Patents and Cumulative Innovation: Causal Evidence from the Courts

Alberto Galasso
University of Toronto/NBER

Mark Schankerman
London School of Economics/CEPR

OECD Conference (Tokyo)
November 2014

Motivation

- Innovation is the engine of growth. Much of this is driven by R&D. Extensive evidence of underinvestment in R&D (Bloom, Schankerman & van Reenen, 2013). Implies some form of R&D support is warranted.

- Patents are a key policy tool to promote innovation. Classic trade-off between static product market distortions (price > marginal cost) and dynamic innovation incentives is well-understood

- But dominant feature of modern innovation is cumulative research (e.g., bio-medical, ICT, software). Modern macro models of (endogenous) growth turn on cumulative innovation.

KEY RESEARCH AND PUBLIC POLICY QUESTION:

How do patents on existing technology affect cumulative innovation? Is this a problem, and if so, in which technology fields and for what types of innovators?

Literature

- **Wide diversity of theories:** patents can have positive, negative or no effect on later innovation (Kitch, 1977; Green & Scotchmer, 1995; Heller & Eisenberg, 1998). Assumption on information and bargaining frictions are crucial.

- Causal evidence shows **negative impact in biomedicine**:
  - Williams (2013): Celera gene IP ↘ publications & products based on human genome by 30%
  - Murray et al (2008): more lenient restrictions on Oncomouse patent license ↗ citations by 20%
  - Murray and Stern (2007): 20% decline in citations after a patent granted for patent-paper pairs

BUT: In most technology areas the relationship between patents and later innovation remains unexplored. And the industrial organization of blockage is unknown (who blocks whom?)

Empirical Implementation

- Exploit *patent invalidation cases* to study effect of patents on later innovation

- U.S. patent law: expiration or invalidation of patent does not affect its prior art status and thus requirement to cite

- Measure cumulative innovation by patent citations received. Only available measure for large scale studies. We show results are robust using non-patent measures for two important sectors: drugs and medical instruments

- Large dataset, multiple technology fields but…

Empirical Challenge: endogeneity of patent invalidation!

Our identification strategy is…

- Court of Appeals for the Federal Circuit (Federal Circuit), established in 1982, consists of 12 active judges. Exclusive jurisdiction for appeals in cases involving patents (no forum shopping).

- Federal Circuit judges are assigned to patent cases through **a computer program that randomly generates 3-judge panels,** subject to availability and requirement that each judge deals with a representative cross-section of the fields of law within the jurisdiction of the court

- We exploit this *random allocation of patents to Federal Circuit judges* in validity cases and construct an index capturing propensity of the three judge panel to vote in favour of patent invalidity as an IV

Analytical Framework

We develop a framework that provides micro-foundation of payoffs. The model involves one upstream innovator and two potential downstream innovators who compete. Two main elements:

(1) ex-post bargaining problem: discourages downstream innovation when patents are present (bargaining failure associated with asymmetric information over the value of follow-on innovation)

(2) coordination problem among downstream potential innovators: discourages innovation when patents are absent

Trade-off is between greater bargaining failure with upstream patents versus coordination failure without upstream patents.

Model

There is a base technology and follow-on patentable innovation, uncertain value.

A1 (Asymmetric Info) Value only known by two downstream innovators

A2 (Coordination) Innovation costs make entry by one firm profitable, but unprofitable for two firms.

Focus on mixed strategy equilibrium: We derive probability of downstream investment with and without upstream patent.

Result: A patent facilitates downstream innovation when the value is "well known" – either low or high. This is when bargaining breakdown with a patent is low, and where the mixed strategy equilibrium (downstream competition) generates a high probability of no innovation. Otherwise, patents make downstream innovation less likely.

Model (2)

***KEY IMPLICATION*:** The effect of patents on later innovation is ambiguous, depends critically on characteristics of the technology and the bargaining environment. Empirically, we would expect heterogeneous effects within and across technology fields and different market structures.

Data

Federal Circuit decisions data from LexisNexis Quicklaw. We manually coded every case involving issues of patent validity from 1982-2008.

- **Case information:** docket number, date of Federal Circuit decision, invalidation (yes/no), names of the 3 judges involved and their votes, decision at the lower court level

- **Patent information**: citations, tech class, grant date, names of the parties in the dispute and owner of the patent

- **Final data:** 1357 decisions (1983-2008)

Variables

- **Post-external cites**: citations received in 5 years after Court decision
- **Invalidated**: Dummy=1 if Court invalidates patent (or part of it)

Other Controls:

- **Pre-external/self-cites**: citations received from grant date to decision
- **Number of claims**
- **Tech field dummies**: 6 NBER classes

Econometrics

OLS Regression

$$\log(PostCites+1) = \beta Invalidated + \lambda_1 \log(\text{PreCites}+1) + \lambda_2 \log(\text{PreSelfCites}+1) + \lambda_3 \log Claims + age + \tau + tech + \varepsilon$$

β = effect of invalidation on citations received

Robust standard errors (also cluster at the patent and docket level)

Endogeneity

Issue: Unobserved heterogeneity of patents affects both citations to patents and the likelihood that judges invalidate the patent

Likely Downward Bias:

Shock in the value of underlying technology may increase citations to a patent and induce patentee to invest heavily in legal protection to avoid invalidation (challenger's incentives are weaker due to free riding)

Judge	*Active Service*	*Validity Decisions 1982-2008*	*Percentage of Decisions in which the Judge voted for Invalidation*
Randall Ray Rader	1990-	242	39.6
Daniel Mortimer Friedman	1982–1989	112	21.2
Pauline Newman	1984-	309	26.9
Glenn Leroy Archer, Jr.	1985–1997	170	34.7
Haldane Robert Mayer	1987–2010	269	42.4
S. Jay Plager	1989–2000	153	35.3
Alan David Lourie	1990-	293	46.8
Raymond Charles Clevenger III	1990–2006	232	37.9
Alvin Anthony Schall	1992–2009	248	37.5
William Curtis Bryson	1994-	238	44.1
Arthur J. Gajarsa	1997–2011	164	41.5
Richard Linn	1999–	111	43.2
Timothy B. Dyk	2000-	131	37.4
Sharon Prost	2001-	106	40.6
Kimberly Ann Moore	2006-	21	76.2
Giles Sutherland Rich	1982–1999	152	40.8
Arnold Wilson Cowen	1982-2007	59	33.9
Oscar Hirsh Davis	1982–1988	70	50.1
Philip Nichols, Jr.	1982-1990	38	26.3
Byron George Skelton	1982–2004	56	33.9
Phillip Benjamin Baldwin	1982-1991	54	25.9
Howard Thomas Markey	1982–1991	138	49.3
Marion Tinsley Bennett	1982–2000	57	57.9
Shiro Kashiwa	1982-1986	34	38.2
Jack Richard Miller	1982-1994	35	42.9
Edward Samuel Smith	1982-2001	91	36.3
Paul Redmond Michel	1988–2010	245	41.6
Helen Wilson Nies	1982–1996	89	38.2
Jean Galloway Bissell	1984–1990	41	24.4

IV Strategy

Judges Invalidity Propensity score:

$$JIP = f^1 f^2 f^3 + f^1 f^2 (1 - f^3) + f^1 (1 - f^2) f^3 + (1 - f^1) f^2 f^3$$

f = % invalidity votes for judge j in decisions ***not involving focal patent***

JIP is expected probability of invalidation by the panel. Can be micro-founded with a strategic voting model with thresholds of validation differing across judges.

Impact of Invalidation on Future Citations		
	1	3
Estimation Method	OLS	2SLS
Dependent Variable	log(PostCites+1)	log(PostCites+1)
Invalidated	**-0.053**	**0.410****
	(0.048)	**(0.196)**
Year effects	YES	YES
Age effects	YES	YES
Technology effects	YES	YES
Instrument		predicted probability from Probit
IV Validity Test		F=94.85
Observations	1357	1357

All regressions control for log(Claims) log(PreCites) and log(Pre-SelfCites)

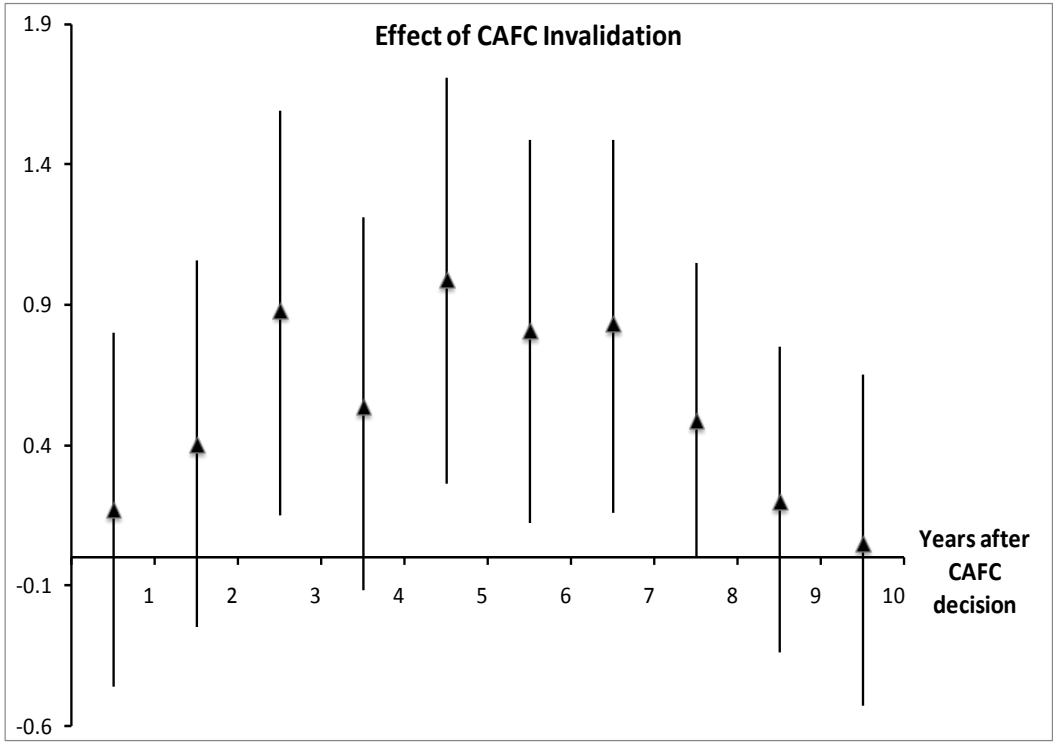
Discussion

Patents, on average, have negative impact on subsequent innovation

Patents invalidated because they are assigned to panels with high JIP experience about a **50% increase in citations**

Lots of robustness checks in the paper (and appendices).

Timing of Invalidity Effect



1982-2003 decisions so ≥ 7 year window (robust to samples)

No effect in first 2 years, suggestive of entry not just publicity

Explaining the Heterogeneity

Economics of innovation literature identifies two features of bargaining environment that affect impact of patents on cumulative innovation. To capture these, we define:

Conc4: share of patenting of four largest assignees in technology sub-category in 5 years before decision

Hypothesis: less negotiation breakdown with higher concentration

Complexity: =1 if electronics, computers, medical instruments

Hypothesis: users require multiple patents, greater risk of breakdown

Sample	Conc4 above Median	Conc4 below Median	Complex Technologies	Non Complex Technologies
Estimation	2SLS	2SLS	2SLS	2SLS
Dependent Variable	log(PostCites)	log(PostCites)	log(PostCites)	log(PostCites)
Invalidated (Instrumented)	**0.086**	**0.985*** **	**0.739** **	**0.317***
	(0.331)	**(0.288)**	**(0.322)**	**(0.183)**
Observations	687	670	437	920

Technology	Effect of Invalidation
Chemical	-0.028
	(0.242)
Mechanical	0.173
	(0.230)
Drugs	0.229
	(0.230)
Computers and Communications	1.024***
	(0.285)
Electrical and Electronics	1.107***
	(0.285)
Medical Inst / Biotech	1.435***
	(0.313)

Similar effects in split samples

Evidence of negative impact of patents on cumulative innovation **only in specific technology fields**

Medical Instruments/Biotech has strongest effect (as in earlier studies)

Blocking at Intensive/Extensive Margins

We decompose the impact on total number of citations into:

- **extensive margin** (number of distinct patent assignees citing)
- **intensive margin** (average number of cites per assignee)

Focus here on total effect only.

Distinguish between:

- large patentees: top quartile (>102 patents)
- small: below median (<5)
- medium (5-102)

	Total Effect (Total External Citations Received)		
	1	**2**	**3**
	Citing Patents in Small Portfolios	Citing Patents in Medium Portfolios	Citing Patents in Large Portfolios
Invalidity	0.075	0.19	0.228
	(0.183)	(0.168)	(0.158)
Invalidity X Large Patentee	**1.840****	0.826	0.689
	(0.726)	(0.663)	(0.837)

Non-Patent Measures

1. *MEDICAL INSTRUMENTS*

- We exploit U.S. FDA regulation requiring approval of clinical trials on new medical devices in order to construct a metric of cumulative innovation linking (later) FDA approval requests to medical instrument patents.

- IV estimates confirm earlier result: patent invalidation increases later approval requests for medical instruments linked to the invalidated patent.

2. *DRUGS*

- We exploit FDA regulation of new drugs. For each drug patent, identify active ingredients and for all subsequent clinical trials and use a *count of clinical trials* that refer to the active ingredients in the invalidated patent.

- IV estimates confirm earlier result: no impact of patent rights on later innovation for pharmaceuticals

Three Alternative Interpretations

1. Media Coverage (Publicity)

Increase in citations generated by press coverage around the decision.

- But press coverage unlikely to be higher for patents that have been (randomly) allocated to judges with high propensity to invalidate
- Predicts sudden burst in citations, not the gradual increase we estimated
- Further, we collect news data to construct measure "Media Mentions." Including it has virtually no effect on our invalidation impact.

2. Substitution among Patents

Increase in citation reflects patentees shifting from other patents to less expensive invalidated patent, rather than more cumulative innovation.

- But why only for small firms for invalidated patents held by large firms? And only in complex technology sectors with fragmented patent rights?

- We use Google patent search (text matching) algorithm to identify "related" patents to the invalidated patent and study whether post-decision citations to them decline, as predicted by the "substitution hypothesis."

- We do find evidence of this (significant negative coefficient), but only able to explain at most 20% of overall impact of invalidation.

3. Strategic Citation

Increase in citation reflects small patentees "strategically withholding" cites to valid patents of large firms

- But previous studies show *large firms* more likely to withhold cites, whereas we find the effect of invalidity is driven by small firm citations

- hard to reconcile with lagged effect of invalidity on cites we find

Conclusions

- Exploit random allocation of Federal Circuit judges to estimate causal effect of patent rights on cumulative innovation: *patent invalidation increases future citations on average*

- Effects are heterogeneous: vary across and within technology fields. Blockage only in complex technology sectors with fragmented patent rights. More research needed to explore this.

- On evidence so far, patents held by large firms impede cumulative innovation by smaller firms, but not for other firm pairings. Suggests that incentives and licensing hurdles depend on parties' asymmetries.

- Remedial policies should be targeted to facilitate bargaining – which is the key here – and thereby promote cumulative innovation. "One size fits all" remedies (broad-based scaling back of patent rights) are not likely to be optimal.

BACK UP SLIDES

SAMPLE COMPARISONS 1980-1999	All Granted Patents not litigated	Litigated at Lower Courts and Not Appealed	Litigated at Lower Courts and Fed. Circuit Appealed
Number of patents	1,808,770	7,216	877
Patent Characteristics			
Cites received per claim	**1.0**	**1.9**	**2.3**
Number of claims	**12.5**	**17.1**	**19.0**
Generality	**0.45**	**0.49**	**0.49**
Originality	**0.36**	**0.39**	**0.40**

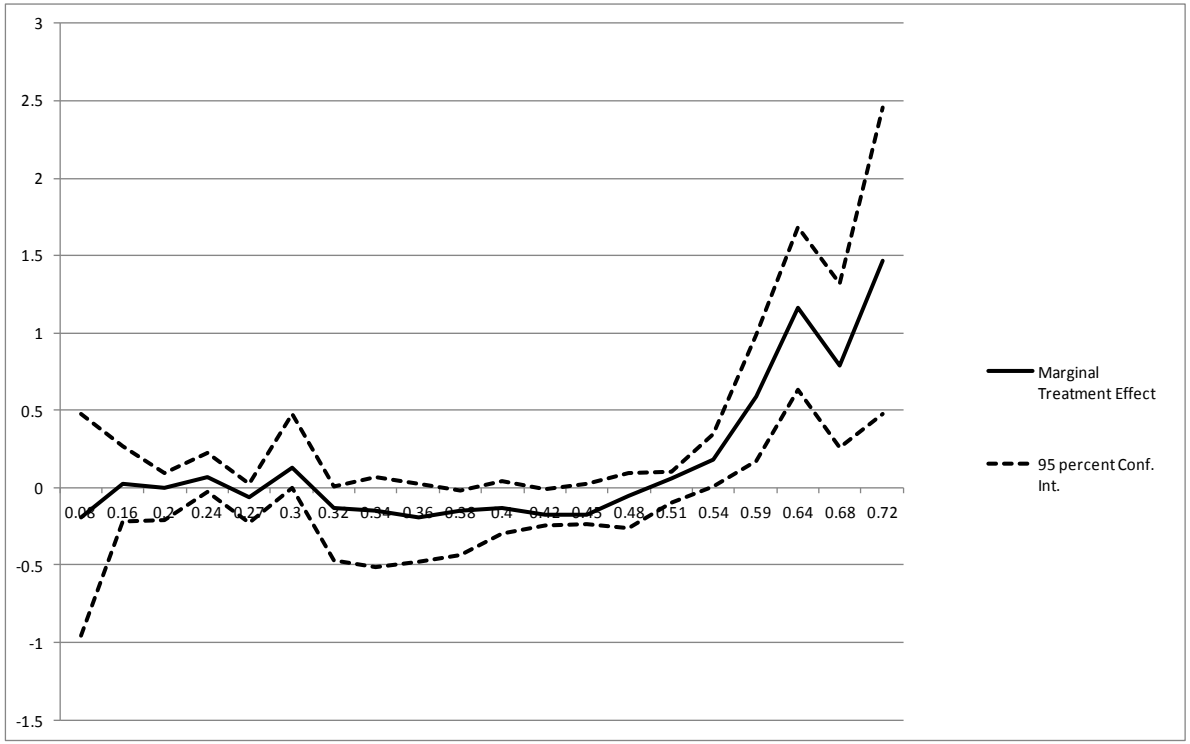
	3	5
Estimation Method	Probit	OLS
Dependent Variable	D_Invalidity	JIP
Judge fixed effects		
Judges Invalidity Propensity (JIP)	**3.131*** **	
	(0.743)	
log(Claims)	0.041	-0.001
	(0.039)	(0.002)
log(PreExCites)	-0.137***	0.001
	(0.040)	(0.002)
log(PreSelfCites	0.002	-0.002
	(0.045)	(0.002)
Year effects	YES***	YES***
Age effects	YES***	YES
Technology effects	YES***	YES
Observations	1357	1357

Heterogeneous Effects

We follow Carneiro, Heckman & Vytlacil (*Ecta*, 2010) to estimate the MTE:

$$\beta_{pt} = \overline{\beta} + \psi_{pt}$$

$$E\left(\overline{\beta} + \psi_{pt} \mid P(X_{pt}, JIP_{pt})\right)$$



- Lot of heterogeneity
- Blockage concentrated among patents with higher estimated probability of being invalidated, based on observables.

Invalidity and Patent Age – 2SLS

	Full Sample	*Age<=20*	*Age<=18*	*Age<=15*	*Age>15*
Invalidated	**0.410****	0.412**	0.457**	0.577**	**0.055**
	(0.196)	(0.203)	(0.216)	(0.239)	**(0.272)**
Obs	1357	1313	1245	1098	259

Effect of invalidity is stronger as we drop older patents from sample.

We find no effect of invalidity on old patents.

	Total Effect (Total External Citations Received)			Extensive Margin (Number of distinct Assignees)			Intensive Margin (External Citations per Assignee)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Citing Patents in Small Portfolios	Citing Patents in Medium Portfolios	Citing Patents in Large Portfolios	Citing Patents in Small Portfolios	Citing Patents in Medium Portfolios	Citing Patents in Large Portfolios	Citing Patents in Small Portfolios	Citing Patents in Medium Portfolios	Citing Patents in Large Portfolios
Invalidity	0.075	0.19	0.228	0.036	0.003	0.123	0.025	0.171	0.088
	(0.183)	(0.168)	(0.158)	(0.155)	(0.105)	(0.104)	(0.053)	(0.105)	(0.079)
Invalidity X Large Patentee	**1.840****	0.826	0.689	**1.347****	0.418	0.041	**0.479***	0.362	0.659
	(0.726)	(0.663)	(0.837)	**(0.556)**	(0.376)	(0.446)	**(0.261)**	(0.393)	(0.535)

Medical Instruments (2)

2SLS regressions: FDA Approvals for Medical Instruments

Dependent Variable	log(Cites)	log(FDA Approvals) Primary Keyword	log(FDA Approvals) All Keywords
	2.447*	1.116*	1.161*
	(1.264)	(0.617)	(0.621)
Observations	121	121	121

Similar results for product codes. Overall, results with FDA data are similar to those obtained with citation data

Drugs (2)

2SLS Regressions - Drug Patents

Dependent Variable Sample	logCites All Drugs	logTrials Matched	logTrials Keyword1	logTrials All Keywords
Invalidity	0.231 (0.449)	0.266 (1.269)	0.364 (1.128)	0.539 (1.200)
Cases	166	94	140	140

No evidence of a statistically significant effect of invalidation. Overall, these findings support the qualitative and quantitative estimates from our regressions with citation data.

Effect of Invalidation on Citations to "Related" Patents

	2SLS	2SLS	2SLS
Dependent Variable	Log(cites) to top related patent	Log(cites) to top 2 related patents	Log(cites) to top 3 related patents
Invalidated	**-0.053** **(0.112)**	**-0.169*** **(0.101)**	**-0.144** **(0.092)**
No. observations	699	1024	1119