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Privatization of knowledge: did the US get it right?

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Ideas or Half-Ideas driven Growth Theory?

- Brilliant ideas, about new products and processes, are key to economic growth and international competitiveness.
- Such ideas often emerge from scientific discoveries which themselves have no immediate commercial value – so rewards may not be aligned to effort.
- To foster innovation and growth, what kinds of discovery should be protected by intellectual property rights and how?

Inventing “Standing on the Shoulders of Giants”

- Several examples of the sequential behavior of research activity come from biotechnology field
- Think about the technique to isolate and grow human embryonic stem cell, patented in 1998 by Wisconsin University, whose exclusive license for experimental use (regarding three cell types) was granted to Geron to develop new organic materials useful for the treatment of important diseases. Could one state that Wisconsin University's scientific achievement was lacking economic value just because further research was required to render it applicable for commercial purpose?

Starting in the early 1980s, the U.S. patent regime experienced major changes …

- Patent policy aims at supplementing market forces, which do not lead on their own to the socially desirable level of innovation
- …over the last 25 years, U.S. Court decisions allowed the patenting of numerous scientific findings lacking in current commercial value

Did the US choose the right path?

- **In a Pre-Eighties Patent Regime** early-stage scientific results were unpatentable and freely disseminated by public research institutions such as the universities.
- **Starting in the early 1980s** early-stage scientific results are patentable
- **Europe:** early-stage scientific results are Not easily patentable (“Industrial Applicability”)
- What is Best to Enhance Innovation?

Schumpeterian Explanation: The Model

- Quality ladder growth model where product improvements occur in consumption goods (Grossman and Helpman, 1991).
- Two-stage product innovation.

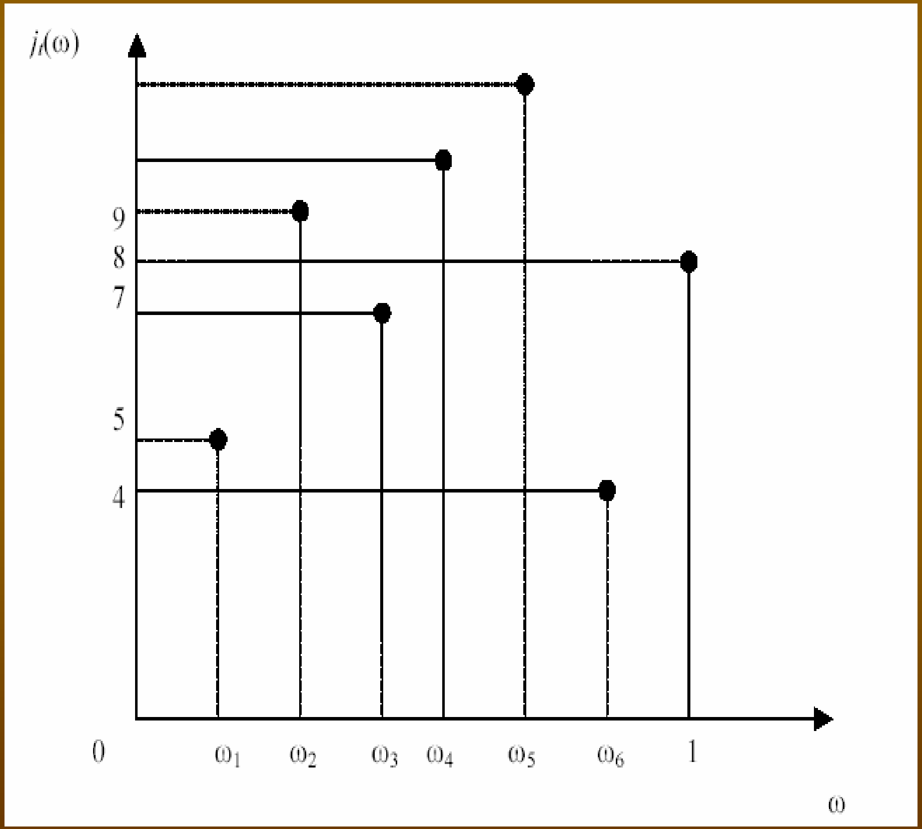
- First stage (BASIC RESEARCH) is defined as research that does not generate immediate commercial objectives, although it presents potential commercial interest:
  - First half-idea.

- Second stage (APPLIED RESEARCH):
  - Tradeable consumption product.

- A first half-idea is new, non-obvious and necessary to get to the product innovation: First half-ideas are *research tools*

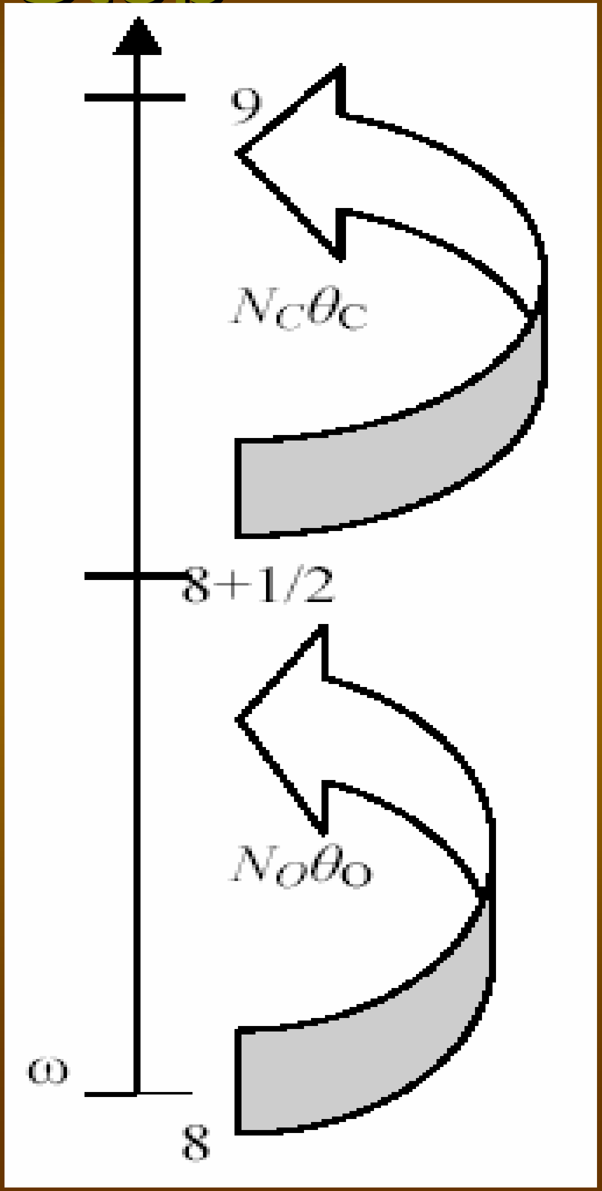
Traditional Quality Ladders Model

- The model economy is made up of differentiated final good sectors and correspodning research and development (R&D) sectors
- Product improvements occur in consumption good sectors
- Let ω denote an industry on the product space (represented by the unit interval)
- When the state-of-the-art quality product in an industry ω is $j_t(\omega)$,skilled R&D workers try to invent the $j_t(\omega)$+1st quality product.



Our Extension: Decomposing an Innovative Step

- In each industry ω, the innovation process involves a two-stage path, so first a firm catches a glimpse of innovation through the $j_t(\omega)+1/2$th half-idea and then other firms engage in a patent race to implement it in the $j_t(\omega)+1$st quality product
- O=OUTSIDER
- C=CHALLENGER
- N_O=mass of outsider labour in basic R&D
- N_C=mass of challenger labour in applied R&D
- θ_O= individual (per worker) probability of inventing in basic R&D
- θ_C represent the individual (per worker) probability of inventing in applied R&D



Final Good Sectors

- In the final good sectors monopolistically competitive top quality patent holders produce differentiated consumption goods
- Monopolies are Created by Patents
- Innovation is the Source of Profits
- Research and Development (R&D) => Patent Races
- Creative Destruction
- Each monopolist earns a flow of profit proportional to the size of its product quality jumps

A General Equilibrium Model

- Heterogeneous labour, skilled and unskilled, is the only factor of production and the whole endowment of labour is constant over time
- Unskilled labor is uniquely employed in the final good sectors
- The representative household maximizes her consumption along all her life-time horizon
- In each final sector, only the good with the lowest quality-adjusted price is consumed, since there is no demand for any other good.
- If two products have the same quality-adjusted price, consumers will buy the higher quality product – although they are formally indifferent between the two products - because the quality leader can always slightly lower the price of its product and drive the rivals out of the market (Bertrand Competition).
- Financial Markets are Perfectly Efficient.
- Perfectly Diversified Portfolios, Equalized Returns to Assets.

R&D Sectors

- Per-unit time Poisson probability intensity to succeed for an outsider and a challenger (normalized) labour unit respectively:

$$\theta_O \equiv \lambda_0 n_O^{-a}$$

$$\theta_C \equiv \lambda_1 n_C^{-a}$$

- Where:
  - λ_0 , λ_1 = R&D laboratory productivity parameters
  - n_O , n_C = employment in each industry
  - constant $a > 0$ = inter-firm intra-sector congestion parameter, capturing the risk of R&D duplications, knowledge theft and other diseconomies of fragmentation in the R&D

R&D Sectors

- Representation of the economy by flows of industries:

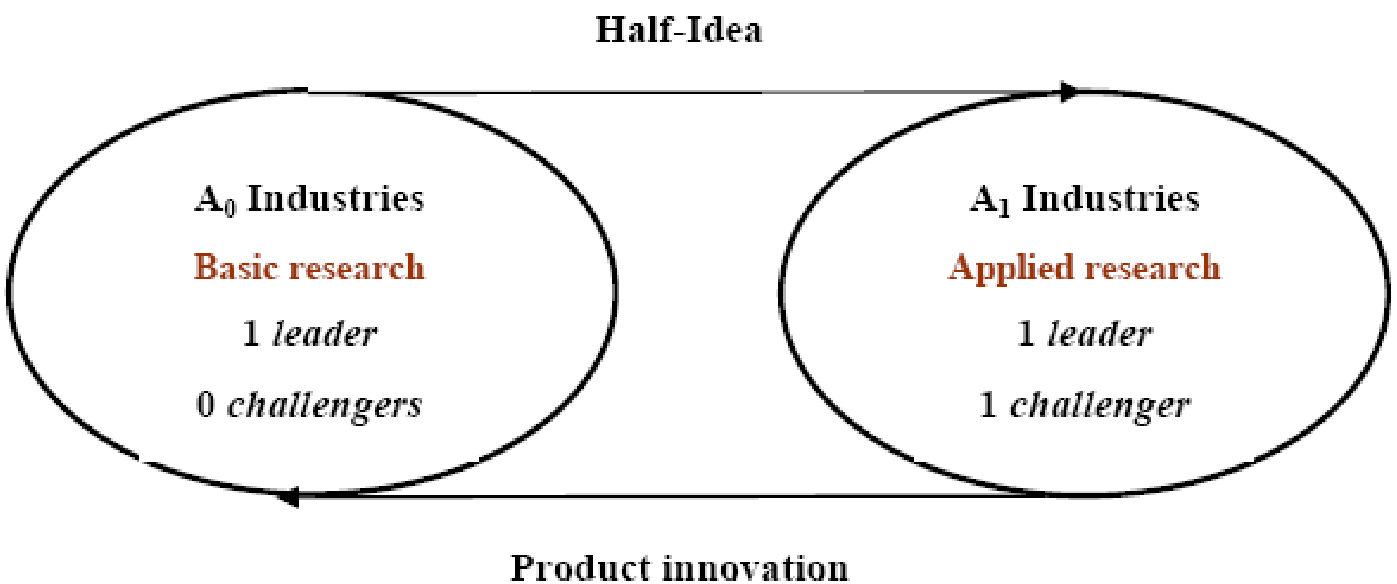


FIGURE 1: REPRESENTATION OF THE ECONOMY BY FLOWS OF INDUSTRIES

Comparing Different Intellectual Property Regimes

- Unpatentable Basic Research (Pre-1980 USA):
  - Unprotected Research Tools - the innovative process would need to resort to non-profit motivated R&D performers to start
  - Inefficient Research Targets - Public universities hire basic R&D scientist and engineers and spread them uniformly over the product space
  - Profit Blind Researchers but Unrestricted Developers
- Patentable Basic Research (Post-1980 USA): Upstream Researchers Share Downstream Rewards:
  - Licensing: Pay to Use Research Tools
  - Reach-Through Royalties: Research Exemption/ Infringement Damages
- Third Way: Kremer's (1998) Mechanism to Encourage Innovations: Upstream Patent Buy-Outs by Governments

Unpatentable Basic Research

- Pre-1980 US patenting regime: Public Universities Freely Disseminate their Scientific Findings
- Free Entry => Patent Race in Downstream Research to become top quality leaders – i.e. monopolist in a final good sector
- Private R&D Firms Vie for Industrial Applications
- Scientists Uninterested in Downstream Profitability : only CV matters in the University
- Inefficiency: After an expected half-idea appears, the public researchers keep carrying out CV-oriented research in that sector, instead of turning their attention towards where a half-idea is needed
- This assumption emphasizes the role of markets to give R&D laboratories incentives to divert their resources from unprofitable sectors

Unpatentable Basic Research

- In Each Sector: Exogenous amount, L_G, of skilled labour in the basic public R&D
- Arbitrage equations :

$$
\begin{aligned}
w_s &= \lambda_1 n_C^{-a} v_L^0 \\
r v_L^0 &= \pi - \bar{L}_G^{1-a} \lambda_0 \left(v_L^0 - v_L^1 \right) + \frac{d v_L^0}{dt} \\
r v_L^1 &= \pi - n_C^{1-a} \lambda_1 v_L^1 + \frac{d v_L^1}{dt}
\end{aligned}
$$

- Free entry/Patent Race into the applied R&D sectors implies that in equilibrium expected R&D profits are dissipated

Unpatentable Basic Research

- Skilled Labour Market Equilibrium:

$$x + \bar{L}_G + (1 - m(A_0))n_C = L$$

- The dynamics of the industries can be described both graphically and analytically:

$$\frac{dm(A_0)}{dt} = (1 - m(A_0))\, n_C^{1-a}\lambda_1 - m(A_0)\bar{L}_G^{1-a}\lambda_0$$

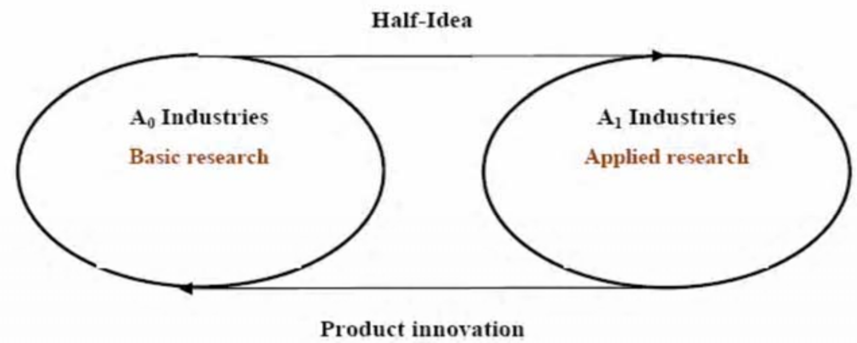


FIGURE 1: REPRESENTATION OF THE ECONOMY BY FLOWS OF INDUSTRIES

Patentable Basic R&D

- Free Entry Into Basic Research => Patentable Upstream Findings
- Restricted Entry into Downstream Research: Profit Motivated Licensing
- The two-lake graphical representation of the economy by flows of industries:

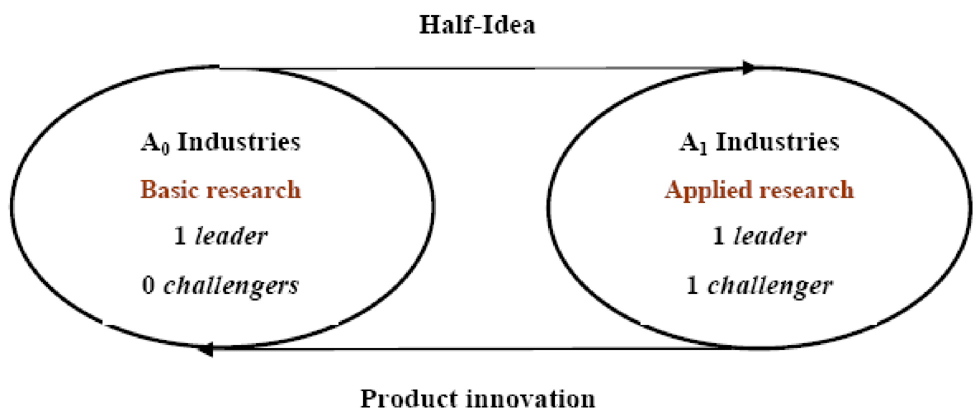


FIGURE 1: REPRESENTATION OF THE ECONOMY BY FLOWS OF INDUSTRIES

is analytically summarized by the following first order ordinary differential equation:

$$\frac{dm(A_0)}{dt} = (1 - m(A_0))\,\lambda_1\,(n_C^*)^{1-a} - m(A_0)\,(n_O)^{1-a}\,\lambda_0$$

Patentable Basic R&D

- **At each instant the following arbitrage equations must hold in equilibrium:**

$$
\begin{aligned}
w_s &= \lambda_0 n_O^{-a} v_C \\
r v_C &= \lambda_1 \left(n_C^*\right)^{1-a} \left(v_L^0 - v_C\right) - w_s n_C^* + \frac{dv_C}{dt} \\
r v_L^0 &= \pi - \left(n_O\right)^{1-a} \lambda_0 \left(v_L^0 - v_L^1\right) + \frac{dv_L^0}{dt} \\
r v_L^1 &= \pi - \left(n_C^*\right)^{1-a} \lambda_1 v_L^1 + \frac{dv_L^1}{dt}
\end{aligned}
$$

- Skilled Labour Market Equilibrium Condition:

$$
x + m(A_0) n_O + \left(1 - m(A_0)\right) n_C^* = L
$$

What System is Best for Growth?

- No Patenting Regime Prevails in General
- When λ_0 is Small and/or λ_1 is Large the Public Basic Research Regime is Better
- When λ_0 is Large and/or λ_1 is Small the Privatized Basic Research Regime is Better
- Monopolistic Patent Holders Harm Innovation More (Less) when Applied R&D is Relatively Easier (Difficult)
- Profit Blind Public Researchers Harm Innovation More (Less) when Basic R&D is Relatively Easier (Difficult)
- Only Empirical Analysis can Assess US Patentability Changes

CALIBRATION : US data

We calibrated our model with U.S. data from 1973 to 1981:

- The values of the skill premium (w_s) are from Krusell et al. (2000 - *Econometrica*)
- The data for the U.S. skilled (completed four years of college or more – number of full-time-equivalent R&D scientists and engineers in R&D-performing companies) (/unskilled) labour employment available at http://www.census.gov/population/socdemo/education/tabA-2.xls
- The data for skilled workers employed in academia (L_G) are from the National Science Board (2006)
- Number of patents granted to U.S. residents - expressed in millions – is from World Intellectual Property Organization (WIPO)

PATENTABLE BASIC RESEARCH:

$$\begin{aligned} w_s &= \lambda_0 n_O^{-a} v_C \\ r v_C &= \left(n_C^*\right)^{1-a} \lambda_1 \left(v_L^0 - v_C\right) - w_s n_C^* \\ r v_L^0 &= \pi - \left(n_O\right)^{1-a} \lambda_0 \left(v_L^0 - v_L^1\right) \\ r v_L^1 &= \pi - \left(n_C^*\right)^{1-a} \lambda_1 v_L^1 \\ \left(1 - m(A_0)\right) \lambda_1 \left(n_C^*\right)^{1-a} &= m(A_0) \left(n_O\right)^{1-a} \lambda_0 \end{aligned}$$

UNPATENTABLE BASIC RESEARCH:

$$\begin{aligned} w_s &= \lambda_1 n_C^{-a} v_L^0 \\ r v_L^0 &= \pi - \bar{L}_G^{1-a} \lambda_0 \left(v_L^0 - v_L^1\right) \\ r v_L^1 &= \pi - n_C^{1-a} \lambda_1 v_L^1 \\ \left(1 - m(A_0)\right) n_C^{1-a} \lambda_1 &= m(A_0) \bar{L}_G^{1-a} \lambda_0 \end{aligned}$$

CALIBRATION : US data

- By solving for the steady state values of the endogenous variables in a way consistent with the data we are able to obtain an estimation of the complexity of basic and applied R&D, as summarized, inversely, by our parameters λ_0 and λ_1

FIGURE 3: Basic research productivity,
Calibrations for the U.S. data from 1973 to 1980.

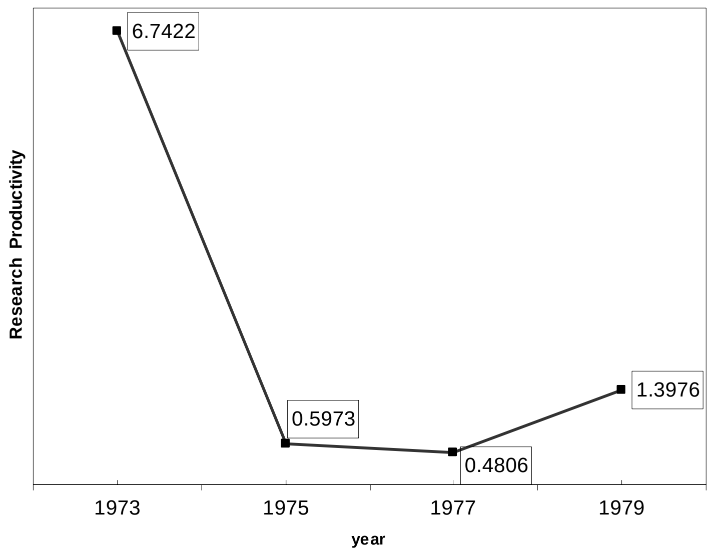
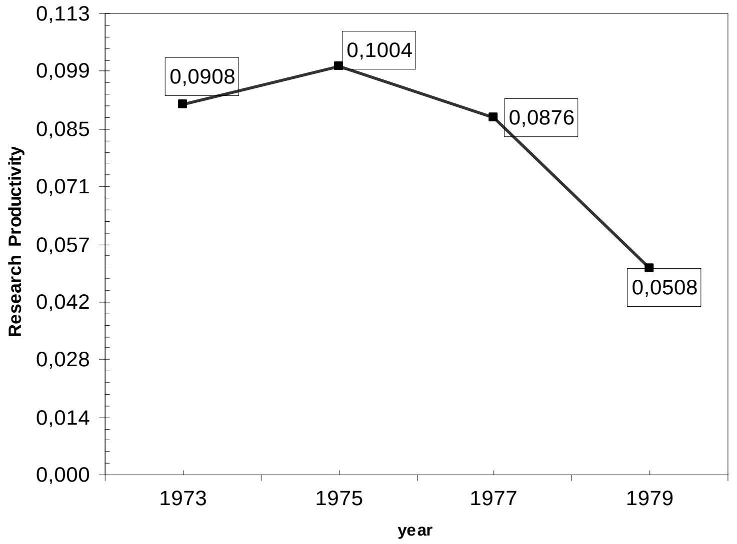


FIGURE 2: Applied research productivity,
Calibrations for the U.S. data from 1973 to 1980.



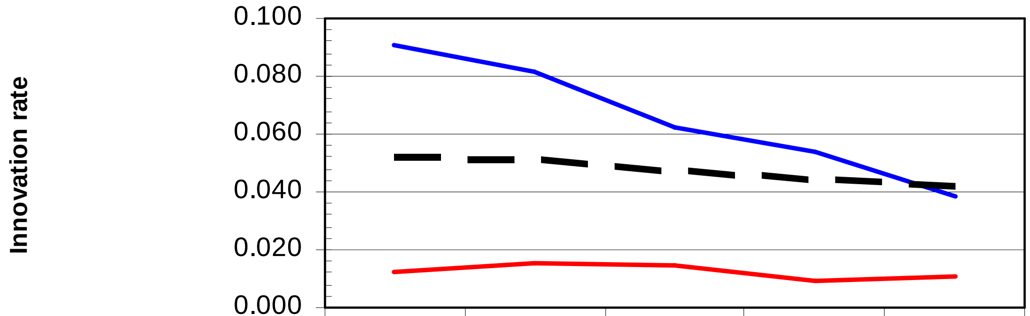
Simulation : US data

- We have used the previously estimated values of the technological parameters λ_0 and λ_1 and of the population composition to compute the hypothetical steady state equilibrium for each (other) year in the alternative scenarios:
  - Patentable research tools ⇒ Privatized
  - Unpatentable research tools ⇒ Public

- To assess the two different regimes, we simulate the two patentability scenarios after constraining the government to choose the same amount of basic R&D as the privatized knowledge economy would in equilibrium

- We compared the equilibrium growth rates of the scenario with patentable research tools with the growth rate that a public system would deliver after controlling for the different endogenous basic R&D labor

Comparative Growth Rates



	1973	1975	1977	1979	1981
PRIVATIZED	0.012015	0.01529	0.01466	0.009068	0.01056
PUBLIC	0.0904	0.0812	0.0621	0.0538	0.0381
AUCTUAL INNOVATION	0.05150	0.05064	0.04660	0.04416	0.04138

year

FIGURE 6: COMPARISON OF THE INNOVATIVE PERFORMANCES, SIMULATION RESULTS.

Danger for Antitrust!

- Incumbent Monopolists could try to Buy Basic Research Patents and Stop Challenging Developments.
- Our Data Suggest: This Use of Blocking Patents could be a Serious Problem.
- Important Role of Anti-Trust Authorities.

Reach-Through Royalties : Research Exemption/Infringement Damages

- *"To be of any economic value, patent rights must be enforced: as has aptly been said, a patent is just a "ticket to sue"".* Denicolò V. (2007, *Economic Policy*)
- We therefore develop a third, unfortunately realistic, scenario:
  - an innovation (a second-half idea) can be patented and yet infringe another patent (the patented research tool).
  - This kind of strategic R&D environment is known as "Research Exemption" (Green and Scotchmer, 1995, *American Economic Review*).
- Research Tool Infringers forced Ex-Post to accept Reach-Through Royalties
- They may even Sign Reach-Through Licensing Agreements Ex Ante

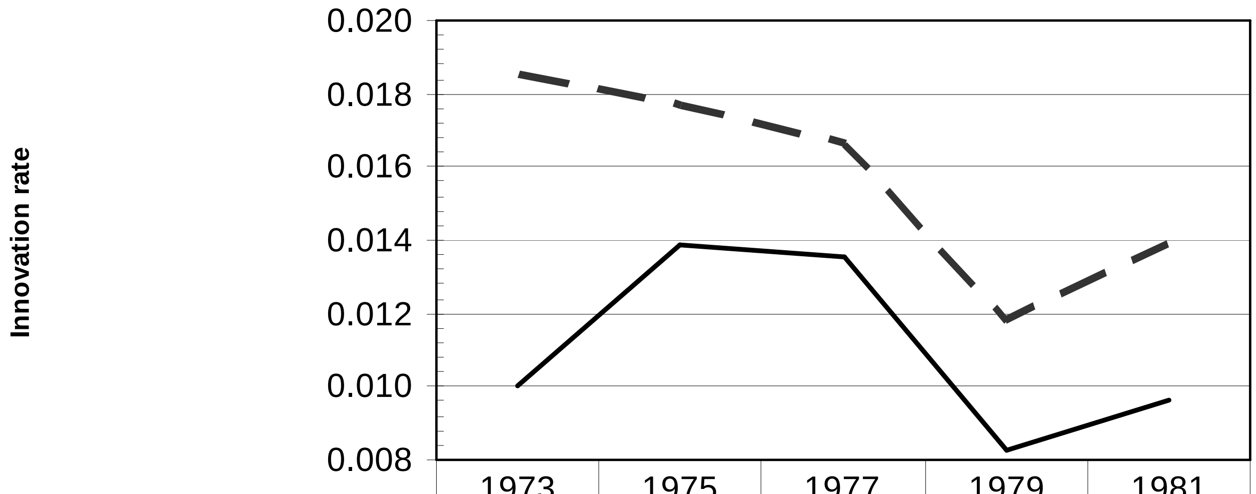
Alternative: Upstream Patent Pre-empts Downstream Patent

- Arbitrage equations:

$$
\begin{aligned}
w_s &= \lambda_0 n_O^{-a} v_B \\
r v_B &= \lambda_1 n_C^{1-a} \left(\beta v_L^0 - v_B\right) \\
w_s &= \lambda_1 n_C^{-a} \left(1 - \beta\right) v_L^0 \\
r v_L^0 &= \pi - n_O^{1-a} \lambda_0 \left(v_L^0 - v_L^1\right) \\
r v_L^1 &= \pi - n_C^{1-a} \lambda_1 v_L^1
\end{aligned}
$$

- Beta = Blocker's Share of Final Rewards

Public Scenario vs. Research Exemption for Use of Patented Knowledge



	1973	1975	1977	1979	1981
Public basic R&D Scenario	0.018499	0.01766	0.016628	0.011765	0.013856
Research exemption scenario	0.01	0.01389	0.01356	0.008238	0.00962

year

FIGURE 6: COMPARISON OF THE INNOVATIVE PERFORMANCES, SIMULATION RESULTS.

Third Way: Kremer's (1998) Auctions

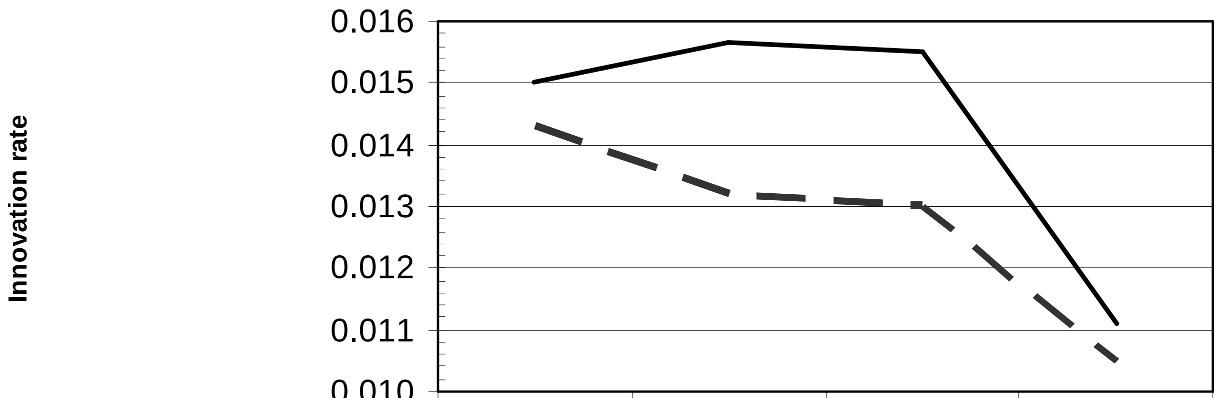
- Kremer (1998, *QJE*) suggested a way to buy out the patent at a price that reflects the innovation full value.
- The value of the invention is likely to be observed by rival firms after the innovation has been made.
- Government appropriates the patent and auctions it to rival firms.
- With small probability (zero in the limit!) Government delivers the patent to the highest bidder in return for the bid price, and otherwise puts the innovation in the publicly domain.

Kremer's (1998) Mechanism

- The Government Buys Out the Patents and Liberalizes the Half Ideas
- Arbitrage equations for Kremer's auctions:

$$
\begin{aligned}
w_s &= \lambda_0 n_O^{-a} v_{CT} \\
r v_{CT} &= \lambda_1 \left(n_{CT}^*\right)^{1-a} \left(v_L^0 - v_{CT}\right) - w_s n_{CT}^* \\
w_s &= \lambda_1 n_C^{-a} v_L^0 \\
r v_L^0 &= \pi - n_O^{1-a} \lambda_0 \left(v_L^0 - v_L^1\right) \\
r v_L^1 &= \pi - n_C^{1-a} \lambda_1 v_L^1
\end{aligned}
$$

Public Scenario vs. Kremer’s Buyout Mechanism



	1973	1975	1977	1979
Public basic R&D Scenario	0.0143	0.0132	0.013	0.0105
Kremer's auctions	0.015	0.015667	0.0155	0.0111

year

FIGURE 5: COMPARISON OF THE INNOVATIVE PERFORMANCES, SIMULATION RESULTS.

CALIBRATION: US data

- Comparing Patentability Regimes:
- Years 1973 through 1981
- Unpatentable Basic Research was More Efficient than any Patentable Basic R&D
- Monopolistic Developers were More Harmful for Growth than Idle Academics

Assessing the Alternatives

- Government Patent Buyouts seems the best Mechanism for Innovation
- Reach-Through Royalties/Research Exemption not Helpful
- Public Upstream Research: Fairly Good

Conclusions

- US Patentability Extension in the Eighties did not seem a Rational Patenting Change at that Time
- Kremer's (1998) Mechanism for Encouraging Innovation would have been the Best
- Need to Assess the Current European Patentability Regime
- Need to Assess the Current US Patentability Regime

Thank you!