Labor Mobility of Scientists, Technological Diffusion, and the Firm's Patenting Decision*

Jinyoung Kim
University at Buffalo, State University of New York

Gerald Marschke
University at Albany, State University of New York

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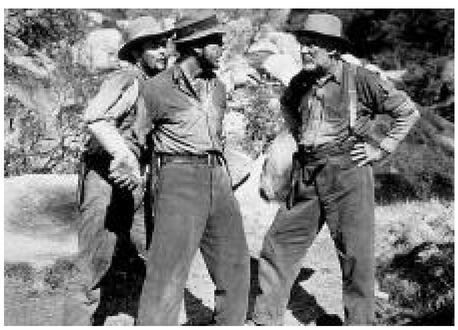
Gold Hat: Oiga, señor. We are *Federales*. You know, the mountid poliss.

Dobbs: If you're the police, where are your badges.

Gold Hat: **Badges? We ain't got no badges! We don't need no badges. I don't have to show you any stinkin' badges!**

Dobbs: You'd better not come any closer.



Oh, I know very well you guys could bump me off any minute you wish, but that's a risk worth running, considering the stakes. Let's lay all our cards on the table. As I see it, you guys have got to do one of three things: kill me, run me off, or take me in with you as a partner. Let's consider the first. Another guy may come along tomorrow or maybe a dozen other guys. You start bumping people off, just how far are you prepared to go with it? Ask yourselves that.

Also, don’t forget, the one actually to do the bumping off would forever be in the power of the other two… As for choice number two, if you run me off, I might very well inform on you. Twenty-five percent of the value of your find is the reward I’d get paid and that would be tempting, mighty tempting. Let’s see what number three has to offer. If you take me in with you as a partner, you don’t stand to lose anything. I will not ask to share in what you’ve made so far, only in the profits to come. Well, what do you say?

--The Treasure of the Sierra Madre (1948)

Questions

- Why do firms patent?
- How does the threat of employee expropriation of intellectual property affect firms’ patenting and R&D decisions?
- Can this threat explain (part of) the increase in patenting we have observed in the last decade?

Main Results

- *Theoretical results*:

An increase in the threat of a scientist leaving causes...

  - Increase in the likelihood that a research project produces a patent
  - Decrease in the firm's out-of-pocket expense of conducting research (Pakes & Nitzan, 1983)
  - Ambiguous effect on patenting, R&D profitability, and R&D expenditures at the firm level

- *Empirical results*:

An increase in the threat of a scientist leaving...

  - Increases patent propensities at the firm level
  - Can account for some of the increase in aggregate U.S. patent-R&D ratio in the 1980s and 1990s
  - Partly explains why small firms have higher patent yields than large firms

Outline

- Literature review
- Model
- Empirical Model
- Data
- Results
- Conclusions

Literature Review

- Contracting with scientists under the misappropriation threat: Pakes and Nitzan (1983)
- Inter-firm mobility of scientists and diffusion of ideas: Arrow (1962), Stephan (1996), Almeida and Kogut (1999), Levin, Klevoric, Nelson, and Winter (1987)
- Geographical localization of knowledge spillovers: Jaffe, Trajtenberg, and Henderson (1993)

Model

- An entrepreneur hires a scientist to develop an idea into a marketable good.
- During development, the scientist learns about the innovation, including its value in other applications.
- After development and before marketing
  - the scientist decides whether to remain with entrepreneur, or to leave for a rival and market a similar good (and perhaps a "spillover" good)
  - the entrepreneur decides whether to patent.

Model (continued)

- Patenting partially protects the entrepreneur in the event the scientist leaves, but is costly.
- The entrepreneur chooses a compensation package and patenting rule to maximize her profit, while attracting the scientist to work for her in the development stage.
- After development, the scientist chooses whether to stay or move to (or set up) a rival to maximize her earnings.

Theoretical Results

The idea: In industries and in periods experiencing especially fertile innovation (spillovers), one will see a higher propensity to patent, more job mobility among scientific personnel, and lower wages in the originating firms.

Theoretical Results

Proposition 1: A rightward shift in the distribution of returns to the technology at a rival

(1) increases the probability that the scientist moves to/sets up a rival

(2) increases the entrepreneur's propensity to patent (even when scientist stays).

Theoretical Results (continued)

Proposition 2: Similar, simultaneous rightward shifts in the distributions of returns for the technology in the original firm and at a rival

(1) increase the probability that the scientist moves to/sets up a rival

(2) increase the entrepreneur's propensity to patent.

Theoretical Results (continued)

Proposition 3&4: Increases in the returns for the technology at a rival (also, equivalent increases in both returns) reduces the R&D costs of developing an innovation

Empirical Model

What is the effect of scientist's mobility on a firm's patenting decision?

Our study combines panel data on firms with industry specific measures of scientist's mobility.

Empirical Model (continued)

$$E(P_{ft} \mid X_{ft}, M_{ft}) = \exp(a_f + X_{ft} b + R_{ft} b^R + M_{ft} z)$$

P_{ft} = number of patents granted to firm *f* in year *t*

X_{ft} = firm characteristics for *f* in year *t*

R_{ft} = log R&D expenditures for *f* in year *t*

M_{ft} = Mobility of scientists in firm *f*'s industry in year *t*

Poisson-based specification (Hausman, Hall, and Griliches, 1984; Hall and Ziedonis, 2001)

Data

l. Mobility variable

- Our measure of departure risk.
- Estimated from scientists and engineers from the Annual Demographic Files (March supplements) of the Current Population Survey.
- M_{ft} = Fraction of scientists currently working who were working for a different employer the previous year, in industry (lnECR) or region (lnGEO) of firm *f*, in year *t*.
- Based on about 2,600 scientists and engineers per year.

2. Panel data

- Created by linking patents from the U.S. Patent and Trademark Office to the Compustat database (which contains all public firms).
- We use years 1975-1992.

Table 2 Sample Statistics

	(1) Full Sample (31503 obs)				(2) R&D Sample (21030 obs)			
Variables	Mean	Std. Dev.	10th percentile	90th percentile	Mean	Std. Dev.	10th percentile	90th percentile
Patents	7.89	40.41	0	10	11.50	48.98	0	20
R&D (million $ 1982-84)	19.08	122.91	0	22.26	28.58	149.53	0.17	41.04
ECR	0.12	0.04	0.07	0.18	0.12	0.04	0.06	0.17
GEO	0.13	0.02	0.10	0.16	0.13	0.02	0.10	0.16
SALES (million $ 1982-84)	863.1	4099.7	6.44	1560.6	1034.6	4705.7	5.72	1984.9
K/L	2006.7	47546.6	0.83	795.0	2645.2	58034.2	0.69	937.9
AGE_ECR	38.32	1.81	35.89	40.47	38.28	1.81	35.88	40.47
AGE_GEO	37.75	0.77	36.97	38.61	37.75	0.78	36.81	38.56
MALE	0.83	0.10	0.69	0.95	0.84	0.10	0.70	0.95
WHITE	0.92	0.04	0.87	0.97	0.92	0.04	0.86	0.97

Notes: (1) R&D sample contains only firms that report positive R&D expenditures
(2) ECR = share of scientists and engineers who changed their employers at least once within the one-year period, by **industry** and year
(3) GEO = share of scientists and engineers who changed their employers at least once within the one-year period, by **location** and year
(4) K/L = Plants and equipments (mil. 1982-84$)/employment (1000s)
(5) AGE_ECR (AGE_GEO) = average age of scientists and engineers by industry and year (by location and year)
(6) MALE (WHITE) = fractions of scientists and engineers who are male (white)

Table 3 Patenting Regressions

Dependent Variable: Patents **Random Effects Poisson Model**

12	(1)		(2)		(3)		(4)		(5)		(6)	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
LnECR	0.0287	5.23	0.0255	4.63	0.0257	4.66						
LnGEO							0.1303	7.03	0.0596	3.11		
LnSALES	0.4128	43.43	0.3971	41.04	0.3962	40.93	0.3469	28.71	0.3649	30.08	0.3917	40.38
LnK/L	-0.0077	-7.16	-0.0034	-2.98	-0.0036	-3.05	0.0334	16.18	0.0381	18.22	-0.0037	-3.16
LnR&D	0.3090	38.53	0.3474	38.15	0.3320	25.43	0.4041	38.15	0.3396	29.53	0.3492	38.29
$(LnR\&D)^2$					0.0022	1.64						
LnAGE	0.9580	17.72	1.0217	8.74	1.0236	18.77	3.2061	17.19	2.2144	11.15	1.0026	18.15
T			-0.0053	-8.92	-0.0057	-8.93			0.0124	14.40	-0.0040	-6.67
ECR											90.0545	6.34
ECR^2											-2377.06	-6.80
ECR^3											30405.25	7.14
Constant	-4.9248	-24.12	-5.1075	24.91	-5.1023	-24.87	-12.818	-19.25	-9.5180	-13.54	-6.4013	-20.97
Observations	21030 (2740 firms)		21030 (2740 firms)		21030 (2740 firms)		14385 (1894 firms)		14385 (1894 firms)		21030 (2740 firms)	
Log Like.	-44599		-44423		-44422		-29286		-29182		-44300	
Wald χ^2	11837.5		12217.0		12234.6		9295.3		9607.2		12474.8	
p value	0.00		0.00		0.00		0.00		0.00		0.00	

Table 4 Patent Regressions: Sensitivity Analyses

Dependent Variable: Patents

	(1)		(2)		(3)		(4)		(5)		(6)	
	GMM		GMM		Poisson w/ year dummies		Poisson w/ industry dummies		Poisson w/ year dummies		Poisson w/ industry dummies	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
LnECR	0.0081	6.34			0.0256	4.36	0.0292	5.31				
LnGEO			0.0471	4.17					0.0157	0.47	0.1264	6.82
LnSALES	0.2810	26.95	0.1746	19.07	0.3420	34.37	0.4324	43.98	0.3198	25.92	0.3662	29.23
LnK/L	0.0025	1.29	0.0407	10.34	0.0334	21.34	-0.0076	-7.13	0.0382	18.29	0.0337	16.32
LnR&D	0.1066	16.82	0.1629	18.39	0.3630	39.47	0.3001	36.86	0.3713	31.92	0.3975	36.91
LnAGE	0.2239	4.21	1.0844	9.71	0.2886	4.90	0.9534	17.62	0.6484	2.45	3.1653	16.96
Observations	19368 (1982 firms)		7747 (904 firms)		21030 (2740 firms)		21030 (2740 firms)		14385 (1894 firms)		14385 (1894 firms)	
Sargan χ^2	495.25		311.02									
d.f.	480		315									
Log Like.					-43394		-44374		-29008		-29223	
Wald χ^2					14562.9		12492.5		10101.1		9522.1	
p value	0.306		0.553		0.00		0.00		0.00		0.00	

Note: The z columns report the ratios of the coefficient to its standard error. The p values given in columns 1 and 2 are for the test of the null hypothesis that the moment conditions hold for all instruments. The p values in columns 3-6 are of the test that the population coefficients are jointly zero. Columns 1 and 2 are the results of the Generalized Method of Moments while the rest of the table is based on random-effects Poisson estimation. The random effects are assumed to follow a gamma distribution. Estimated coefficients for calendar year dummies and industry dummies in columns 3-6 are not reported to save space.

Table 4 Patent Regressions: Sensitivity Analyses (continued)

Dependent Variable: Patents

	(7) Poisson High tech firms		(8) Poisson Non high tech firms		(9) Poisson High tech firms		(10) Poisson Non high tech firms	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
LnECR	0.0154	9.11	0.0032	1.46				
LnGEO					0.1637	6.33	0.0878	3.29
LnSALES	0.4195	29.65	0.3953	29.76	0.4078	22.96	0.2872	16.46
LnK/L	0.0071	4.43	-0.0166	-11.34	0.0283	8.42	0.0356	13.48
LnR&D	0.2985	25.41	0.3108	27.78	0.3563	23.86	0.4390	28.00
LnAGE	1.9293	25.34	0.2368	3.08	5.1963	21.26	0.2688	0.92
Constant	-8.4566	-30.05	-2.3169	-7.93	-20.0725	-23.09	-2.0734	-1.99
Observations	11012 (1490 firms)		10545 (1255 firms)		8072 (1125 firms)		6313 (771 firms)	
Log Like.	-22369		-22951		-15636		-13545	
Wald χ^2	8679.4		4024.5		6320.7		3119.6	
p value	0.00		0.00		0.00		0.00	

Note: The z columns report the ratios of the coefficient to its standard error. The p values are of the test that the population coefficients are jointly zero. The results in all columns are based on random-effects Poisson estimation. The random effects follow a gamma distribution. High tech industries include Computers & computing equipment (industry 8), Electrical machinery (9), Electronic instruments & communication equipment (10), Transportation equipment (11), Optical & medical instruments (13) and Pharmaceuticals (14). This grouping follows Chandler (Business History Review, Summer 1994).

Concluding Remarks

Theoretical results:

- Increase in technological knowledge obtained by worker-scientists reduces wages, R&D expenditures.

2. Increase in the external value of technological knowledge leads to more scientist exits.

3. Increase in the threat of a scientist leaving leads to more patenting (per R&D dollar). Greater patenting even if scientist doesn't leave. Whenever patenting reduces the entrepreneur’s loss when the scientist leaves or his wage when he stays by more than the patenting cost, the entrepreneur patents.

Empirical results:

Economic significance of our findings:

(i) 50% increase in industry-specific measure of mobility increases the patent-R&D ratio by 2%.

(ii) Changes in research personnel mobility may explain 5 to 16 percent of the 18 percent increase in patent-R&D ratios in U.S. economy between 1984 and 1997.

(iii) Mobility differences faced by small and large firms may account for 18 to 47 percent of the difference in patent yields between small and large firms (*the firm size-patent-R&D ratio puzzle*).

Implications:

1. Increase in mobility raises patenting yield of R&D, even when we control for endogeneity of mobility. This is consistent with a story that firms' patent to minimize harm due to departing scientists.
    - Thus, patents may play a role in protecting an innovating firm from insiders as well as outsiders.
    - Our evidence suggests that turnover of scientific personnel may be an indicator of technological diffusion/spillover across firms within an industry.

Implications (continued):

2. *Geographical spillovers:* Jaffe, Trajtenberg, and Henderson (1993) report that in patent applications, firms often cite the work of external scientists, but that these scientists tend to work locally. Their findings suggest that geographical proximity is necessary for a technological spillover to take place.

   Our finding that geographical mobility shows a strong, statistically significant positive effect on patent-R&D ratio suggests that the movement of researchers among firms (and between academia and firms) may be an important mechanism for the transmission of these geographical spillovers.