

# Network Science and Law: A Sales Pitch and an Application to the “Patent Explosion”

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# OUTLINE

I. NETWORK SCIENCE AND LAW:  
IS THERE A CONNECTION?

II. THE PATENT CITATION  
NETWORK

III. CITATION NETWORK GROWTH

IV. DEGREE DISTRIBUTION

# WHY NETWORK SCIENCE IS RELEVANT TO LAW

- **Networks are everywhere in law**
  - Legal citations, patent citations, social networks, collaborative networks, networks of firms, etc.
- **Legal scholarship is (to some extent) “applied social science”**
  - seeks to understand and predict collective, social results of changes in legal rules, social realities
  - has mostly applied economics
  - generalize from pairwise interactions (>2000 cites to Prisoner’s Dilemma)
  - “mean field” approach (social norms)

# WHY NETWORK SCIENCE IS RELEVANT TO LAW

- **Network science provides analysis and modeling that accounts for heterogeneity, relatedness, local context in social structures and results could have implications for legal policy**
- **Law provides “natural experiments” for network science (how does legal change affect network structure, collective behavior on network?)**
- **Law provides some very extensive datasets**

# PATENT CITATION NETWORK

## WHY STUDY IT?

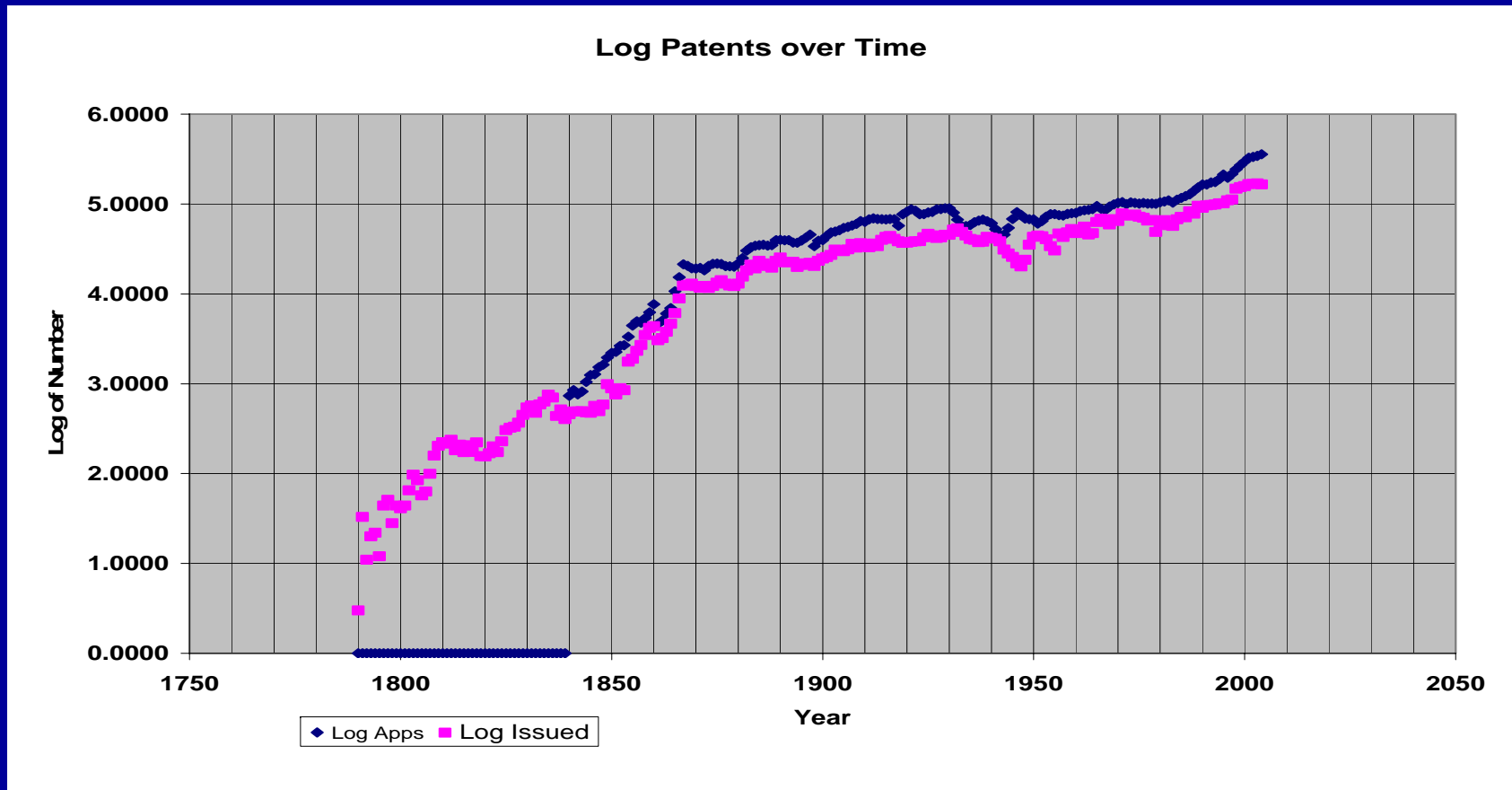
- **Very large network (> 4 million nodes)**
- **Data available electronically (NBER dataset + USPTO)**
- **Complete history available**
- **Comparison to scientific citation networks**
- **Relevance to patent policy**

# POLICY MOTIVATION

- Number of patents and patent applications is increasing exponentially over time, “explosion” since early 1980’s
- Perception that patents are increasingly “trivial”, patent “thicket”
- Various theories about how changes to the patent system have affected patent “quality”
- NAS study, FTC study, Patent Reform Act

**USE NETWORK APPROACH TO STUDY HOW THE PATENT SYSTEM IS CHANGING**

# EXPONENTIAL GROWTH IN PATENTING



# BEHIND THE PATENT "EXPLOSION"

- Increasing pace of technology?
- Increasing breadth of patented technology? (Scientific breakthroughs or legal broadening of patentable subject matter)
- Decreasing patentability standard?

**HAS THERE REALLY BEEN A  
SUBSTANTIVE CHANGE?**

# PATENT CITATION PRIMER

- Patentable inventions are **NEW, USEFUL, and NONOBVIOUS**
- Determined by comparison to **PRIOR ART** (patents, publications, prior uses)
- Citation if “material to patentability”
  - improvement
  - distinguish
- Citations come from
  - applicants (who need not search)
  - examiners (who must search)

# PATENT NETWORK GROWTH

- **Stochastic growth model:**

**Assume  $P[e \text{ cites node } i] = A(k_i(t); I_i(t))/S(t)$**

**$A(k, I)$  “attractiveness”**

**$k$  - number of previous citations (in-degree)**

**$I$  - age in patent numbers**

**$S(t)$  normalization factor =  $\sum A(k(t), I(t))$**

**$t$  - time in patent numbers**

- **Extract  $A(k, I)$ ,  $S(t)$  numerically from the data using a self-consistent iterative method**
- **Assume  $A(k, I)$  time-independent for now**

# PATENT NETWORK GROWTH

- **Extract  $A(k,l)$ ,  $S(t)$  numerically from the data using an iterative method**
- **Method is general for any network for which history is known**
- **Can extract  $A(\bullet, \bullet, \bullet, \dots)$  for variables of interest, e.g., degree, age, recent degree**
  - **simulate network evolution**
  - **compare to assess validity of model (ONGOING WORK)**

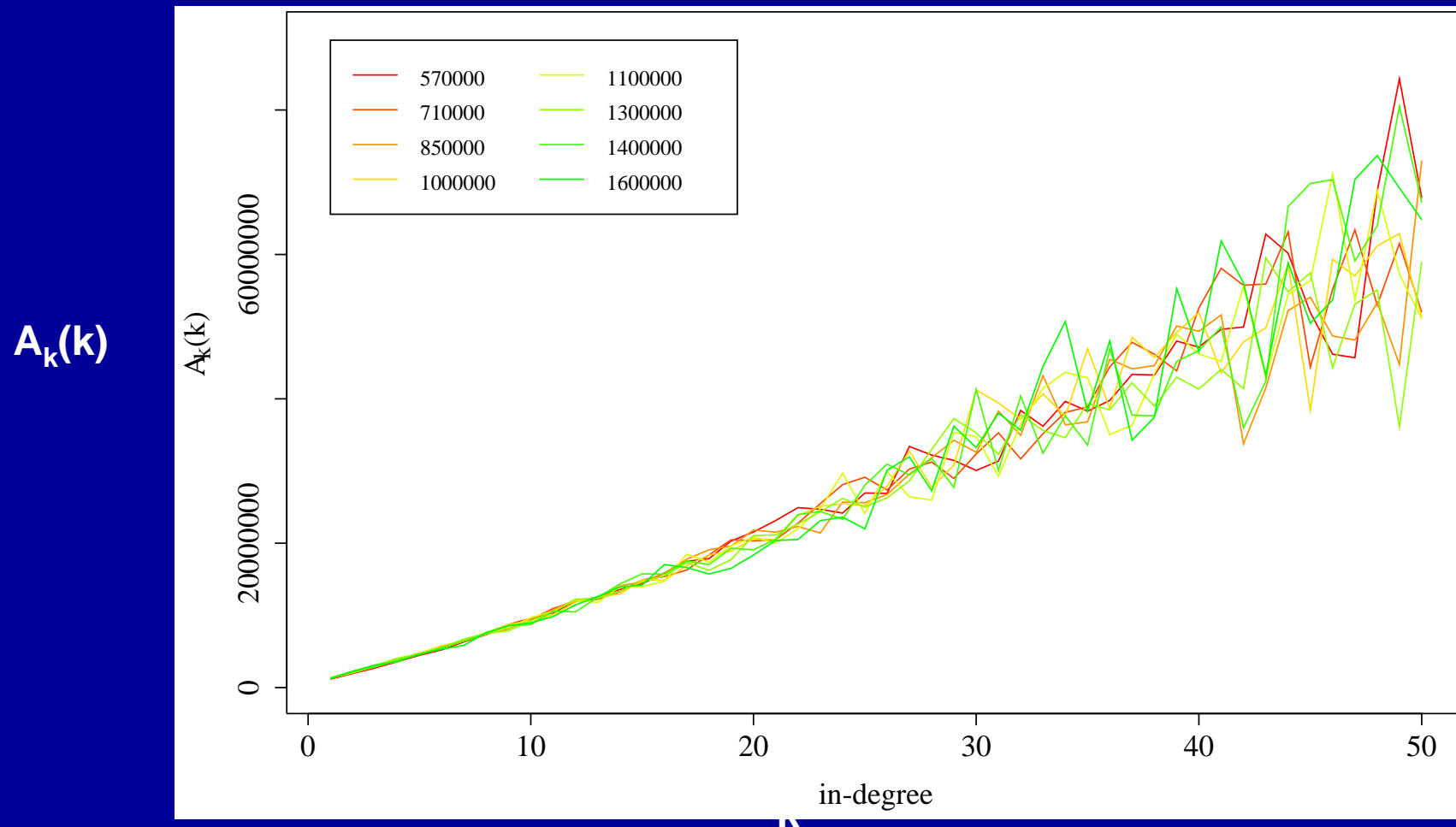
# PATENT NETWORK GROWTH

- We don't assume a particular form for  $A(k,l)$  or  $S(t)$ , we extract them from the data
- We only account for US patents, so we may systematically underestimate technological relationships
- We don't assume a particular meaning for citations (no assumption of knowledge flow)
- Time in patent numbers takes out any simple dependence on pace of technology

## SOME RESULTS

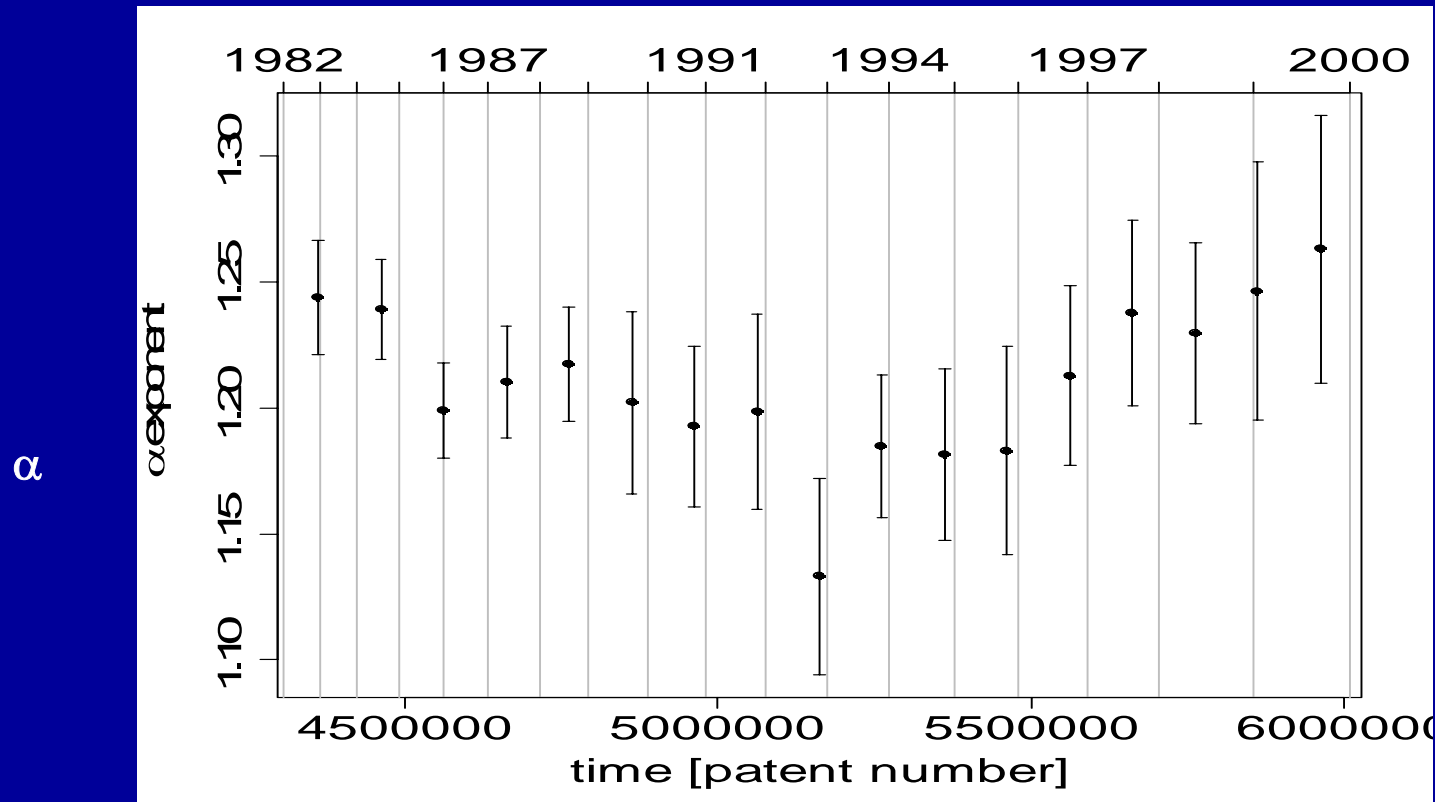
- Old patents less likely to be cited (aging)
- Patents already cited more likely to be cited (preferential attachment)
- $A(k,l) = (\text{approx.}) A_k(k)A_l(l)$   
- approximately separable for all  $k$  and  $l$

# PREFERENTIAL ATTACHMENT



$$A_k \sim k^\alpha, \alpha = 1.201 \pm 0.006$$

# RELAX ASSUMPTION OF TIME- INDEPENDENT $A(k,l)$



- Allow  $\alpha$  to vary with time and look at a sliding time window of 500,000 patents
  - $\alpha$  decreasing or flat until ~1993 and increased since  
**INCREASING STRATIFICATION,  
NOT JUST MORE PATENTING**

# INTERPRETATION OF INCREASING STRATIFICATION

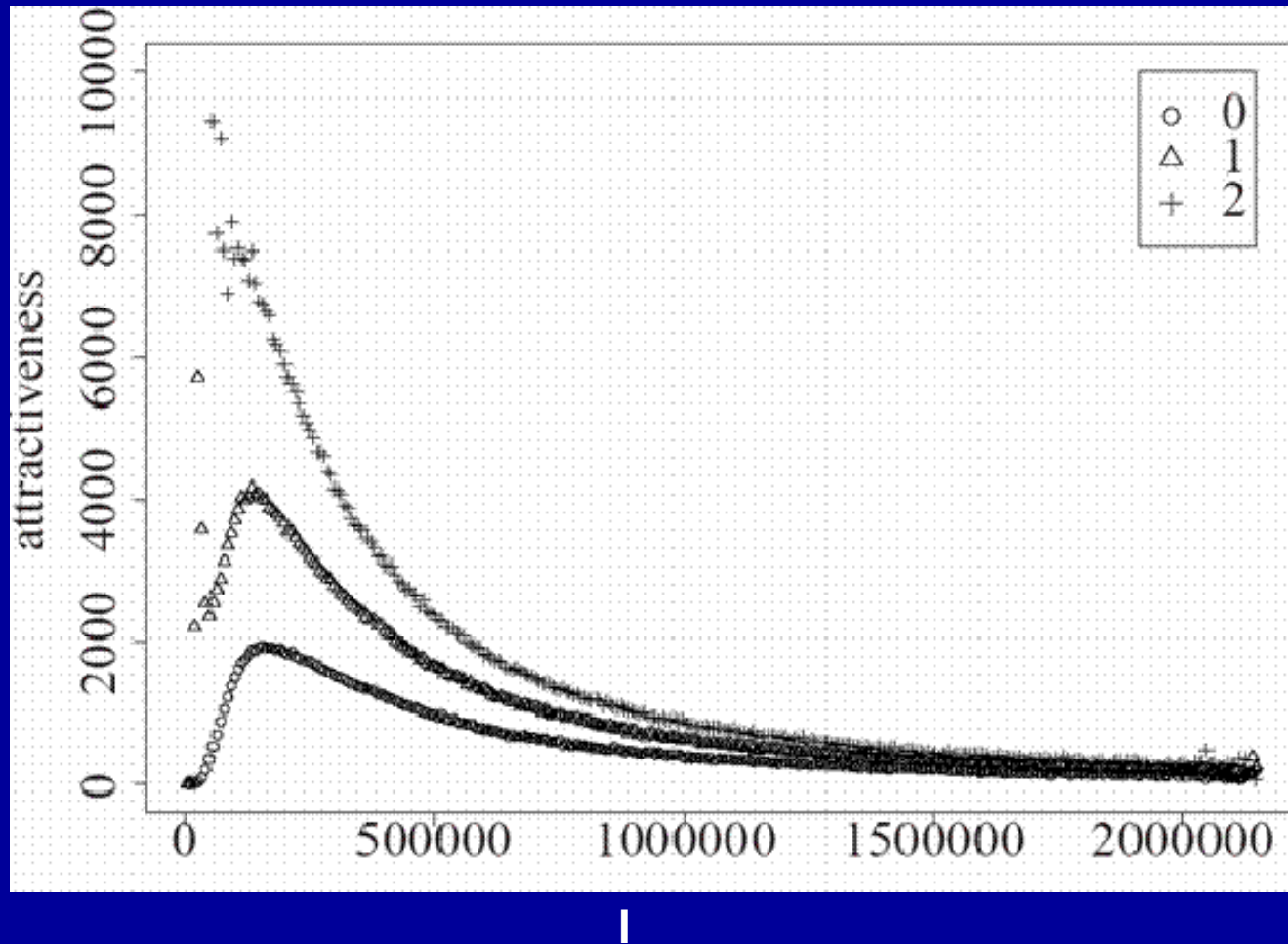
- Most “citable” patents are increasingly “more citable” than “least citable” patents. Why?

## MAY RELATE TO LEGAL CHANGES

- Lowering patentability standard?
  - consistent with anecdotal evidence
  - possibly related to lowered standard for nonobviousness
- Increased patenting of upstream science?

# AGE DEPENDENCE

$A(k,l)$



$k$

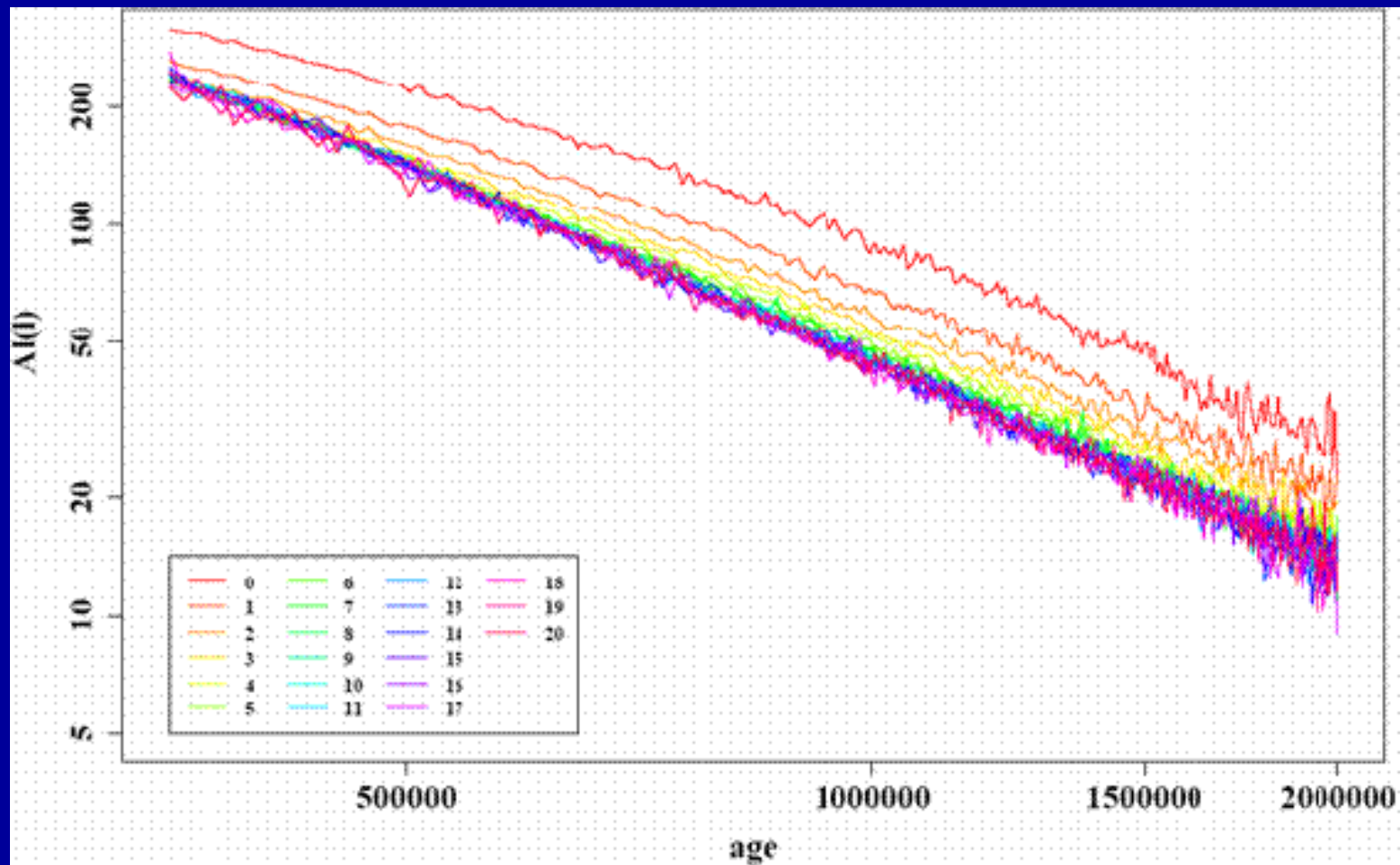
$A(k,l)$  has the same dependence on  $l$   
(age) for all  $k$  (citations)

# AGE DEPENDENCE

- **Two “pieces” to the aging function**
  - **Citation probability peaks about about 200K patents (around 1-2 years or so) for all k, “typical” citations**
  - **BUT there is a significant power law tail of delayed citations**

# AGE DEPENDENCE

$A_1(l)$

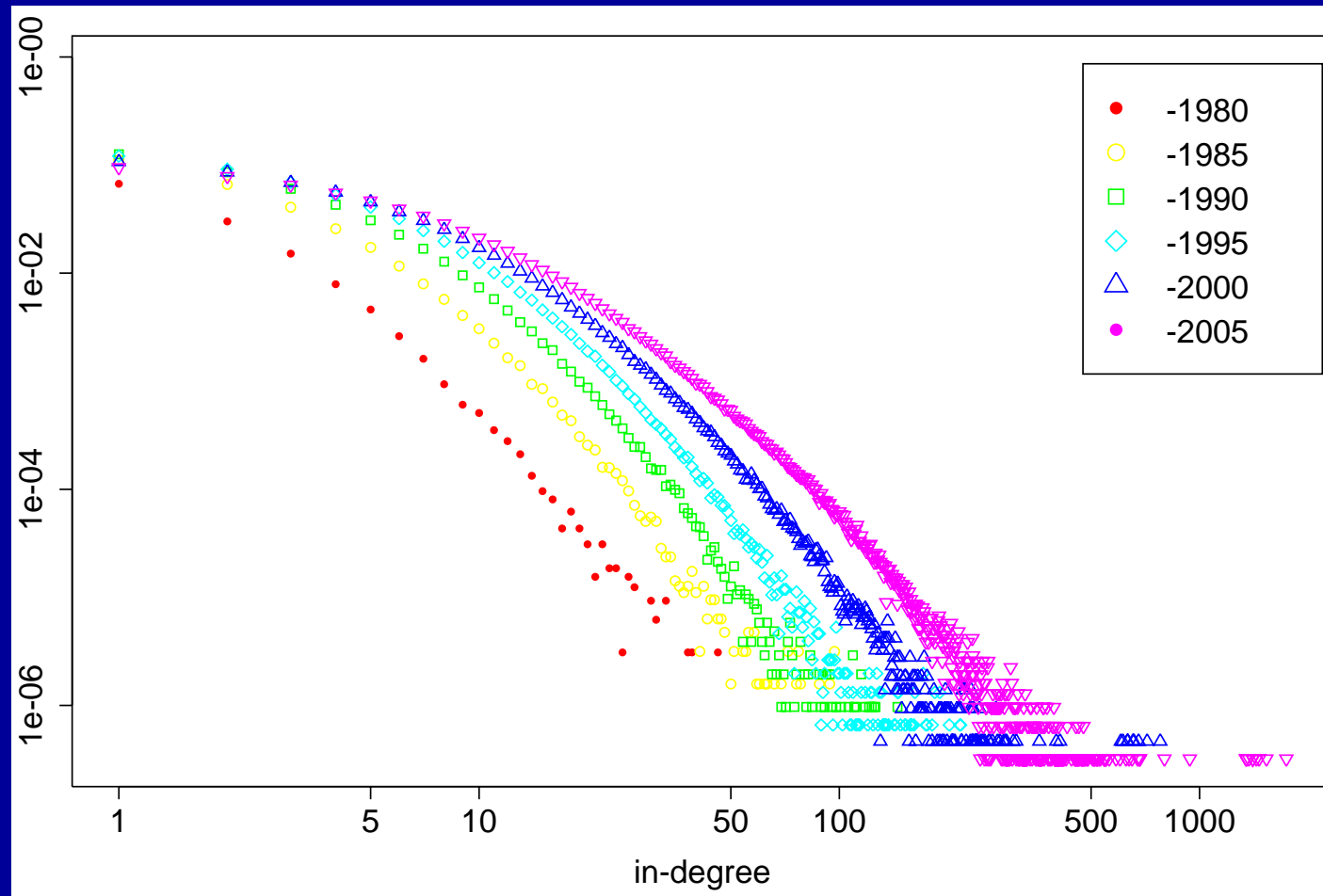


Long tail of delayed citations for all  $k$   
Roughly Universal for  $k > \sim 5$ , exponent  $\sim 1.6$

# AGE DEPENDENCE

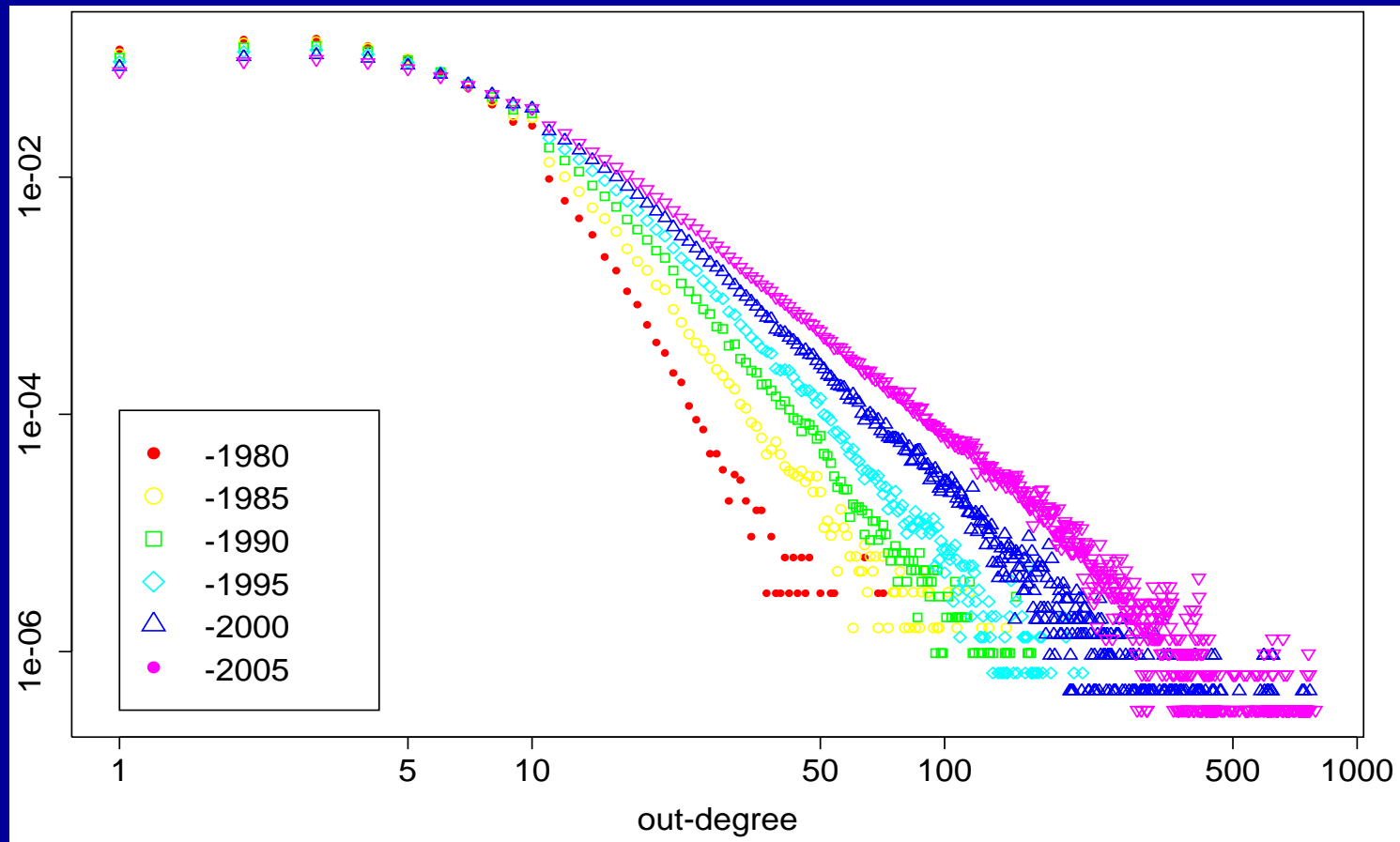
- **Slow decay means that some patents continue to be cited for very long times, “pioneer” patents**
- **Slow decay is there for all values of  $k$**
- **Some “sleeper” patents that have never or rarely been cited will be cited after long periods of time**
- **Suggests unpredictability of technological progress**
- **There is no natural “cutoff” for patent influence**

# IN-DEGREE DISTRIBUTION



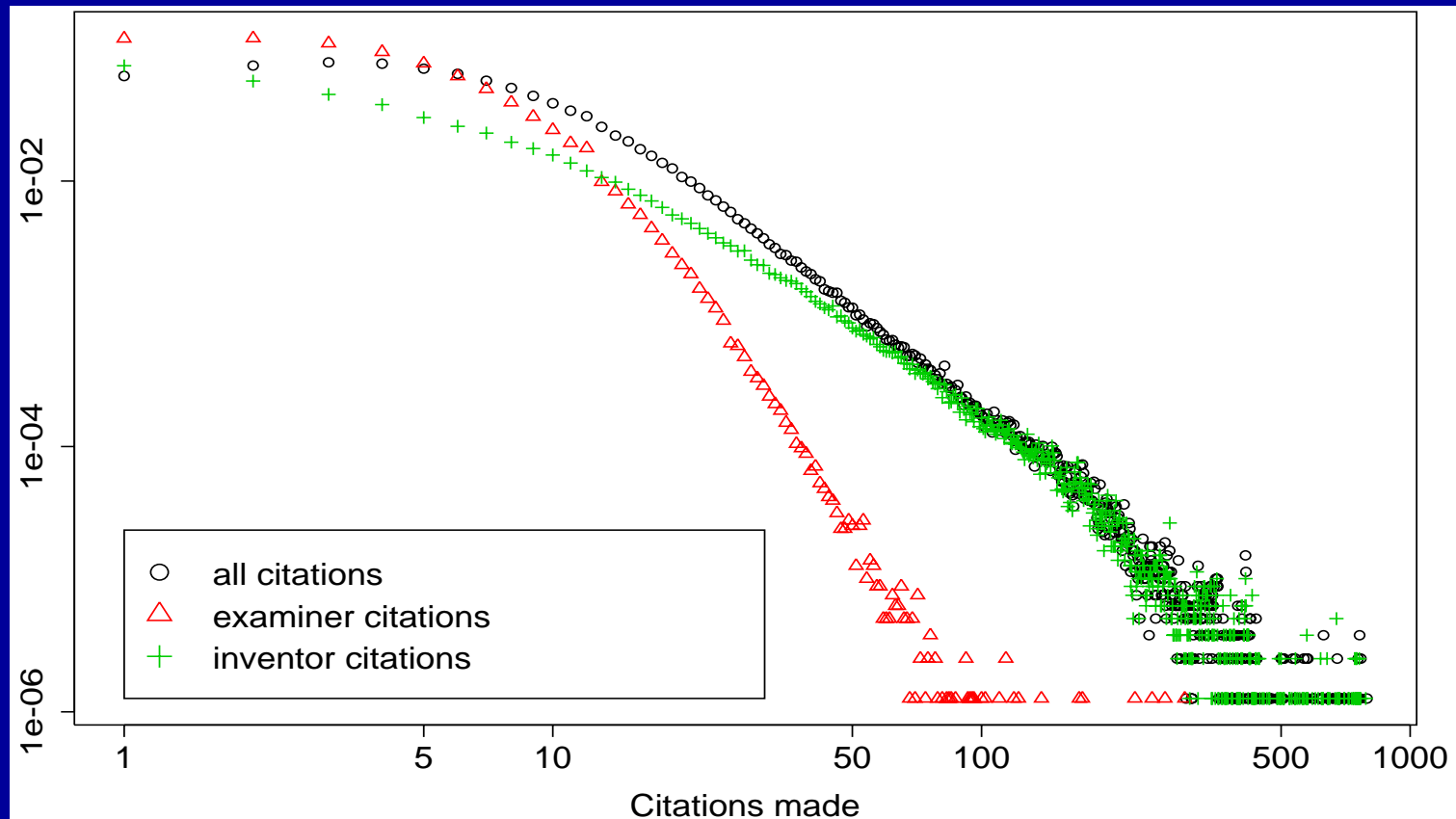
- Approximately log-normal distribution
- Evolves from more power-law-like
- Aging effects

# OUT-DEGREE DISTRIBUTION



- Power law tail (better than citations received)
- Mechanism? (not preferential attachment)
- Very different from scientific citations (exponential?)

# Patent Examiner v. Inventor Citations



- Tail dominated by inventor citations
- Very different from scientific citations
- Mechanism? Related to patentee valuation of inventions?

# References

**Physics version:**

**Modeling Innovation by a Kinetic Description of the Patent Citation System, [www.arxiv.org/physics/0508132](http://www.arxiv.org/physics/0508132)**

**Estimating the Dynamics of Kernel-Based Evolving Methods, [www.arxiv.org/cond-mat/0605497](http://www.arxiv.org/cond-mat/0605497)**

**Law version:**

**Network Science and Law: A Sales Pitch and an Application to the Patent Explosion  
<http://ssrn.com/abstract=887663>**