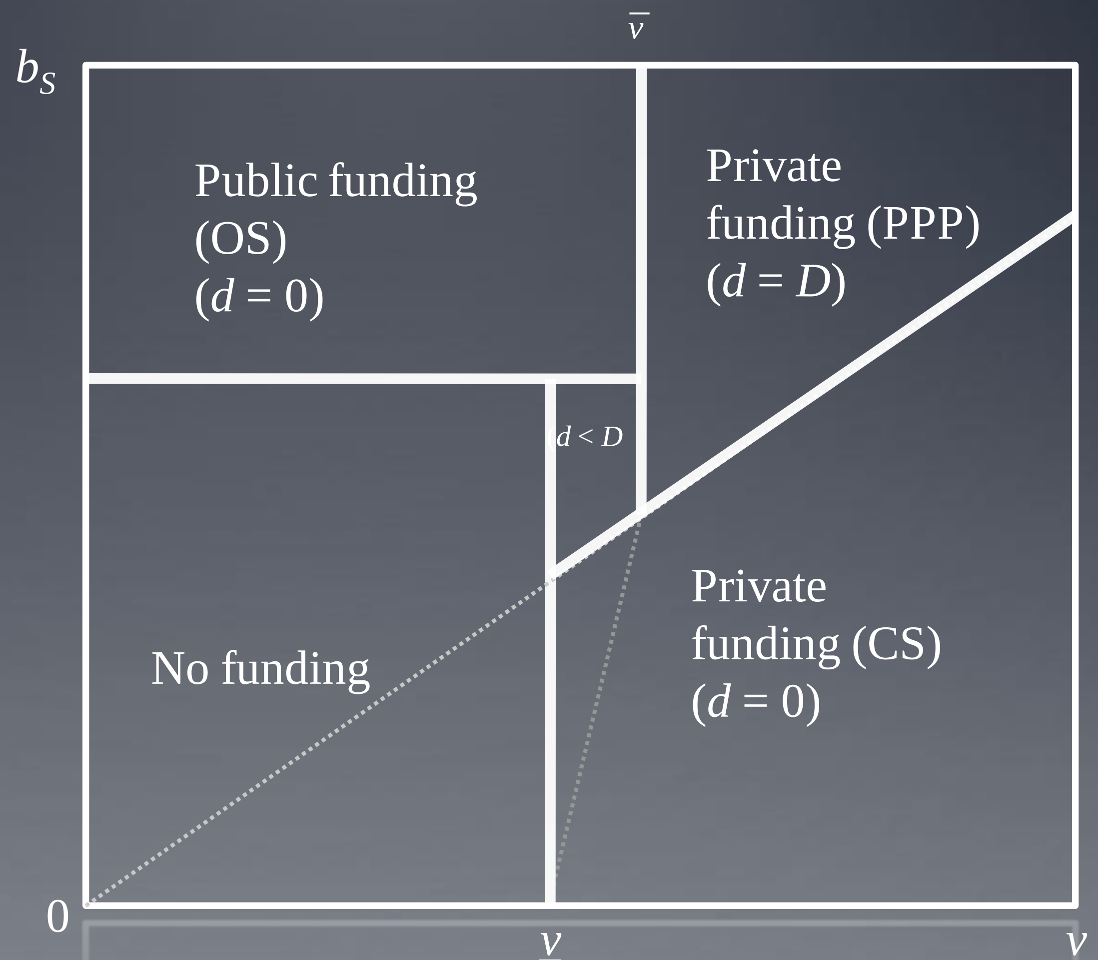


Pre-Bayh-Dole (low *K*)

Restricted public funding:
(i) no commercial returns to scientist; and
(ii) full disclosure

Select on basis of scientific merit (b_S)

Relatively low *K*

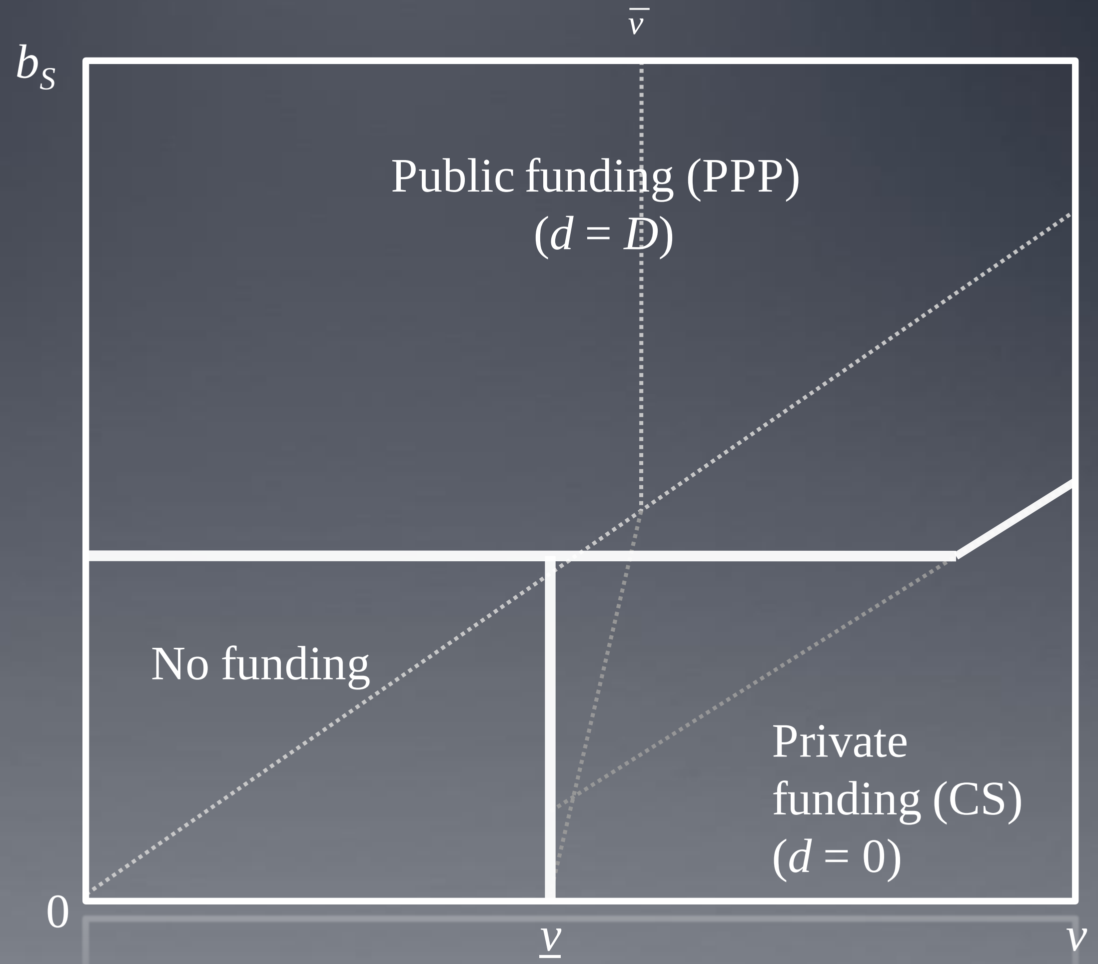


Post-Bayh-Dole (high K)

Unrestricted public funding:
(i) allow commercial returns to scientist; and
(ii) full disclosure

Select on basis of scientific merit (b_S)

Relatively high K

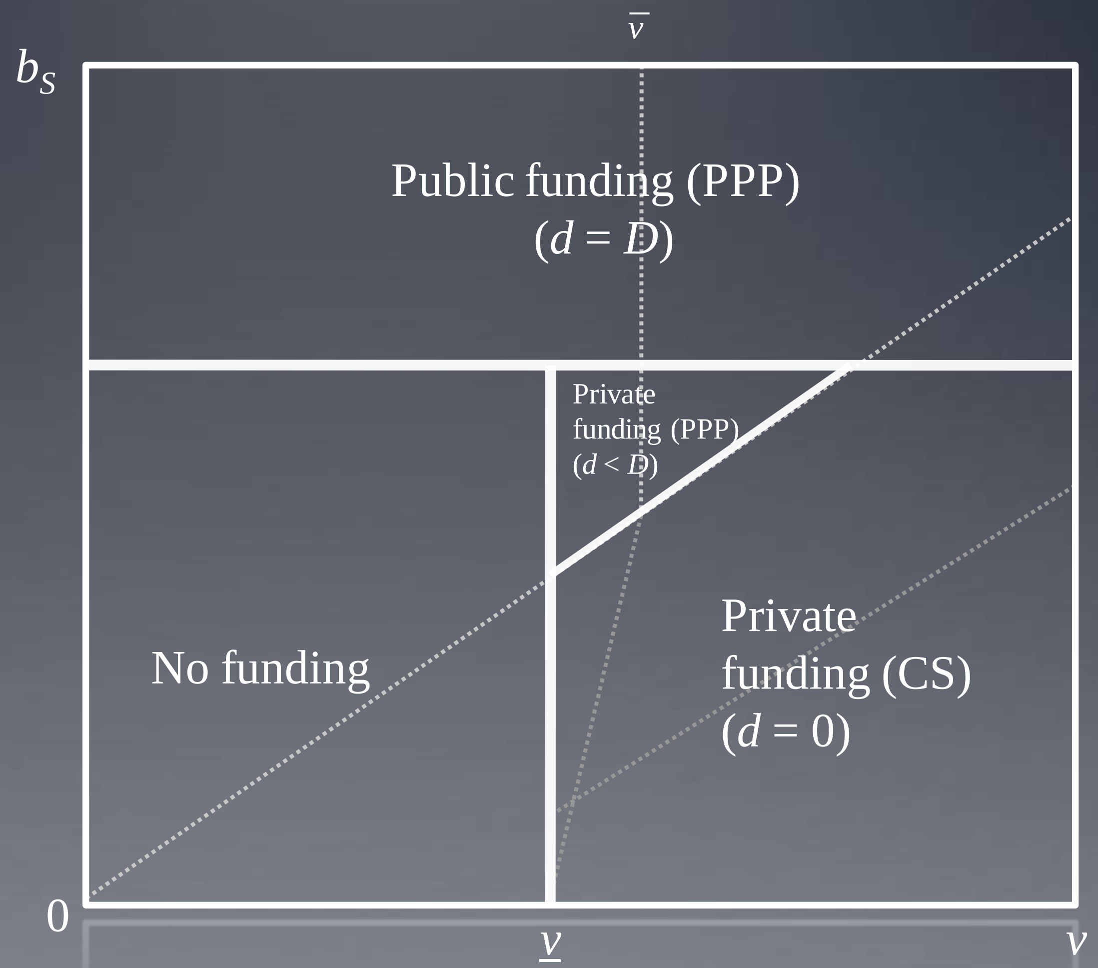


Post-Bayh-Dole (low *K*)

Unrestricted public funding:
(i) allow commercial returns to scientist; and
(ii) full disclosure

Select on basis of scientific merit (b_S)

Relatively low *K*



Conclusions

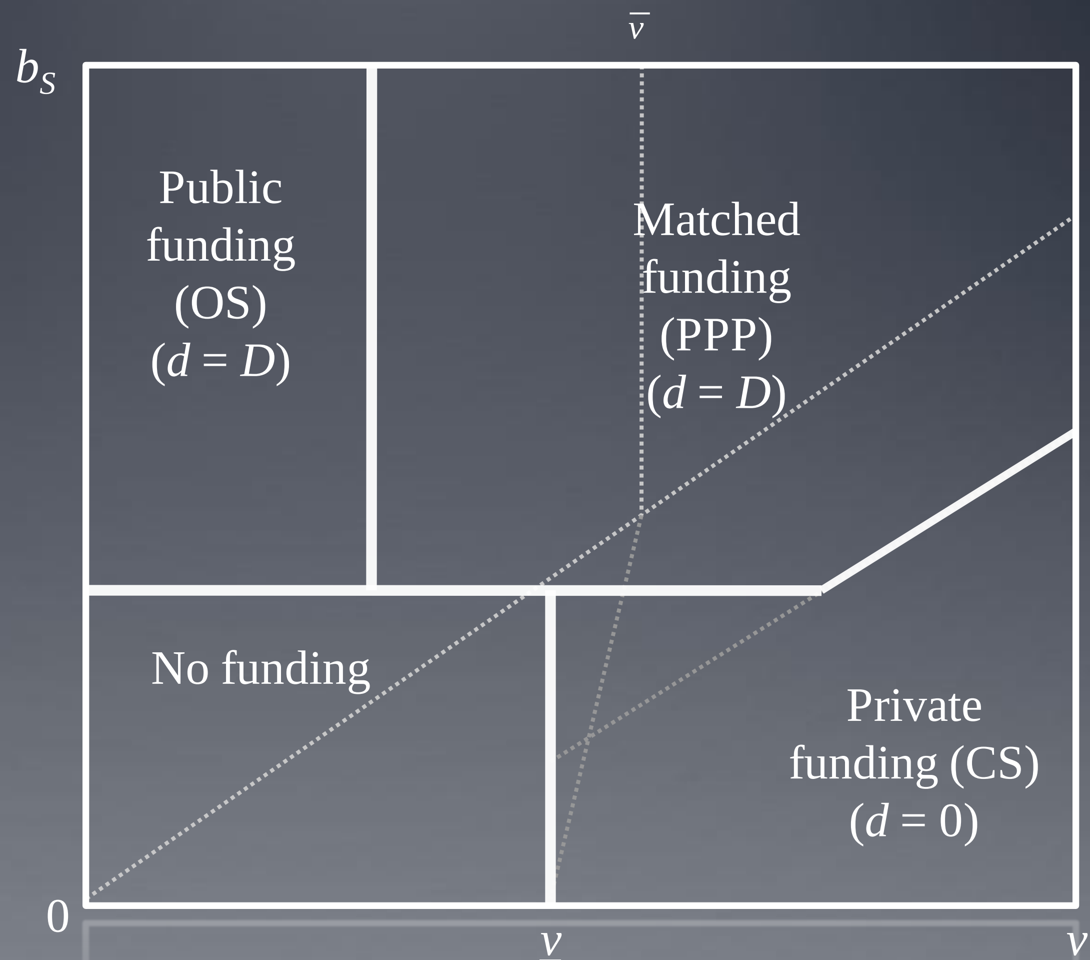
- Restrictions on public funding
  - Limit crowding out
  - Increase disclosure choices of some high *v* projects (but only when there is high public funds available)
  - Therefore, removing restrictions will not stimulate more private funding
  - Matching grants would help but not remove these forces
- What if the public funder could not (easily) observe disclosure?
  - Insist on a minimal level of disclosure only
  - Creates a bigger incentive to obtain public funding
  - But less disclosure from that funding

Mixed Options

Suppose funder cares but cannot observe v

Offer a menu of options with full funding for restricted grants and matched funding for unrestricted ones.

Select on basis of scientific merit (b_S)

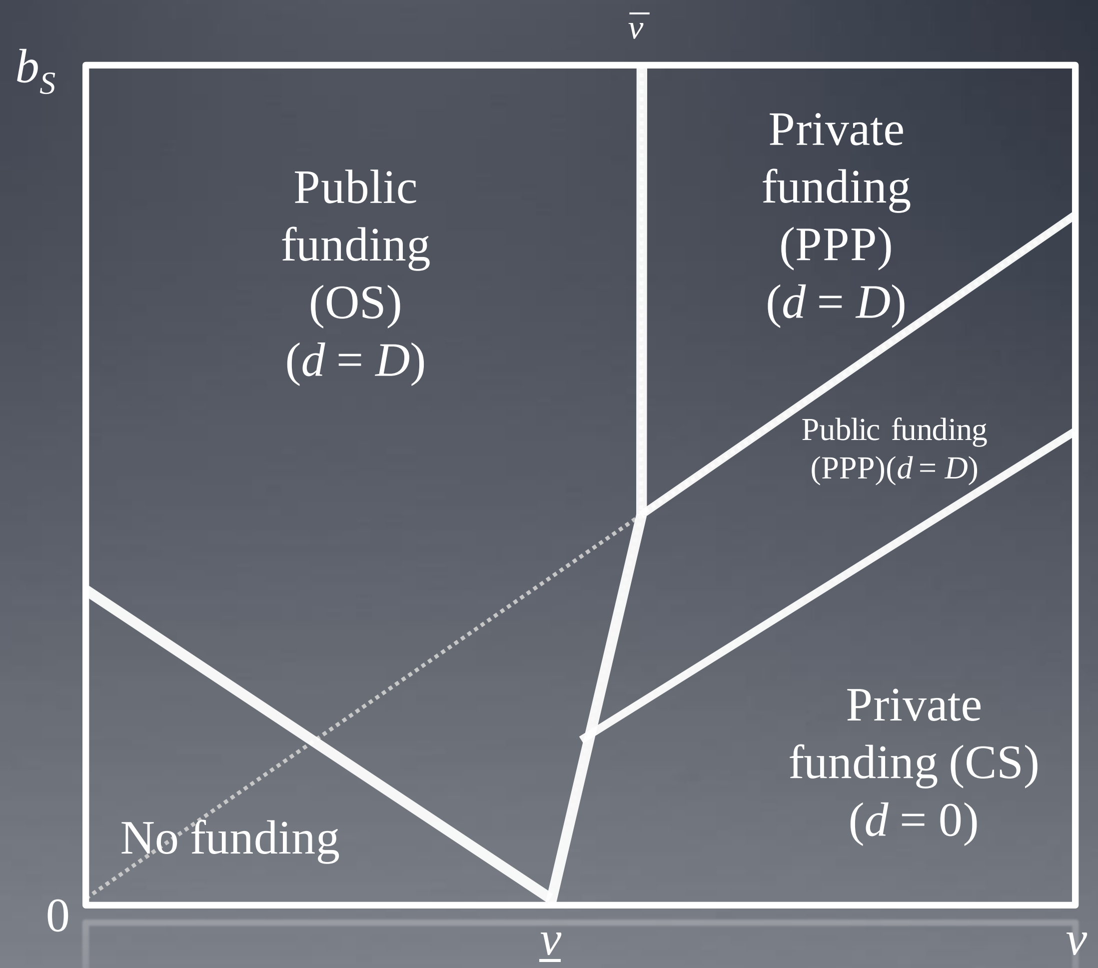


Complete observability

Suppose funder cares but can observe *v*

Select on basis of scientific merit (b_S) and immediate prospects.

Assume: no liquidity constraints on public funder



Competition

How do scientific and commercial competition drive disclosure choices?

Races for Priority

- Another explanation for why commercial firms may want disclosure: increase the speed of research by scientists
- Suppose that scientists – to research more intensively (i.e., in a focused manner) – must sacrifice other academic activities
- When will a firm sponsor several research teams with disclosure rather than incur delay?

Single Research Team

- Two periods: 1 and 2
- Delay reduces total surplus:

$$(1-\delta)\max_d\left\{b_S d + \Pi - (\pi - \lambda + b_E d)(\Pi - \pi)\right\} > \underbrace{z}_{\text{Private value of alt activities if done today}}$$

- Cannot contract on research intensity so to speed up scientist firm must allow a minimum level of disclosure:

$$\underline{d} = \frac{z}{(1-\delta)b_S} < D$$

- Firm will choose disclosure to prevent delay if:

$$\Delta_d \geq \frac{z}{(1-\delta)^2\left(\Pi - (\pi - \lambda)(\Pi - \pi)\right) + \delta z}$$

- It may be that disclosure is negotiated with $\Delta_d < 1$

Competing Teams

- Suppose that there is a *single sponsor* of two competing teams
- If other team is slow, then fast research requires:

$$b_S d \geq z + \delta \tfrac{1}{2} b_S d \Rightarrow d \geq \frac{z}{b_S(1 - \frac{\delta}{2})}$$

- If other team is fast, then fast research requires:

$$\tfrac{1}{2} b_S d \geq z \Rightarrow d \geq \frac{2z}{b_S}$$

- Therefore, choose equilibrium where only one team goes fast. Thus, disclosure will be optimal if:

$$\Delta_d \geq \frac{z}{(1-\delta)(1-\delta/2)\left(\Pi-(\pi-\lambda)(\Pi-\pi)\right)+\frac{1}{2}\delta z}$$

- Less disclosure required than single team case and hence, more likely to commit to disclosure.

Competing Teams

- Suppose there were two independent teams and firms who compete for priority in kudos and for a patent
- Three possible outcomes:
  - No publication (for Δ_d very low)
  - One team commits to publication (for medium Δ_d)
  - Both teams commit to publication (for large Δ_d)
- Thus, more competition implies more disclosure

Future Directions

- Dynamics
  - Publications: only receive kudos if cited
  - Patents: can earn future license fees
  - These decisions can interact
- Competition for status
- Role of scientific elites