Mobility and Patent Productivity of Korean Inventors

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Introduction

- Technological progress is considered as a key factor for improving quality of life and for economic growth.
- As a measure of technological progress at firm level or at country level, patent data have been extensively used.
- However, most researches that study patent data from patent offices around the world have been conducted at *patent* or *firm* level.
- Important piece of information not utilized so far is the identity of inventors. Inventor-level studies were seldom carried out because unique inventors cannot be identified across patents.

Introduction

- Lately we are witnessing a wave of new research at *inventor* level owing to numerous projects on matching inventor names, or disambiguation (e.g. Trajtenberg, Shiff, Melamed, 2006; Lai, D'Amour, Fleming, 2009)
- Name matching is conducted by using information on patents such as assignees, addresses, citations and co-inventors.
- One caveat: accuracy in name matching (especially problematic for East Asian names)
  - Under-matching error (Type I): more likely for prolific inventors
  - Over-matching error (Type II): more likely for popular names (the "John Smith" problem)
- Inventor mobility cannot be well identified because firm affiliations are utilized for name matching.

Introduction

- Korean Intellectual Property Office (KIPO): collecting inventors' resident registration numbers (similar to social security numbers in Switzerland or US) since 1991, which is not for public use
- We were able to acquire from KIPO unique ID's for inventors along with information on birth year and gender.
- Unique advantages of our Korean inventor data:

  (i) measuring patent productivity of inventors accurately at each age, and by gender

  (ii) identifying job turnover accurately unlike inventor-level data by disambiguation

Introduction

- In this study, we investigate determinants of inventor productivity, including the effects of labor mobility and age.
- Labor mobility and technology transfer
  – Inter-firm mobility of scientists transmits technological know-how across firms (Arrow, 1962; Stephan, 1996): .
- We ask two questions about labor mobility:
  (1) Do inventors get more productive after job turnover?
  (2) Do movers affect co-workers' productivities in a new firm?
- Theoretical explanations for the age effect on productivity
  (a) Physical capacity
  (b) Cognitive (mental) abilities: declining with age except verbal abilities
  (c) Experience

Preliminary Findings

- Own patent productivity gets higher after job turnover.
- Own patent productivity jumps up after move, and then gradually converges to the average within 5 to 8 years.
- More incoming inventors to a firm enhances productivities of co-workers in the firm.
- Patent productivity declines with age in terms of annual patent counts per inventor as well as the weighted number of patents.
- We observe a rising productivity over time. Productivity is higher for younger cohorts.
- There is trade-off between claims and patent counts. Bigger teams produce more patents.

Outline

1. Literature Review
2. Data Description
3. Descriptive Statistics
4. Empirical Analysis: Methodology and Findings
5. Concluding Remarks

Literature on Researcher Mobility

- Numerous studies on technology transfer via inter-firm mobility of researchers
- Levin, Klevoric, Nelson, Winter (1987): providing survey evidence that firms count the hiring of R&D employees from innovating firms as a means of learning about new technologies
- Almeida, Kogut (1999): scientific references that firms cite in their patents reflect the employment histories of their scientists in semiconductor industry, suggesting that ideas in this industry are spread by the movement of key engineers among firms
- Kerstetter (2000), Hibbard (1998): high profile examples of employee raids designed to gain access to competitors' technologies
- Cohen, Nelson, Walsh (2002): firms access externally-located technology through the hiring of researchers from the outside

Literature on the Productivity Effect of Age

(a) Income of independent workers: objective and easy to estimate, but applicable only to limited occupations

– Oliviera, Cohn, Kiker (1989): self-employed in 1983 PSID, inverted U-shaped

(b) Supervisor's evaluation: subjective and may be given in the form of rewards for past performances

– Medoff, Abraham (1981): white-collar employees in large US firms, seniority not or negatively related with performances

(c) Output per person: objective indicator, but possible only when individual production can be easily monitored (Artistic works, publications, patents)

– Galenson, Weinberg (2000): artists; peak at 51 for those born before 1920, 29 for those born after 1920

– Levin, Stephan (1988): US academic scientists; negative age effect in physics, earth science, physiology, biochemistry

– Oster, Hammermesh (1998): economists; publications declining sharply with age

– Weinberg, Galenson (2007): Nobel laureates in economics; peak at the mid-50's for experimental laureates while age 25 for conceptual laureates

Data Description

- We merge the Korean patent data to the firm data from Korea Investors Service (KIS Value data).

- Korean patent data:

  - Years 1991-2005 (earlier years available but inventor id information not available)

  - Foreign inventors excluded

  - Annual patent number grew from 9,970 in 1991 to 82,898 in 2005

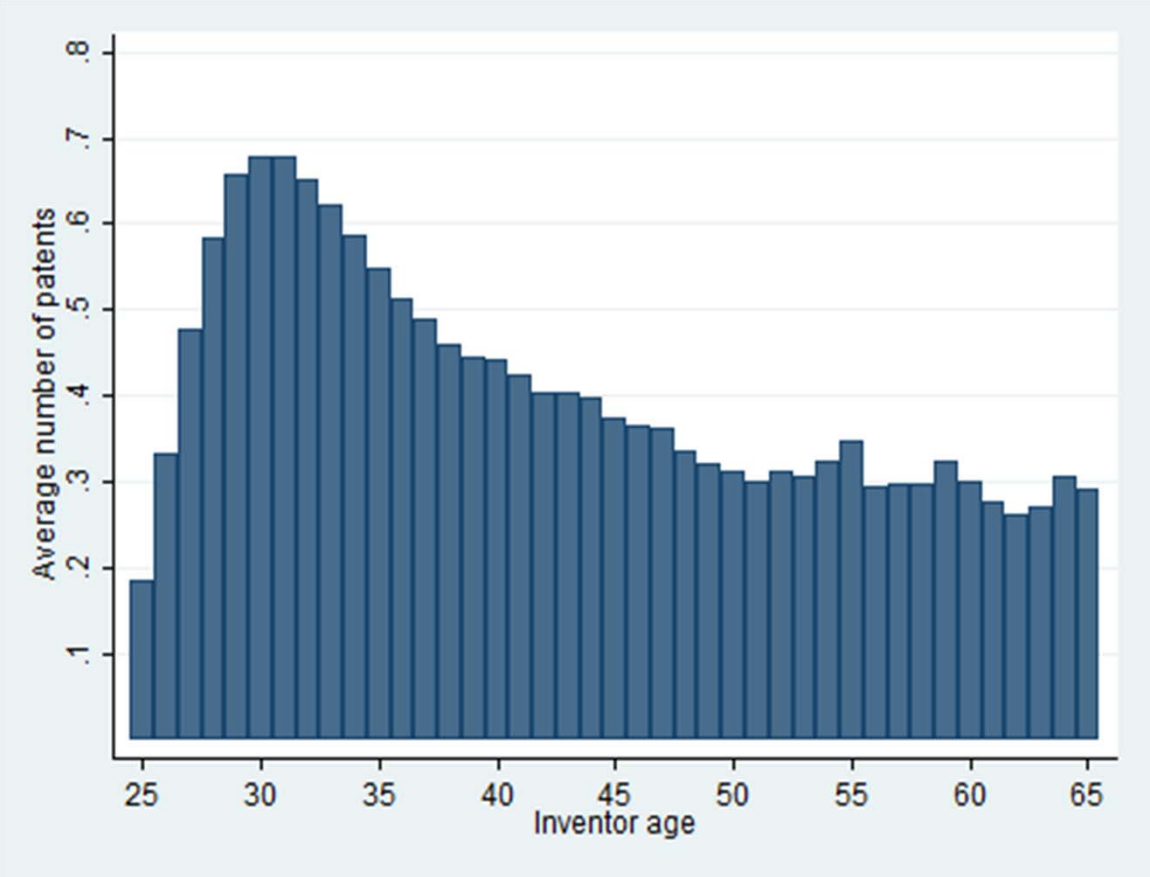
  - About 100,000 unique inventors (female: less than 2%)

- KIS Value data:

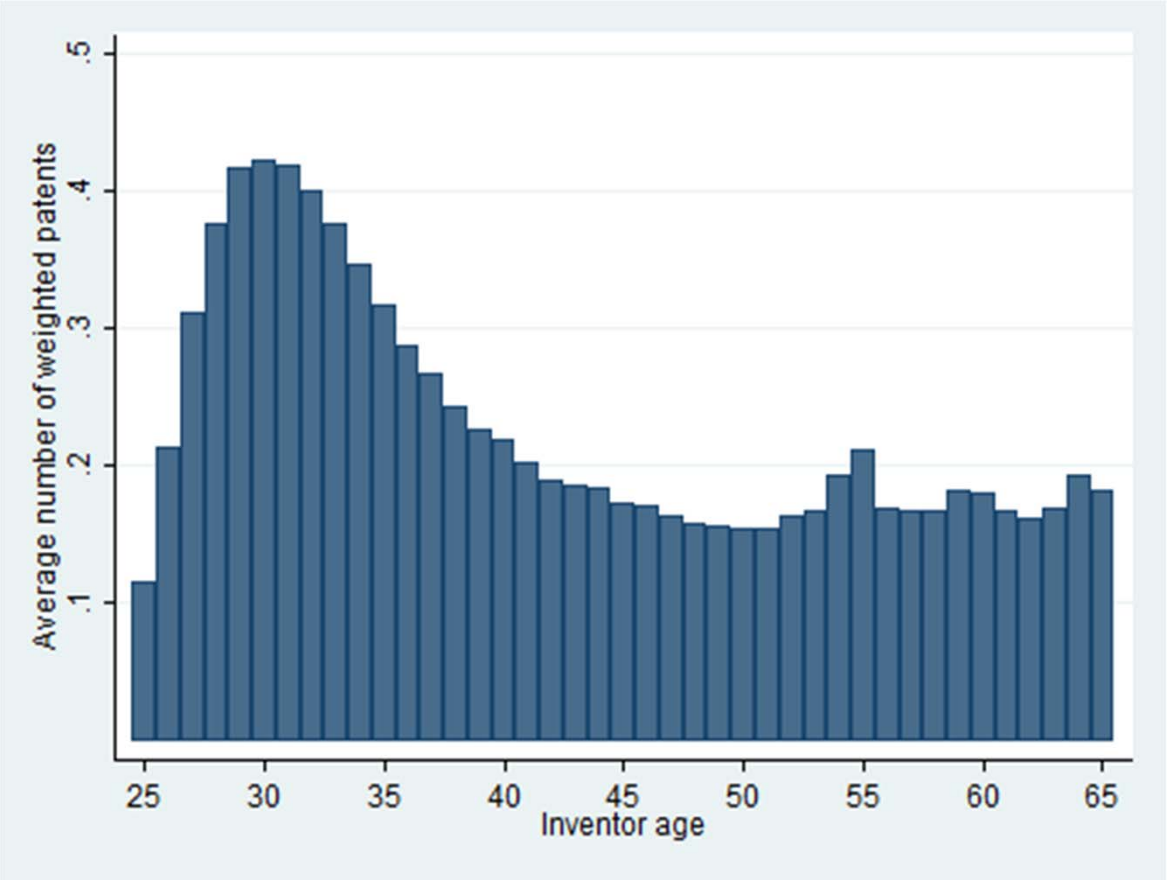
  - Equivalent to Compustat data (for US corporations)

  - Annual data on capital, sales, employment, R&D

Age-Productivity Profile



Co-inventor-weighted Patent Counts



Note: For example, my productivity from a patent invented with 2 co-inventors is 1/3 of a patent.

Regression Analysis

- Dependent variable = annual number of patents of an inventor (or, co-inventor-weighted number of patents)

- We use a panel-data negative binomial model with inventor-specific fixed effects to estimate the determinants of patent productivity. (Alternatively we use a fixed-effects linear regression model for weighted number of patents.)

Strategies for Empirics

- In order to sort out the age effect from the cohort and the calendar year effects, we postulate that the calendar year (or time) effect is due to changes in the overall propensity of patenting, and it is proxied by the total annual number of patent applications and the total annual number of inventors:

$$Y\_EFF_t = f(TPAT_t, TINV_t)$$

$$\cong \beta_1 TPAT_t + \beta_2 TPAT^2_t + \beta_3 TPAT^3_t$$

$$+ \beta_4 TINV_t + \beta_5 TINV^2_t + \beta_6 TINV^3_t$$

(approximated by Taylor expansion)

Model Specification

$$\ln E(PAT_{it}) = \alpha_0 + \alpha_1 AGE_{it} + \alpha_2 AGE^2_{it} + \alpha_3 AGE^3_{it} + \alpha_4 TPAT_t + \alpha_5 TPAT^2_t + \alpha_6 TPAT^3_t + \alpha_7 TINV_t + \alpha_8 TINV^2_t + \alpha_9 TINV^3_t + \alpha_{10} COH_i + \beta X_{it} + \varepsilon_{it},$$

PAT_{it} = number of patents of inventor i in year t

AGE_{it} = age of inventor i in year t (We include linear, quadratic, and cubic terms because of an inverted-U shaped profile with a long tail.)

$TPAT_t$ = total number of patents applied for in year t

$TINV_t$ = total number of unique inventors in year t

COH_i = cohort dummies

X_{it} = vector of other determinants, including (i) **labor mobility variables** (own job turnover, mobility of new colleagues), (ii) gender, and (iii) patent-specific variables (no. of claims, no. of co-inventors)

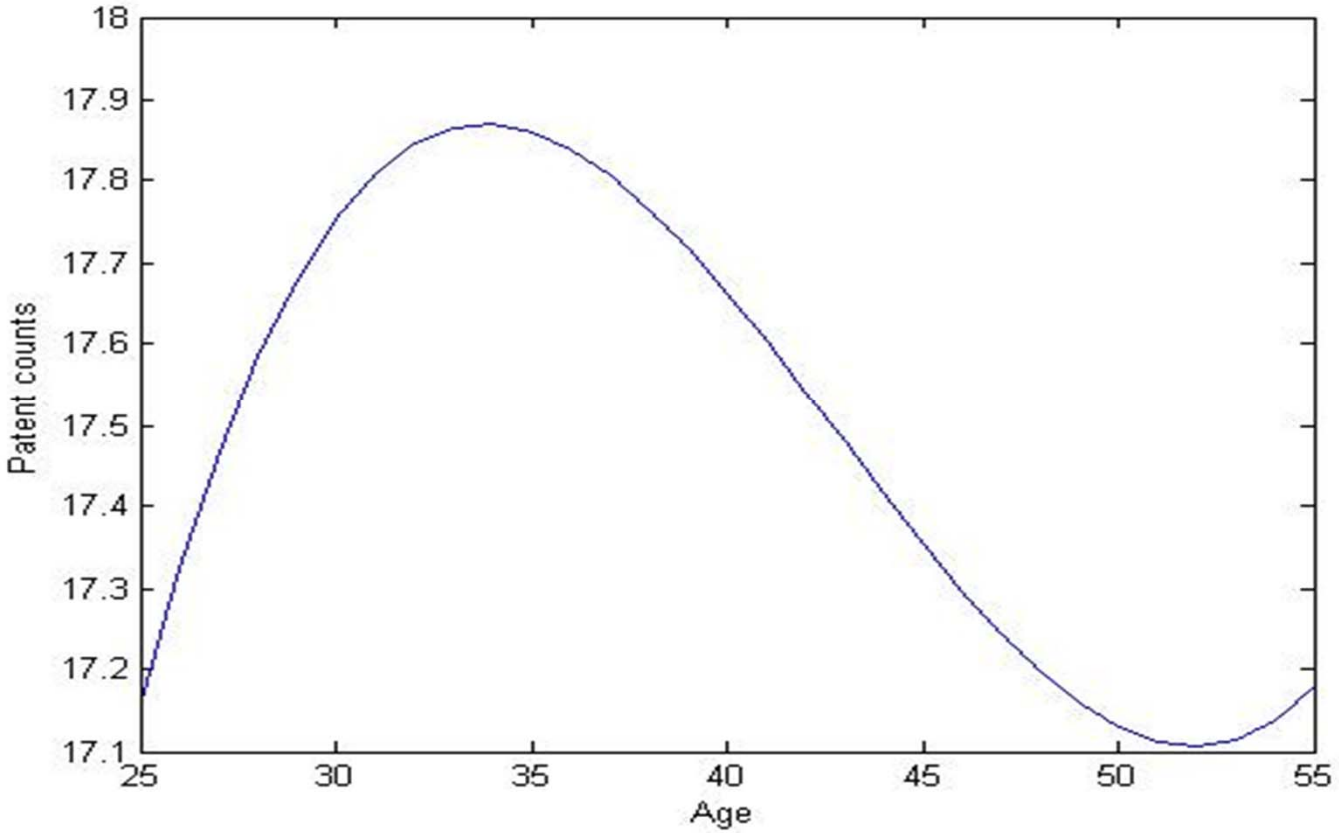
Table 1. Summary Statistics

Variable	Description	Mean	St. Dev	Min	Max
PAT	Number of patents per inventor	0.497357	2.088789	0	362
WPAT	Weighted number of patents per inventor	0.28938	1.40347	0	362
AGE	Age of inventor	35.08163	7.512854	25	65
MALE	1 if an inventor is male	0.963191	0.188294	0	1
TPAT	Total num. of patents applied	48859.45	20132.78	9970	82898
TINV	Total nun. of unique inventors	14186.81	4870.435	5864	21493
CLAIM	Average number of claims	5.840245	5.620374	0.027027	554
COINV	Average number of co-inventors	2.626251	2.107685	1	39
OWN_JTO	Dummy variable for own job turnover	0.020060	0.140204	0	1
NEWEXP	Years at a new firm since moved	0.073425	0.618143	0	14
INCOMER	Number of new employees who moved to a firm (only those who moved once)	69.28283	123.271	0	659

Table 2. Patents Counts

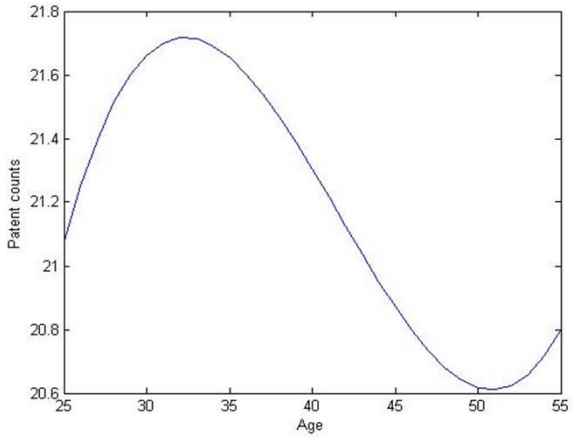
	(1) All inventors		(2) All inventors	
	Coef.	z	Coef.	z
AGE	1.35042	119.48	0.189555	12.14
AGE^2	-0.03298	-114.62	-0.005	-12.35
AGE^3	0.000257	108.09	3.95E-05	11.51
MALE	0.165033	8.53	-0.16092	-3.30
TPAT	5.88E-05	23.04	2.05E-06	0.80
TPAT2	-8.43E-10	-14.33	1.26E-10	2.15
TPAT3	4.47E-15	10.33	-8.71E-16	-2.03
TINV	-9.2E-05	-4.59	0.000104	5.33
TINV2	5.95E-09	3.97	-8.37E-09	-5.68
TINV3	-1.01E-13	-2.72	1.98E-13	5.43
lnCLAIM			-0.02278	-9.47
D_CLAIM0			-0.40002	-25.30
lnCOINV			0.256473	69.85
D_COINV0			-26.3746	-0.04
Obs.	2,293,235		2,293,235	

Age Profile of All: Model (1)

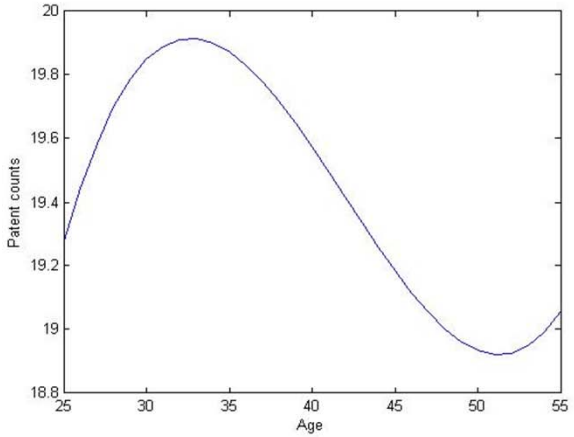


These profiles are based on coefficients w.r.t. AGE, AGE2, and AGE3 in Model 1 of Table 2.

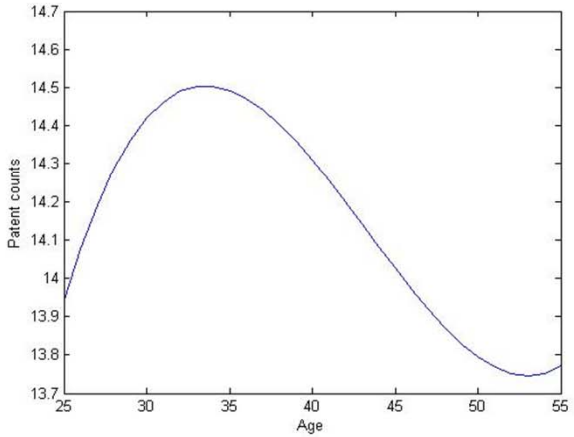
Age Profile: By Industry



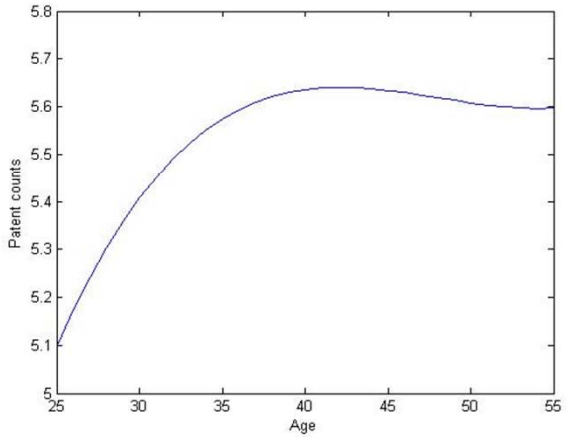
Computers & computing equipments



Electronic instruments & communication equipments



Motor vehicles



Pharmaceuticals

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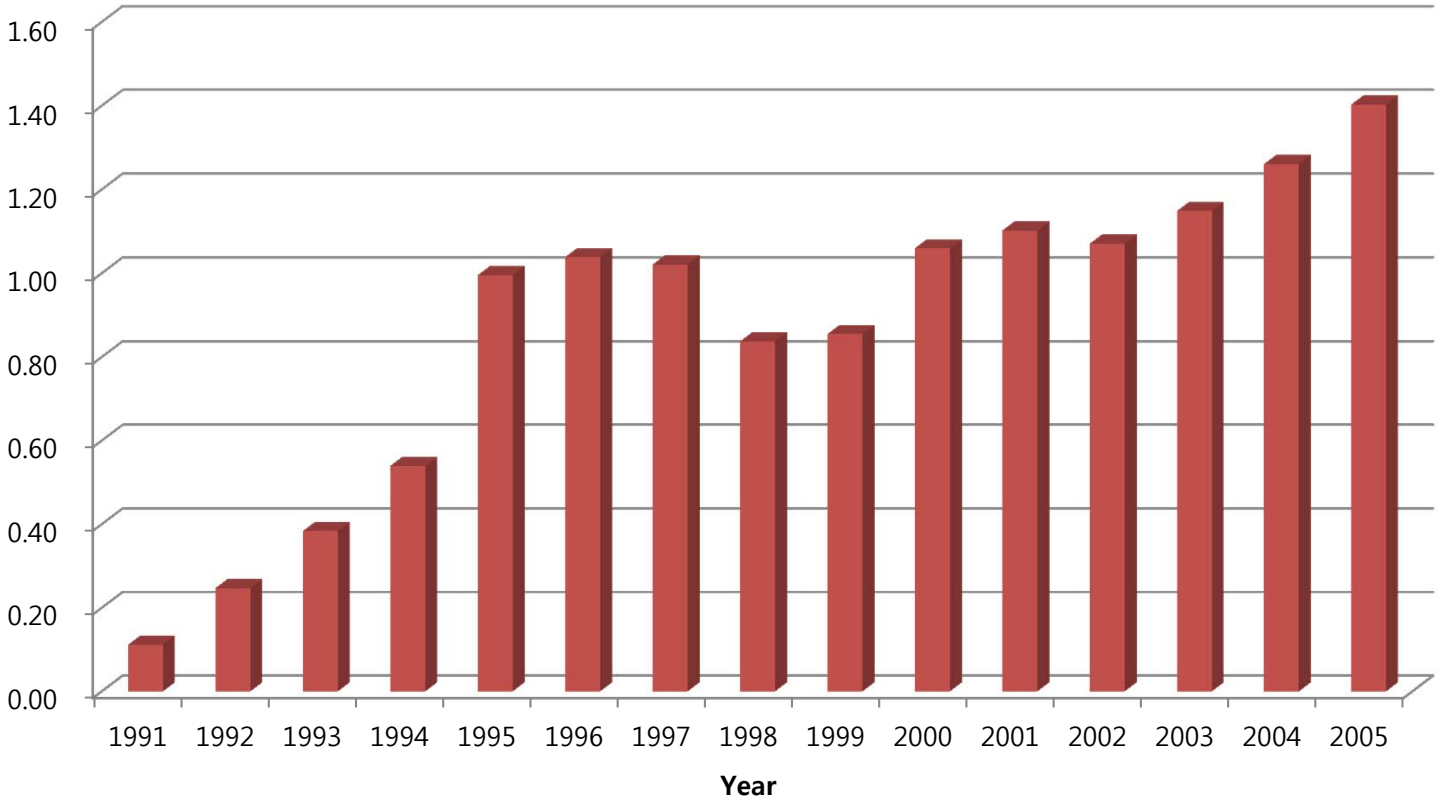
Calendar-year Effects



Sum of the products of estimated coefficients in Model 1 and actual values of TPAT and TINV in each year $(= \alpha_4 \, TPAT_t + \alpha_5 \, TPAT^2_t + \alpha_6 \, TPAT^3_t + \alpha_7 \, TINV_t + \alpha_8 \, TINV^2_t + \alpha_9 \, TINV^3_t)$

Cohort Effects

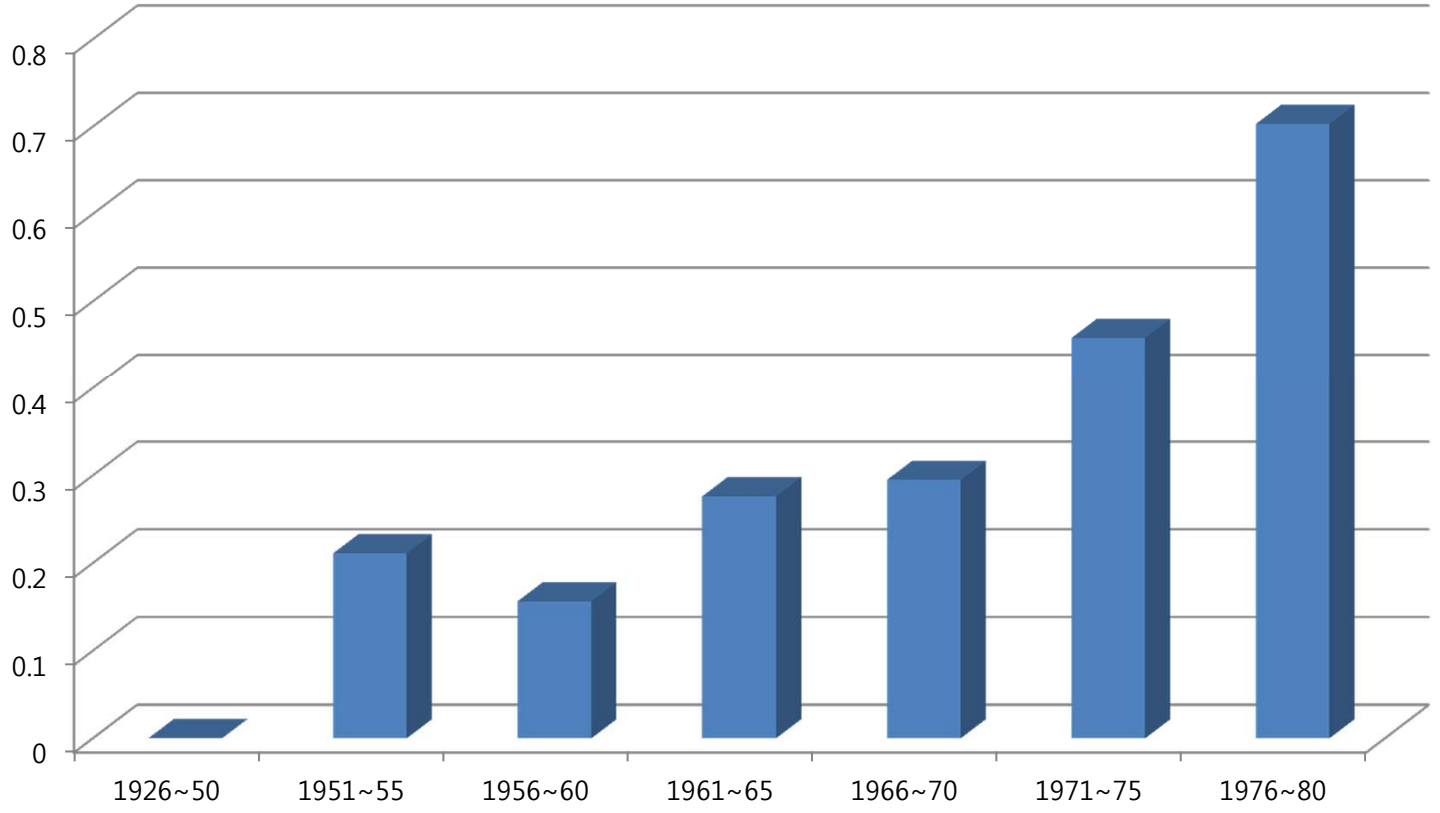


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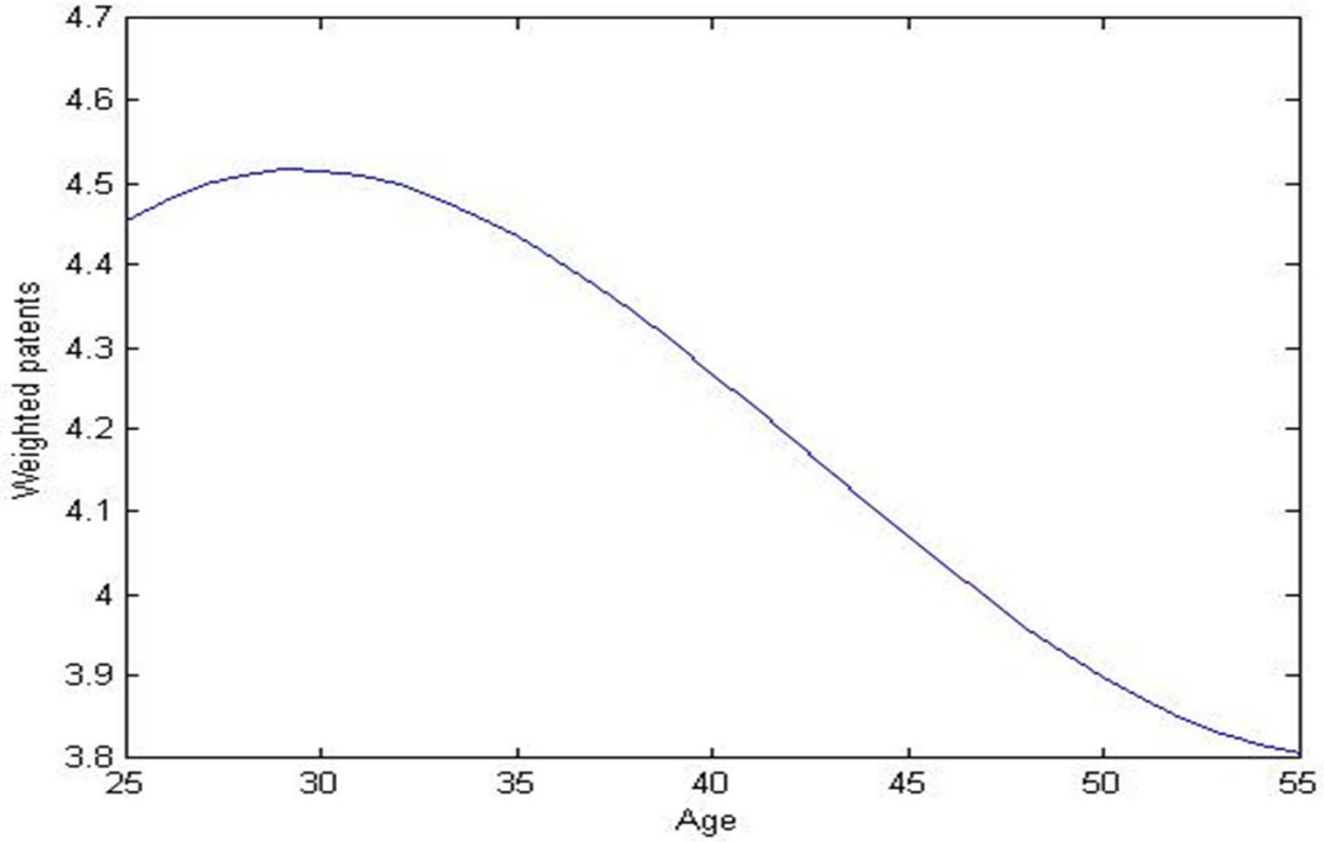
Table 3. Co-inventor-weighted Patent Counts

	(1) All inventors		(2) All inventors	
	Coef.	z	Coef.	z
AGE	0.372306	60.84	0.078748	14.05
AGE^2	-0.00965	-62.18	-0.0024	-16.88
AGE^3	7.53E-05	58.57	1.87E-05	15.86
TPAT	1.37E-05	10.73	8.17E-06	7.03
TPAT2	-1.45E-10	-4.42	-9.15E-11	-3.06
TPAT3	9.55E-16	3.74	7.77E-16	3.33
TINV	-2.1E-05	-2.18	-3.5E-05	-4.00
TINV2	1.83E-09	2.29	2.98E-09	4.08
TINV3	-4.86E-14	-2.28	-8.55E-14	-4.40
lnCLAIM			-0.05633	-22.62
D_CLAIM0			-0.83649	-48.93
Obs.	2,294,089		2,294,089	

We use a fixed-effects linear regression model for this table.

Weighted Patent Counts, Model (1)



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TINV	-2.1E-05	-2.18	-3.5E-05	-4.00
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D_CLAIM0			-0.83649	-48.93
Obs.	2,294,089		2,294,089	

Two Questions on Labor Mobility Effects

(1) Do inventors get more productive after job turnover?

- Effect on own productivity after moving to a new firm

(2) Does an inventor's move affect co-workers' productivities in a new firm?

- Effect of movers on co-workers' productivities in a new firm

(1) Effect on Own Productivity after Move

- Theoretical reasons for **lower** productivity after move

  (i) Adjustment costs in a new place

  (ii) Learning of new skills, or skill adjustment (new practices, protocols, routines, new management procedures)

  (iii) Loss of knowledge specific to the old firm

  - Likely to be temporary effects

- Theoretical reasons for **higher** productivity after move

  (i) Better job match

  (ii) Better work environment with better equipment

  (iii) Peer effects (enabling to acquire tacit knowledge)

(1) Effect on Own Productivity after Move

- We use only those inventors who

  (i) produced at least one patent in 2 years on average, and

  (ii) did not move or moved once (producing patents for a firm in year t and for another firm in year t+1).

- We use only those inventors with patents in consecutive years to identify turnover since it is difficult to identify the exact date of job turnover.

  - Those who do not patent due to temporary productivity slowdown are not included.

  - We therefore use more prolific inventors only.

- OWN_JTO = 1 for years after move, 0 for years before move

  NEWEXP = years elapsed since moved (up to cubic terms)

Table 4. Effect on Own Productivity after Move

	(1) Base		(2) Years after move		(3) Weighted counts		(4) 1 patent per year	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
AGE	2.66471	121.93	2.65425	121.39	1.80926	51.26	2.88495	98.82
AGE^2	-0.06660	-117.30	-0.06631	-116.75	-0.04934	-52.35	-0.07173	-93.83
AGE^3	0.00052	109.04	0.000519	108.54	0.000401	48.72	0.000558	85.77
SEX	0.12120	4.49	0.12214	4.52			-0.01317	-0.41
TPAT	7.75E-05	16.37	0.000076	16.12	0.000085	13.09	0.000081	13.23
TPAT2	-1.16E-09	-11.03	-1.14E-09	-10.88	-1.27E-09	-7.94	-1.26E-09	-9.37
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TINV	-0.00020	-5.60	-0.000210	-5.77	-0.000185	-3.79	-0.000276	-5.89
TINV2	1.42E-08	5.41	1.47E-08	5.61	1.79E-08	4.59	2.08E-08	6.20
TINV3	-3.50E-13	-5.55	-3.63E-13	-5.77	-5.21E-13	-5.17	-5.37E-13	-6.70
OWN_JTO	0.60705	26.68	2.01619	36.48	1.43702	11.87	1.65660	23.50
NEWEXP			-0.73792	-15.38	-0.45615	-5.04	-0.46364	-8.02
$NEWEXP^2$			0.08548	7.81	0.05228	2.84	0.04715	3.67
$NEWEXP^3$			-0.00346	-5.00	-0.00223	-2.12	-0.00166	-2.09
Obs.	376,835		376,835		377,475		185,826	

Column 4 is based on the data that include only those inventors who produced at least one patent per year on average.

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TPAT2	-1.16E-09	-11.03	-1.14E-09	-10.88	-1.27E-09	-7.94	-1.26E-09	-9.37
TPAT3	7.90E-15	10.44	7.88E-15	10.42	9.39E-15	7.73	8.97E-15	9.30
TINV	-0.00020	-5.60	-0.000210	-5.77	-0.000185	-3.79	-0.000276	-5.89
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TINV3	-3.50E-13	-5.55	-3.63E-13	-5.77	-5.21E-13	-5.17	-5.37E-13	-6.70
OWN_JTO	0.60705	26.68	2.01619	36.48	1.43702	11.87	1.65660	23.50
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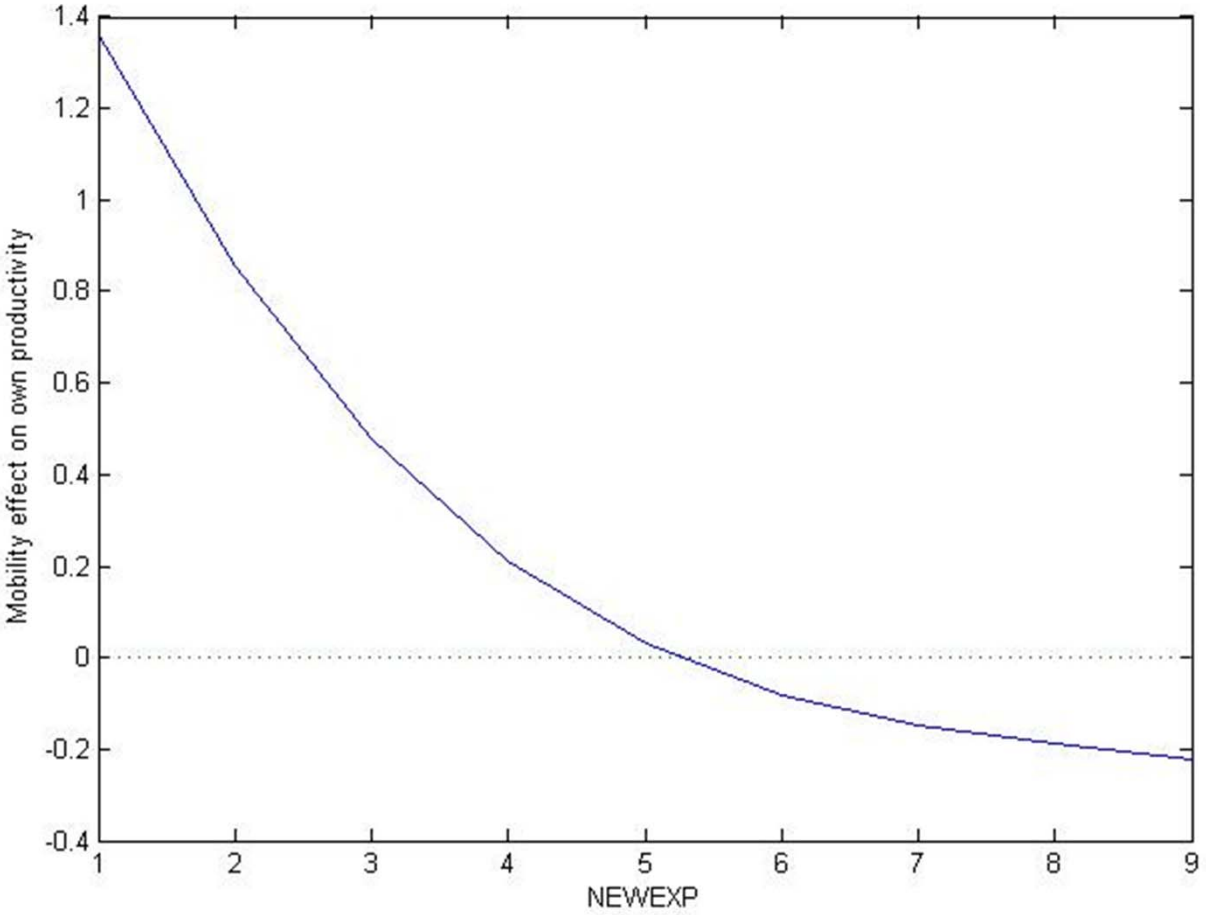
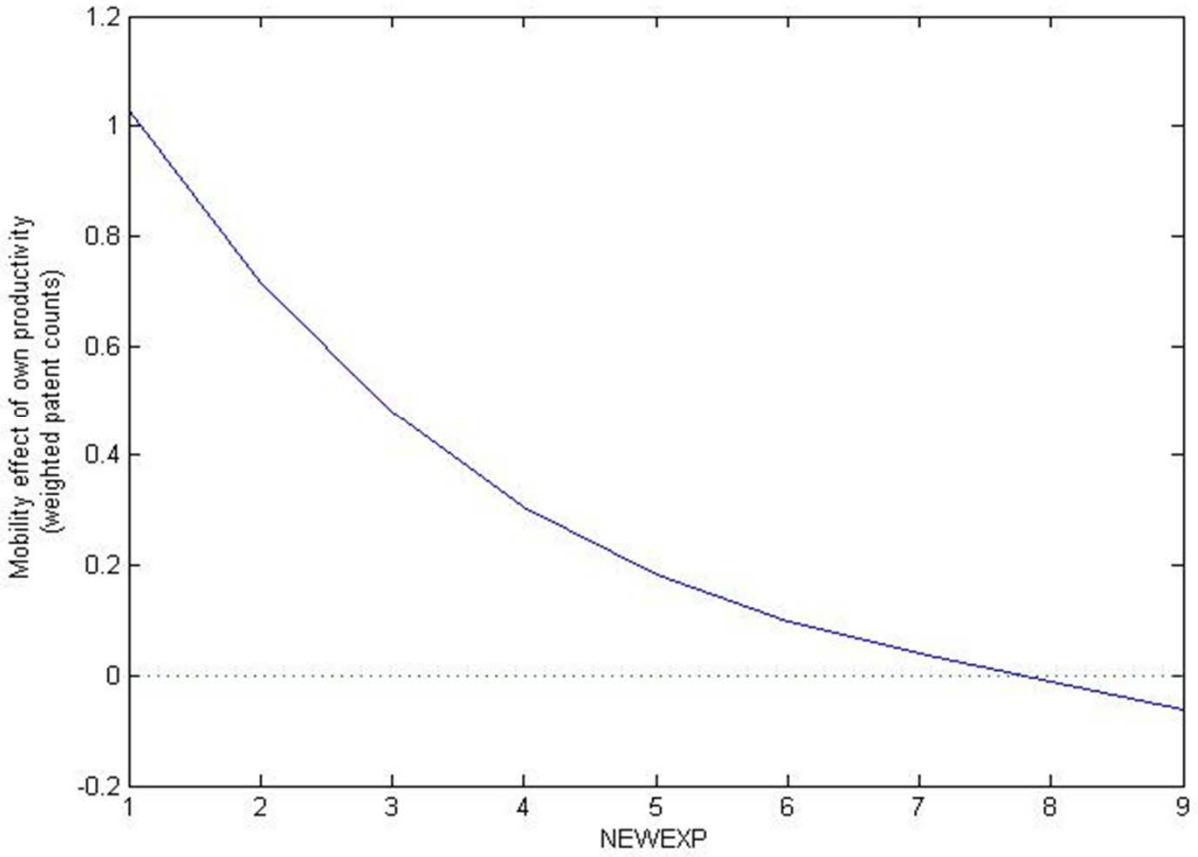
Productivity Path after Move



The curve shows the value of (δ_0***OWN_JTO** + δ_1***NEWEXP** + δ_2***NEWEXP**^{2} + δ_3***NEWEXP**^{3}) where the coefficients are from Model 2 of Table 4. It depicts additional number of patents produced after move above the age productivity profile.

Productivity Path after Move (weighted patent counts)



The curve shows the value of (δ_0***OWN_JTO** + δ_1***NEWEXP** + δ_2***NEWEXP**^{2} + δ_3***NEWEXP**^{3}) where the coefficients are from Model 3 of Table 4. It depicts additional weighted number of patents produced after move above the age productivity profile.

(1) Effect on Own Productivity after Move

- Time path of productivity after move

  - Productivity is shown to converge to the average within 5 to 8 years.

- If better job match is the reason for higher productivity after move, the productivity rise may be permanent showing no convergence to the average.

- Convergence may take place because inventors with special expertise are recruited to participate in a new project.

(2) Effect on New Co-workers' Productivities

- Do new comers have spillover effects on co-workers in a new firm?
- We use only those inventors who
  (i) produced at least one patent in 2 years on average, and
  (ii) did not move.
- INCOMER = number of new incoming inventors for a firm in the past 3 years (incomers who moved once and produced patents for the old firm in year t and the new firm in year t+1)

Table 5. Spillover Effect of New Incomers

	(1) Base		(2) Weighted count		(3) All movers		(4) 1 patent per year	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
AGE	2.86058	119.15	2.14181	50.09	2.86422	119.33	3.08814	97.13
AGE^2	-0.07160	-114.71	-0.05844	-50.98	-0.07164	-114.80	-0.07684	-92.24
AGE^3	0.000561	106.42	0.000478	47.48	0.000561	106.42	0.000598	84.06
SEX	0.11337	4.08			0.11238	4.05	-0.01332	-0.41
TPAT	0.000074	4.54	0.000060	2.27	0.000069	4.24	0.000083	4.01
TPAT2	-1.08E-09	-3.59	-7.95E-10	-1.59	-1.00E-09	-3.31	-1.31E-09	-3.40
TPAT3	7.46E-15	4.03	6.54E-15	2.09	7.02E-15	3.80	9.29E-15	3.95
TINV	-0.000102	-1.06	0.000045	0.28	-0.000074	-0.77	-0.000210	-1.71
TINV2	7.28E-09	1.13	2.79E-09	0.26	5.42E-09	0.84	1.64E-08	2.01
TINV3	-2.05E-13	-1.44	-1.99E-13	-0.81	-1.62E-13	-1.14	-4.52E-13	-2.51
INCOMER	0.00105	27.95	0.00111	13.27			0.00104	23.23
INCOMER+					0.000066	23.62		
Obs.	328,257		330,428		328,257		163,218	

Column 4 is based on the data that include only those inventors who produced at least one patent per year on average.
The magnitude of the effect of INCOMER: 69 (sample average of INCOMER) x 0.00105 = 0.07 patents.

Table 5. Spillover Effect of New Incomers

	(1) Base		(2) Weighted count		(3) All movers		(4) 1 patent per year	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z
AGE	2.86058	119.15	2.14181	50.09	2.86422	119.33	3.08814	97.13
AGE^2	-0.07160	-114.71	-0.05844	-50.98	-0.07164	-114.80	-0.07684	-92.24
AGE^3	0.000561	106.42	0.000478	47.48	0.000561	106.42	0.000598	84.06
SEX	0.11337	4.08			0.11238	4.05	-0.01332	-0.41
TPAT	0.000074	4.54	0.000060	2.27	0.000069	4.24	0.000083	4.01
TPAT2	-1.08E-09	-3.59	-7.95E-10	-1.59	-1.00E-09	-3.31	-1.31E-09	-3.40
TPAT3	7.46E-15	4.03	6.54E-15	2.09	7.02E-15	3.80	9.29E-15	3.95
TINV	-0.000102	-1.06	0.000045	0.28	-0.000074	-0.77	-0.000210	-1.71
TINV2	7.28E-09	1.13	2.79E-09	0.26	5.42E-09	0.84	1.64E-08	2.01
TINV3	-2.05E-13	-1.44	-1.99E-13	-0.81	-1.62E-13	-1.14	-4.52E-13	-2.51
INCOMER	0.00105	27.95	0.00111	13.27			0.00104	23.23
INCOMER+					0.000066	23.62		
Obs.	328,257		330,428		328,257		163,218	

In column 3, INCOMER+ is constructed with the number of inventors who moved once or more times.

Table 5. Spillover Effect of New Incomers (cont.)

	(5) Past 2 years		(6) Past 5 years	
	Coef.	z	Coef.	z
AGE	2.82268	121.12	3.03027	111.66
AGE^2	-0.07057	-116.57	-0.07598	-106.96
AGE^3	0.000553	108.29	0.000596	98.50
SEX	0.11408	4.13	0.09993	3.48
TPAT	0.000052	3.89	-0.000045	-1.45
TPAT2	-6.67E-10	-2.66	1.09E-09	1.93
TPAT3	4.84E-15	3.14	-5.48E-15	-1.64
TINV	-2.63E-06	-0.03	0.000148	1.43
TINV2	3.71E-11	0.01	-1.13E-08	-1.59
TINV3	-3.25E-14	-0.25	2.48E-13	1.55
INCOMER2	0.00109	23.57		
INCOMER5			0.000759	27.91
Obs.	341,159		295,155	

In this table, INCOMER2 (INCOMER5) is constructed to include new incoming inventors in the past two (five) years.

Concluding Remarks

- We find (i) patent productivity declines with age, (ii) productivity seems to rise over time and is higher for younger groups, and (iii) trade-off b/w claims and patent number.

- We also find (iv) patent productivity rises after move, (v) it jumps up immediately after move (about 1 more patent), and then gradually converges to the average within 5 to 8 years, (vi) having more incoming inventors in the past enhances productivities of co-workers in the firm, which is corroborated in various models of our sensitivity analysis.

- Further research agenda:
  - Selection issue
  - Team formation (the old working with the young?)
  - Team persistence