The role of research and ownership in generating patent quality: China's experience

GWU 10th Anniversary Conference
Oct. 6, 2017

Gary H. Jefferson
jefferson@brandeis.edu
Jiang Renai
Li Lintong
Sam Zucker

Research objectives

- Profile and evaluate the evolution of the quantity and quality of Chinese patents vs. those of the U.S., Japan, and other OECD countries.
- Analyze the impact of research collaboration and patent ownership on patent quality.
  - ➢ How does the number of inventors affect patent quality?
  - ➢ How does the affiliation of inventors across corporations, universities, and research institutes affect patent quality?
  - ➢ How does the distribution of inventors across countries affect patent quality?
  - ➢ Similarly, how does the assignment of patent ownership affect patent quality – number, affiliation, nationality?

Stefan Wuchty, Benjamin F. Jones, Brian Uzzi, 2007. "The Increasing Dominance of Teams in Production of Knowledge," *Science*

- Use 19.9 million papers over 5 decades and 2.1 million patents to demonstrate that teams increasingly dominate solo authors in the production of knowledge.
- Findings:
  - ➢ Research is increasingly done in teams across nearly all fields. Teams typically produce more frequently cited research than individuals do, and this advantage has been increasing over time.
  - ➢ Teams now also produce the exceptionally high-impact research, even where that distinction was once the domain of solo authors.
- These results suggest that the process of knowledge creation has fundamentally changed.

Patent counts (USPTO)

2015: U.S. = 146,883; non-U.S. = 142,981

Table 1. Number of patents				
Year	**1990**	**2000**	**2010**	**2015**
China	**26**	**95**	**2,355**	**7,450**
U.S.	37,536	80,313	109,152	146,883
Japan	18,898	32,787	47,731	55,110
S. Korea	**163**	**3,285**	**12,519**	**20,305**
Germany	6,520	9,530	12,431	16,220
Other EU	14,028	22,211	30,282	43,896

Table 2. Comparing USPTO and SIPO (2015)					
	USPTO (Granted patents)	SIPO (Patent applications	SIPO (Granted patents)	US patents	Chinese patents
Number of patents	325,980	2,798,500	1,718,192	n.a.	n.a.
top tier patents %	**91.5**	39.4	**20.9**	n.a.	n.a.
international patents %	**49.8% (inventor country) 55.1% (assignee country)**	5.7% (total patent) 12.1% (invention patent)	**7.1% (total patent) 26.7% (invention patent)**	n.a.	n.a.
% with inter-national inventor	n.a.	n.a.	n.a.	**10.4%**	**24.8%**
% with inter-national assignee	n.a.	n.a.	n.a.	**1.0%**	**12.9%**

USPTO Data (Li Lintong)

- U.S. Patent Code (USPC) – 453 technology codes
- Sample period – 1975-2015 (5,726,987 granted patents)
- Measures of patent quality
  - ➢ Backward citations
  - ➢ Claims
  - ➢ Forward citations
- Measures of research/ownership collaboration
  - ➢ Inventors (city, country)
  - ➢ Assignees (institutional affiliations, city, country)

Number of backward citations

Table 3. Average number of backward citations				
	1990	2000	2010	2015
China	5.81	6.83	12.37	14.63
U.S.	8.96	13.04	**41.85**	**56.95**
Japan	5.42	6.51	17.14	21.42
S. Korea	4.74	6.62	16.72	17.88
Germany	5.36	5.57	18.52	24.23
Other EU	5.61	6.16	20.42	24.79

Number of claims/patent breadth

Table 4. Average number of claims				
	1990	2000	2010	2015
China	11.73	9.29	12.22	**12.42**
U.S.	**14.31**	**17.49**	**18.08**	**17.61**
Japan	10.25	13.81	11.70	**11.42**
S. Korea	8.60	12.97	14.52	**13.26**
Germany	11.44	13.22	15.28	**14.56**
Other EU	11.11	13.78	15.59	**14.99**

Number of forward citations

Table 5. Average number of forward citations				
	1990	2000	2010	2015
China	**20.96**	**6.67**	**3.20**	n.a.
U.S.	23.57	27.20	5.74	n.a.
Japan	14.99	14.46	2.59	n.a.
S. Korea	10.73	13.05	3.06	n.a.
Germany	10.65	10.51	2.74	n.a.
Other EU	11.87	12.18	3.13	n.a.

Inputs to patent quality

- R&D spending/R&D personnel
  - % basic research
- IPR
- Inventors?
  - Basic research institutions
  - Home country research collaboration
  - **International research collaboration**
- Assignees?
  - Basic research institutions (universities, RIs)
  - Home country joint ownership
  - **International joint ownership**

Table 7 . Research & ownership (team) collaboration, 1975-05 vs. 2006-15

		# of inventors	# of inventor countries	# of assignee organizations	# of assignee countries
U.S.	1975-2005	**1.977**	1.036	1.004	1.004
	2006-2015	**2.676**	1.094	1.009	1.009
Japan	1975-2005	2.678	1.019	1.005	1.006
	2006-2015	2.613	1.033	1.014	1.012
China	1975-2005	**2.426**	**1.337**	1.074	**1.033**
	2006-2015	**2.945**	**1.333**	1.061	**1.274**
S.Korea	1975-2005	**2.091**	1.040	1.012	1.006
	2006-2015	**3.024**	1.045	1.024	1.009
Germany	1975-2005	**2.433**	**1.097**	1.004	1.006
	2006-2015	**2.908**	**1.236**	1.013	1.021
Other	1975-2005	**1.874**	1.027	1.004	1.001
	2006-2015	**2.268**	1.050	1.010	1.004

Empirical strategy I

- Issue: The aggregate figures convey only averages, not the link between the ways in which patterns of research collaboration and ownership affect the **quality of individual patents**.
- Impact of **inventor collaboration** on patent quality:
  - ➢ $PAT(1,2,3)_{it} = \beta_1 + \beta_2 INV\_NUM_{it} + \beta_3 INTL_{it} + \varepsilon_{1it}$
  - ➢ 1 = backward citations, 2 = claims, 3 = forward citations

Table 8. Role of Inventor Status in Patent Quality

	backward	claims	forward	
Total population, 1975-2015				
INV_NUM	**3.203**	**0.819**	**0.187**	
	(236.78)	**(273.18)**	**(27.29)**	
INT'L	**-3.975**	**-0.487**	**-3.731**	
	(51.85)	**(28.65)**	**(96.13)**	
Constant	11.545	12.497	111.335	
	(297.49)	(1452.98)	(0.196)	
Obs.	5,726,987	5,726,987	5,726,987	
Adj R-sq	0.010	0.013	0.002	
US sample only, 1975-2015				
INV_NUM	**5.559**	**1.125**	**0.515**	**Domestic collaboration of significant benefit**
	(229.35)	**(239.95)**	**(43.68)**	
INT'L	**-2.624**	**-0.149**	**-5.077**	**International collaboration of negative benefit**
	(14.64)	**(4.31)**	**(58.18)**	
Constant	11.677	13.418	13.570	
	(176.62)	(1048.98	(421.65)	
Obs.	3,079,353	3,078,307	3,079,353	
Adj R-sq	0.018	0.02	0.0014	
China sample only, 1975-2015				
INV_NUM	**1.845**	**0.635**	**-0.152**	**For claims and forward citations, domestic collaboration of limited benefit** **Int'l collaboration is of substantial benefit**
	(27.87)	**(34.17)**	**(8.68)**	
INT'L	**6.264**	**2.211**	**1.485**	
	(20.53)	**(25.81)**	**(18.43)**	
Constant	9.092	9.858	2.803	
	(40.32)	(155.75)	(47.05)	
Obs.	60,219	60,219	60,219	

Individual sectors: research and ownership collaboration…

- How consistent and uniform is this finding?
  - ➢ Jaffe – citation data of more use when patents are clustered by technology group…
- Automobiles
- Pharmaceuticals
- Semi-conductors
- Solar

	Automobiles - claims			Pharmaceuticals - claims		
	US	China	Other	US	China	Other
INVNUM	**1.160**	**0.622**	.688	**0.665**	**0.085**	0.041
	(40.30)	**(4.01)**	(42.74)	**(33.25)**	**(0.93)**	(29.94)
INT'L	**-0.634**	**3.303**	**3.576**	**-0.940**	**5.301**	**3.520**
	(2.90)	**(4.95)**	**(70.93)**	**(6.00)**	**(8.45)**	**(52.32)**
Constant	13.277	10.827	10.625	15.211	11.807	12.414
	(188.60)	(22.84)	(211.21)	(196.81)	(22.01)	(175.06)
Obs.	73,313	702	159,704	108,519	1,558	187,429
Adj R-sq.	0.023	0.075	0.039	0.010	0.049	0.018
	Semiconductor - claims			Solar - claims		
	US	China	Other	US	China	Other
INVNUM	**0.117**	**-0.291**	.317	**1.709**	**0.136**	1.077
	(3.77)	**(1.81)**	(16.29)	**(32.88)**	**(0.78)**	(35.60)
INT'L	**0.539**	**4.542**	**3.556**	**0.061**	**4.077**	**3.921**
	(2.62)	**(7.38)**	**(50.59)**	**(0.17)**	**(3.96)**	**(40.24)**
Constant	17.987	14.120	13.906	14.370	14.506	11.793
	(178.13)	(26.88)	(196.76)	(110.54)	(16.62)	(116.33)
Obs.	54,296	1,118	114,429	33,746	348	65,236
Adj R-sq.	0.001	0.045	0.025	0.033	0.040	0.039

Conclusions re: impact of inventor research collaboration on patent quality

- The U.S. and Chinese patents use/respond to inventor research collaboration in different ways.
- Both derive benefit from inventor collaboration.
  - ➢ For the U.S. the benefit is largely from domestic collaboration; benefit from international collaboration is uneven or negligible.
  - ➢ China derives substantial benefit from international collaboration; limited benefit from domestic collaboration.

Assignee ownership

- Impact of **joint assignee ownership** on patent quality:
  - ➢ $PAT(1,2,3)_{I,t} = \beta_1 + \beta_2 INV\_NUM + \beta_3 INTL + \varepsilon_1$
  - ➢ 1 = backward citations, 2 = claims, 3 = forward citations

Table 8. Role of Assignee Status in Patent Quality

Total population, 1975-2015				
	backward	**claims**	forward	
INV_NUM	1.950 (13.32)	0.441 (14.18)	-3.263 (46.36)	
INT'L	-7.816 (75.85)	-1.640 (75.00	-4.484 (90.56)	
Constant	18.275 (120.86)	14.542 (453.2)	14.944 (205.67)	
Obs.	4,936,082	4,935,218	4,936,082	
Adj R-sq	0.001	0.001	0.002	
US sample only, 1975-2015				
INV_NUM	8.028 (19.45)	**2.133** **(28.12)**	-3.211 (16.73)	Domestic joint ownership of significant benefit for claims; not forward
INT'L	-1.976 (2.68)	**-0.412** **(3.04)**	-2.174 (6.35)	International ownership of negative advantage
Constant	17.997 (43.09)	**14.597** **(190.19)**	17.971 (92.56)	
Obs.	2,556,308	**2,555,786**	2,556,308	
Adj R-sq	0.0002	**0.0004**	0.0003	
China sample only, 1975-2015				
INV_NUM	-1.175 (2.55)	**1.213** **(7.67)**	-0.584 (4.37)	Domestic joint ownership of significant benefits for claims; not citations
INT'L	-0.277 (0.54)	**0.401** **(2.27)**	0.497 (3.32)	International ownership of substantial benefit to claims/forward
Constant	14.962 (29.17)	**10.136** **(57.65)**	2.504 (16.85)	
Obs.	34,528	**34,528**	34,528	

With assignee data we can do better

- Does it matter what kind or organization the assignee is or the nature of the joint ownership?
- $PATclaims_{I,t} = \beta_1 + \beta_2 \mathbf{INV\_NUM} + \alpha_1 CORP + \alpha_2 UNIV + \alpha_3 RI + \alpha_4 CORP*UNIV + \alpha_5 CORP*RI + \alpha_6 UNIV*RI + \alpha_7 CORP*UNIV*RI + \beta_3 \mathbf{INTL} + \varepsilon_2$

Table 9. Impact of Ownership Assignment (Assignees) on Patent Quality (claims)

	Overall	U.S. (18)	China (12)	Results
Constant	13.281 (359.02)	13.966 (154.60)	10.398 (32.80)	
ASSG_NUM	-0.297 (8.70)	1.202 (13.95)	0.180 (1.01)	US>>China
Corp	2.131 (122.52)	1.581 (43.19)	0.617 (2.29)	Univ & RI > Corp US > China
Univ	4.721 (105.14)	3.373 (53.30)	1.912 (5.77)	
RI	3.619 (93.89)	2.580 (39.84)	2.147 (6.29)	
Corp*Univ	4.819 (36.95)	3.797 (17.61)	3.984 (11.29)	
Corp*RI	3.258 (21.04)	3.725 (12.15)	4.185 (8.81)	
Univ*RI	5.643 (21.46)	2.803 (7.86)	**-0.562** **(0.49)**	**US**: Corp*Univ*RI>> all others; **China**: Corp*Univ*<< All others
Corp*Univ*RI	8.631 (12.74)	7.183 (7.42)	**-0.220** **(0.10)**	
INTL	-0.821 (36.27)	0.239 (1.74)	1.205 (6.33)	China<<US
Obs.	4,935,218	2,555,786	34,528	
Adj. R-sq	0.006	0.002	0.019	

Conclusions re: impact of joint assignee ownership on patent quality

- Both China and U.S.:
  - ➢ UNIV & RI separately > CORP
  - ➢ Corp*UNIV & Corp*RI > CORP
- For the U.S.:
  - ➢ International ownership of negative advantage
- For China:
  - ➢ International ownership of substantial benefit to claims/forward citations
- CORP*UNIV*RI for US >>> China; UNIV*RI bodes poorly for China.

Assignee ownership/inventor ratio?

- Here are the different possibilities:

  X = # of assignees; Y = # of inventors

- Is there an X/Y effect? Possible hypotheses:
  - ➢ Incentive effect: I'll work at my research job harder if I receive a piece of the action, i.e. ownership… → X/Y should approach 1.
  - ➢ Resource/scale effect: Sole or concentrated ownership motivates or scales greater possibilities for hiring in research capabilities… → X/Y should approach 0.

Table 10. China: Impact of assignee/inventor ratios on patent quality

	Overall	Corporations	Universities	Research institutes	Results
Claims					**China: 15/24 > 0, i.e., seemingly more emphasis on the incentive effect; fewer resource or scale effects.**
1/1	-3.734	-3.899	-2.324	2.210	
1/y, y > 1	-1.207	-4.011	13.91	9.177	
x/y, x&y > 1	-1.731	-1.964	1.247	-5.114	
Forward					
1/1	1.02	0.959	0.625	2.195	
1/y, y > 1	2.558	2.370	1.467	7.543	
x/y, x&y > 1	0.082	0.036	-0.219	1.818	

US: Impact of assignee/inventor ratios on patent quality

Claims					**All but 1 of the claims coefficients have < 0; U.S. the resource effect dominates…21/24 < 0**
1/1	-2.154	-2.093	-1.370	-0.005	
1/y, y > 1	-4.655	-4.548	-4.391	-3.167	
x/y, x&y > 1	-2.039	-2.023	-1.561	0.423	
Forward					
1/1	-0.914	-0.909	-0.027	-0.127	
1/y, y > 1	-4.347	-4.255	-5.803	-4-954	
x/y, x&y > 1	0.255	0.972	-1.880	-3.442	

Conclusions: How China stacks up vs. U.S. and other countries

- Past 15 years establishing an international patenting presence.
- 2015 – only 5% of U.S. - USPTO patent count.
- U.S. and China both show positive returns to inventor collaboration – but different.
  - ➢ U.S.: returns to domestic collaboration > 0; returns to international collaboration << 0.
  - ➢ China: returns to domestic collaboration ~ 0; returns to international collaboration >> 0.
- Argues against excessive reliance on "indigenous innovation," i.e., Chinese purchases of imported technology have fallen significantly over the past 10 years.

The End

Thank you