Frictional Inventor Markets and Knowledge Diffusion

Yasutaka Koike-Mori[1], Toshitaka Maruyama[2], Koki Okumura[3]

March 6, 2022

[1]UCLA, 4th year
[2]UCLA, 3rd year
[3]UCLA, 3rd year

Inventor Mobility and Knowledge Diffusion

- Literature on inventor mobility and knowledge diffusion
  - Inventor mobility facilitates knowledge diffusion across firms
- **Labor markets** where inventors and firms match would play important roles
  - Firms' hiring decision
  - Inventors' job choice

Impact of Inventor Market Frictions?

- Inventor market frictions $\rightarrow$
  - inventor mobility?
  - in-house R&D activity?
  - knowledge diffusion?
  - economic growth?
- Environment
  - Inventors and firms match in frictional labor markets
  - Inventors engage in in-house R&D
  - Poaching firms learn from poached firms

New Theory and Data

- Endogenous growth model of inventor market frictions
  - Literature on knowledge diffusion and growth / international
  - Literature on firm dynamics and labor market frictions
- German administrative data
  - inventors' patent information
  - their labor market career
  - their employing establishment

Literature

- Inventor mobility and knowledge diffusion
  - Song, Almeida, and Wu (2003); Almeida, Dokko, and Rosenkopf(2003); Breschi and Lissoni (2009); Singh and Agrawal (2011)
- Knowledge diffusion and growth / international / spacial
  - Lucas and Moll (2014); Akcigit et. al. (2018); Buera and Oberfield (2020); Benhabib, Perla, and Tonetti (2021); Prato (2022); Crews (2023)
- Labor market frictions and firm dynamics
  - Kaas and Kircher (2015); Schaal (2017); Elsby and Gottfries (2021); Bilal, Engbom, Mongey, and Violante (2022)
- Labor market frictions and knowledge diffusion
  - Herkenhoff, Lise, Menzio, and Phillips (2018); Shi (2022)

Today's Outline

1. Characteristics of inventors' job flow
2. Comparison with general workers
3. Endogenous growth model of inventor market frictions
4. Numerical exercises

Characteristics of Inventors' Job Flow

INV-BIO Data

- What are the characteristics of inventors' job flows?
- Investigate using German linked inventor biography data (INV-BIO)
  - Inventors' patent information (EPO)
    $+$ Employer-employee match data (Germany)
  - 1980 - 2014
  - 152,350 inventors (have patents during 1998-2014)
  - 643,856 patents

Available Variables in INV-BIO

- Inventors' biography
  - age, education, place, nationality, ...
- Employment characteristics
  - wage, occupation, unemployment status, ...
- Establishment characteristics
  - industry, age(1975-), # of employees, mean wage, place, ...
- Patent characteristics
  - date, citations, technology area, ...

Inventor's Job Flows: Methods

- Classified establishments into the ranks based on their productivity/knowledge
- Proxy for productivity/knowledge of establishments: distribution
  1. Patent citations per inventor
  2. Number of employees
  3. Mean wage
- Analyze inventor mobility across the ranks

Inventor's Job Flows: Citation/Inventors robustness calibration

Share of total flow (%)		Destination est. citations per inventor					
		≤50%	50-60	60-70	70-80	80-90	90-100
Origin est. citations per inventor	≤50%	0.7	0.2	0.2	0.3	0.5	0.8
	50-60	1.1	0.4	0.3	0.5	1.0	1.5
	60-70	1.2	0.4	0.4	0.7	1.3	1.8
	70-80	2.4	0.7	0.8	1.7	3.0	4.1
	80-90	5.1	1.2	1.4	3.3	8.8	10.4
	90-100	7.2	1.6	1.6	3.7	9.9	20.1

Notes: As a productivity measure, we use 3-year backward moving averages of the number of 5-year forward citations. The table shows the total gross flow from 1983 to 2014.

- Higher → Lower: 41.5, Lower → Higher: 26.5

Comparison with General Workers

Difference from General Workers

- How different is inventors' job flow from general workers?
- Investigate using the linked employer-employee data in Germany

  Sample of Integrated Labour Market Biographies (SIAB)

  - 2% random sample of administrative data
  - 2000 - 2019
  - 1,940,961 individuals

How to Identify Inventors in SIAB

- From German inventor biography data (INV-BIO), identify the following occupations that most inventors belong to
  - "research and development" (20.2%[4])
  - "machine-building and operations" (19.8%)
  - "mathematics, biology, and physics" (19.1%)
  - "mechatronics, energy, and electronics" (18.8%)
- Assumption: workers in above occup in SIAB ≈ inventors

identified inventors

[4] Percentage of inventors belonging to the occupations in INV-BIO

Comparison of Job Flows

- Construct the following dummy variables for all job changers

$$I_{it} = \begin{cases} 1 & \text{if inventor} \\ 0 & \text{otherwise} \end{cases}$$

$$D_{it} = \begin{cases} 1 & \text{if moving to less productive est.} \\ 0 & \text{if moving to more productive est.} \end{cases}$$

- Proxy for productivity of establishments
  1. Size
  2. Mean wage

Probit Model

- Do inventors tend to move from high to low relative to general workers?

$$P(D_{it} = 1 | I_{it}, X_{it}) = \Phi(\beta_0 + \beta_1 I_{it} + \beta_2 X_{it})$$

  - i: job changer without unemployment spell
  - t: 2000 - 2019
  - X_{it}: age, a square of age, gender, and education
  - No consistency in MLE with FE $\Rightarrow$ No FE

Liner Model

- When moving from high to low, do inventors' wages decrease relative to general workers' wage?

$$\log w_{it} - \log w_{it-1} = \beta_0 + \beta_1 D_{it} + \beta_2 D_{it} I_{it} + \beta_3 X_{it} + \alpha_e + \alpha_t + \varepsilon_{it}$$

- w_{it}: daily wage of job changer i in year t
- t: 2001 - 2019
- α_e: Destination establishment
- α_t: Year FE

Estimation Result: Size robustness

	$P(D_{it} = 1 \mid I_{it}, X_{it})$		$\log w_{it} - \log w_{it-1}$
	Whole sample	Sample with wage ↑	
I_{it}	.006***	.007***	
	(.003)	(.003)	
D_{it}			-.160***
			(0.08)
$D_{it} \times I_{it}$			.047***
			(.007)
Const.	.988***	-.243***	.908***
	(.010)	(.014)	(.019)
Control	√	√	√
FE			√
Year	2000∼2019	2000∼2019	2001∼2019
Observations	2,096,497	1,236,728	857,339

Notes: In the first and second columns, robust SEs are reported in parentheses. In the third column, SEs clustered by year and establishments are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Inventor Job Flow: Summary and Implication

- Inventors are more likely to move to less productive est. in comparison with general workers
- Inventors experience less wage decrease by moving to less productive est. in comparison with general workers

- Inventors may transfer substantial knowledge from high to low
- Firms may compensate for knowledge diffusion

Endogenous Growth Model of Inventor Market Frictions

Model Overview

- Inventors and firms randomly match in a frictional market
- Inventors engage in in-house R&D
- A poaching firm learns from a poached firm

Inventors and Firms

- Inventors are ex-ante homogeneous
- Firms are heterogeneous over
  1. detrended productivity/knowledge $z \in (0, \overline{z}]$
  2. the number of inventors $n \in (0, \infty)$

Matching Technology

- Posting v vacancies costs $c(v)Z_t$
  - $c(v)$: increasing and convex in v
  - Z_t: average productivity
- A vacancy randomly matches an inventor in other firm at an exogenous rate A

Productivity Dynamics

- **In-house R&D**: A firm's productivity increases by $\gamma(n)z$
  - $\gamma_n(n) \geq 0$
- **Knowledge diffusion**: When a firm z poaches an inventor from a firm z', the productivity increases by $\alpha(z, z')Z_t$
  - $\alpha(z, z') \geq 0$, $\alpha_z(z, z') \leq 0$, $\alpha_{z'}(z, z') \geq 0$
- **Leapfrog** to the technology frontier $\overline{z}$ with a rate η

Contractual Environment

- Bertrand competition
  1. the poaching firm makes the take-leave wage offer
  2. the targeted firm makes the take-leave wage offer
  3. the inventor decides
- Limited commitment
  - inventors can always move to another firm when they match.
  - inventors cannot commit to any other inventors in-side the firm.
- Privately efficient
  - the firm posts the privately efficient amount of vacancies
  - the firm posts the privately efficient take-leave wage offer

Joint Value

- The firm and its incumbent inventors maximize their joint value Ω
- State space: (1) firm's productivity z and (2) $\#$ of inventors n
- Independent of the wage distributions within firms
- Allocations are obtained from Ω

Which Firms Learn from Which Firms?

- Firm (z, n) can poach inventors from firm (z', n') if

$$\underbrace{\Omega_n(z,n)}_{\substack{\text{Marginal value of inventors}\\ \text{due to in-house R\&D}}} + \underbrace{\alpha(z,z')Z\Omega_z(z,n)}_{\substack{\text{Marginal value of inventors}\\ \text{due to knowledge diffusion}}} > \underbrace{\Omega_n(z',n')}_{\text{Marginal value of inventors}}$$

Hamilton-Jacobi-Bellman Equation

$$
\begin{aligned}
\underbrace{\rho\Omega(z,n)}_{\text{Required return}} &= \max_{v\geq 0} \underbrace{z}_{\text{Production}} - \underbrace{c(v)Z}_{\text{Hiring cost}} \\
&+ \underbrace{Av\int\left[\Omega_n(z,n)+\alpha(z,z')Z\Omega_z(z,n)-\Omega_n(z',n')\right]^+ dF_n(z',n')}_{\text{Poaching hire}} \\
&+ \underbrace{\left[\gamma(n)-g\right]z\Omega_z(z,n)}_{\text{In-house R\&D - Obsolescence}} + \underbrace{\eta\left[\Omega(\bar{z},n)-\Omega(z,n)\right]}_{\text{Leapfrog}}
\end{aligned}
$$

- g: economic growth rate
- F_n: inventor-weighted firm distribution

Firm-Level Productivity Change

$$\mu_z(z,n)z = \underbrace{\gamma(n)z}_{\text{In-house R\&D}} + \underbrace{Av(z,n)Z\int \mathbb{1}_P(z,n,z',n')\alpha(z,z')dF_n(z',n')}_{\text{Knowledge diffusion}}$$

- $\mathbb{1}_P$: indicator function that takes 1 if the poach successes
- $g = \max_{n\in\{n \mid f(\overline{z},n)>0\}} \mu_z(\overline{z},n)$
  - the economic growth rate $=$ the highest productivity growth rate of firms at the technology frotier

Firm-Level Change in the # of Inventors

$$\mu_n(z,n)n = \underbrace{Av(z,n)\int \mathbb{1}_P(z,n,z',n')dF_n(z',n')}_{\text{Poaching hire}}$$
$$- \underbrace{A\mathtt{v}\frac{n}{\mathtt{n}}\int \mathbb{1}_P(z',n',z,n)dF_v(z',n')}_{\text{Poached by other firms}}$$

- $\mathtt{v}$: total vacancies posted by firms
- $\mathtt{n}$: total inventors
- F_v: vacancy-weighted firm distribution

Kolmogorov Forward Equation

$$0 = \underbrace{-\frac{\partial}{\partial n}\left(\mu_n(z,n)nf(z,n)\right)}_{\#\text{ of inventor growth}} \underbrace{-\frac{\partial}{\partial z}\left(\left(\mu_z(z,n)-g\right)zf(z,n)\right)}_{\text{Productivity growth}}$$

$$\underbrace{-\eta f(z,n) + \eta\int_0^{\overline{z}} f(z,n)\,dz\Delta(\overline{z})}_{\text{Leapfrog}}$$

- $\Delta(\overline{z})$: Dirac delta function

Numerical Exercises

Numerical Exercises: Functional Forms

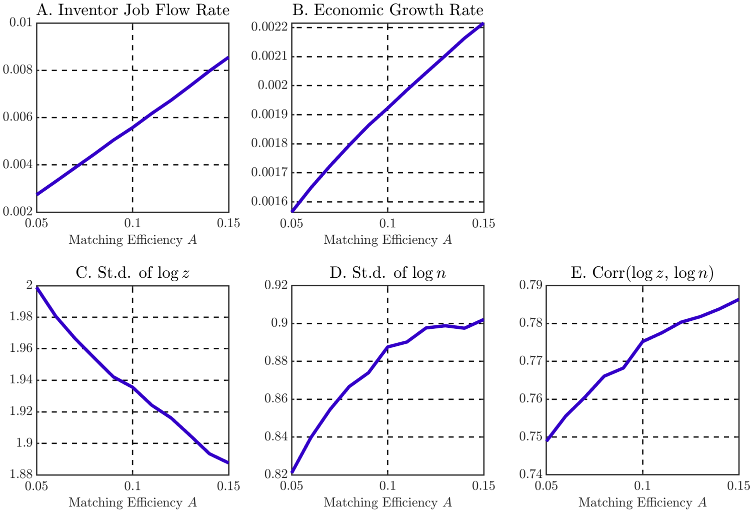
- Vacancy cost function: $c(v) = \frac{\overline{c}}{\phi+1} v^{\phi+1}$
- In-house R&D rate function: $\gamma(n, i) = \gamma_i n^{\delta}$
  - $i \in \{h, l\}$: firm's innovation state
  - Following two-state Markov process
    - $h \to l$ at rate λ_h
    - $l \to h$ at rate λ_l
  - Now, the state variables are (z, n, i)
- Knowledge diffusion rate function: $\alpha(z, z') = \alpha \left(\frac{z'}{z}\right)^{\beta}$

Numerical Exercises: Parameter Values

ρ	discount rate	0.0041	5 % annual real interest rate
γ_h	R&D coefficient	0.0005	2 % economic growth
γ_l	R&D coefficient	0	normalization
δ	R&D curvature	0.5	
A	matching efficiency	0.1	
α	diffusion rate	0.002	
β	diffusion curvature	0.5	
$\overline{c}$	vacancy cost coefficient	100	normalization
ϕ	vacancy cost elasticity	3.45	Bilal et al. (2022)
$\overline{z}$	detrended frontier productivity	1	normalization
$\mathtt{m}$	total mass of firms	1	normalization
$\mathtt{n}$	average/total # of inventors	1	normalization
η	leapfrog	0.0003	
λ_h	$h \rightarrow l$	0.02	
λ_l	$l \rightarrow h$	0.01	

Comparative Statics: Matching Efficiency A

density of firms



Inventor Market Frictions $\uparrow$ (A $\downarrow$) $\rightarrow$

1. Inventor job flow $\downarrow$
2. Knowledge diffusion $\downarrow$
3. Productivity dispersion (Var(z)) $\uparrow$
4. Firms' incentive of inventor hiring changes ($\rightarrow$ Corr(z,n) $\downarrow$)
   - High productivity firms (in-house R&D)
   - Low productivity firms (knowledge diffusion) $\uparrow$
5. The number of inventors at technology frontier firms $\downarrow$
6. Economic growth rate $\downarrow$

A↓ is Consistent with German Data

inventor job flow trend

	1998	2014
Inventor job flow rate	49.4%	12.5%
TFP growth rate (5 year ave)	2.31%	0.48%
CV of z	0.93	1.12
CV of n	4.34	3.14
Corr(z, n)	0.17	0.09

- TFP: EU KLEMS, manufacturing
- z: patent citation per inventor in each establishment
- n: the number of inventors in each establishment

Next steps

- Analytical results
  - existence and uniqueness of stationary equilibrium
  - canalization of highest/lowest productivity firms
- Structural estimation / transition dynamics / policy implication
- Causal effect of inventor job flows on knowledge diffusion using INV-BIO
  - Use exogenous reasons for the job change

Appendix

Plan for Structural Estimation

Plan for Structural Estimation

δ	R&D curvature	
β	diffusion curvature	
A	matching efficiency	gross inventor job flow
γ_h	R&D coefficient	economic growth rate
α	diffusion rate	
λ_h, λ_l	$h \to l$, $l \to h$	
η	leapfrog	

- Other candidate of moments
  - inventors' job flow over productivity ranks inventor flows
  - inventors' distribution over productivity ranks inventor dist.
- "IAB Job Vacancy Survey" provides moments related to vacancy.

Empirical Fact on Establishment-Level Knowledge Growth

Firm-Level Knowledge Change: Regression Equation

$$
\begin{aligned}
Z_{et+j} - Z_{et} = {} & \beta_0 + \beta_1 \log(N_{et}) + \beta_2 J_{Het} \\
& + \beta_3 X_{et} + \alpha_e + \alpha_t + \varepsilon_{et} \quad \text{(for } j = 1 \sim 5\text{)}
\end{aligned}
$$

- $t = 1980 \sim 2014{-}j$
- Z_{et}: (2-years forward) patent citations per inventor at est. e in year t
- N_{et}: N of inventors
- J_{Het}: N of job changers from a higher productivity est. (incl. 0)
- X_{et}: Z_{et} and log of the establishment's size
- α_e/α_t: Establishment/Year FE

Estimation Reslut Robustness

	$Z_{et+j} - Z_{et}$				
	j=1	j=2	j=3	j=4	j=5
$\log(N_{et})$	.12***	.096***	.083***	.024	.011
	(.020)	(.025)	(.021)	(.021)	(.022)
J_{Het}	.013***	.013***	.012***	.012***	.013***
	(.003)	(.002)	(.003)	(.003)	(.003)
Const.	-.92***	-.847***	-.774***	-.853***	-.748***
	(.17)	(.18)	(.17)	(.19)	(.20)
Control	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
FE	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
Observations	52,326	51,194	49,637	47,833	45,531

Notes: Z_{et} is the ratio of the number of forward citations of the establishment's patent after 2 years from t, to the number of inventors at the establishment. J_{Het} is the number of inventors who moved from establishments with a higher backward 3-year moving average of the number of citations. SEs clustered by establishment and year are reported in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Establishment-Level Knowledge Growth: Summary

- Est. with more inventors have higher knowledge growth
  - $N \uparrow$ by 10% $\sim$ Citation $\uparrow$ by 0.1
- Est. poaching more from higher knowledge est. have higher knowledge growth
  - $J_H \uparrow$ by 10 $\sim$ Citation $\uparrow$ by 0.1
- Plan to treat endogeneity issue by using reasons for the job left

Distribution of inventors back calibration

Est. size	$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Share of Inventors (%)	9.3	3.9	5.2	7.5	12.3	61.7

Est. mean wage	$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Share of Inventors (%)	10.2	6.6	10.5	14.8	24.5	33.3

Est. citations/inventors	$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Share of Inventors (%)	11.3	3.9	4.6	10.4	26.5	43.3

Model z	$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Share of Inventors (%)	19.7	2.8	5.5	12.6	25.6	33.9

Inventor's Job Flows: Mean Wage back

Share of flow (%)		Destination est. mean wage					
		$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Origin est. mean wage	$\leq 50\%$	2.9	1.1	1.0	1.1	1.6	1.9
	50-60	0.8	0.9	1.1	0.9	1.0	1.3
	60-70	1.0	0.9	2.0	2.1	1.9	2.2
	70-80	1.4	1.0	1.7	3.6	3.9	3.4
	80-90	2.3	1.5	2.2	3.2	8.1	7.3
	90-100	3.2	2.1	3.2	4.0	7.0	15.2

- Higher $\rightarrow$ Lower: 35.52, Lower $\rightarrow$ Higher: 35.48

Inventor's Job Flows: Size

Share of flow (%)		Destination est. size					
		$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Origin est. size	$\leq 50\%$	2.6	0.9	0.7	0.8	1.3	5.0
	50-60	0.4	0.5	0.6	0.4	0.5	1.8
	60-70	0.5	0.2	0.7	0.9	0.7	2.3
	70-80	0.6	0.3	0.4	1.3	1.6	3.2
	80-90	1.0	0.4	0.6	0.9	2.9	6.1
	90-100	4.8	2.1	2.8	3.8	6.4	40.3

Notes: Every year, we classify the establishments and calculate the flows for the year based on these classifications. The table shows the total gross flow from 1980 to 2014. The data excludes the employment-unemployment-employment flow.

- Higher $\rightarrow$ Lower: 25.2, Lower $\rightarrow$ Higher: 26.8

Inventor's Job Flows: Size (Inventor Wage $\uparrow$)

Share of flow (%)		Destination est. size					
		$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Origin est. size	$\leq 50\%$	3.8	1.2	0.9	0.9	1.3	5.3
	50-60	0.4	0.8	0.9	0.5	0.5	1.6
	60-70	0.4	0.2	1.1	1.2	0.8	2.0
	70-80	0.5	0.3	0.4	1.9	2.1	2.8
	80-90	0.7	0.3	0.4	0.8	4.0	5.9
	90-100	2.8	1.2	1.7	2.3	4.2	44.1

- Higher $\rightarrow$ Lower: 16.6, Lower $\rightarrow$ Higher: 27.9

Inventor's Job Flows: Mean Wage (Inventor Wage ↑)

Share of flow (%)		Destination est. mean wage					
		$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Origin est. mean wage	$\leq 50\%$	4.4	1.5	1.3	1.4	2.0	2.4
	50-60	0.9	1.3	1.6	1.1	1.1	1.4
	60-70	0.8	0.9	2.6	2.9	1.9	2.2
	70-80	0.7	0.6	1.6	4.8	4.4	3.0
	80-90	1.0	0.7	1.4	2.6	10.5	7.7
	90-100	1.0	0.9	1.4	2.3	5.4	18.8

- Higher → Lower: 22.0, Lower → Higher: 35.7

Inventor's Job Flows: Citations/Inventors (Inventor Wage $\uparrow$)

Share of flow (%)		Destination est. citation per inventor					
		$\leq 50\%$	50-60	60-70	70-80	80-90	90-100
Origin est. citations per inventor	$\leq 50\%$	0.7	0.3	0.2	0.3	0.5	0.8
	50-60	1.2	0.6	0.4	0.64	1.0	1.4
	60-70	1.1	0.5	0.6	0.9	1.3	1.5
	70-80	1.9	0.7	1.0	2.2	3.1	3.1
	80-90	3.6	1.0	1.2	3.5	10.2	8.2
	90-100	5.9	1.3	1.4	3.7	10.9	23.4

- Higher $\rightarrow$ Lower: 38.8 $>$ Lower $\rightarrow$ Higher: 23.6

Identified Inventors back

Descriptive statistics (2000 ∼ 2014)		SIAB Workers	SIAB "Inventors"	INV-BIO Inventors
Daily wage, €	Mean	63.6	96.3	156.2
	S.D.	52.8	60.0	30.0
Age	Mean	40.3	40.5	42.4
	S.D.	13.1	12.3	9.0
Females, %		48.3	14.8	5.7
N of obs., thousand		10,727	1,238	420

Notes: Workers include "inventors." Available sample periods of SIAB and INV-BIO are 2000∼2019 and 1980∼2014, respectively

Estimation Result: Mean Wage back

	$P(D_{it} = 1 \mid I_{it}, X_{it})$		$\log w_{it} - \log w_{it-1}$
	Whole sample	Sample with wage ↑	
I_{it}	.015***	.022***	
	(.003)	(.003)	
D_{it}			-.041***
			(0.08)
$D_{it} \times I_{it}$			.047***
			(.011)
Const.	1.060***	-.507***	.077***
	(.010)	(.014)	(.018)
Control	√	√	√
FE			√
Year	2000∼2019	2000∼2019	2001∼2019
Observations	2,054,898	1,215,995	848,727

Notes: In the first and second columns, robust SEs are reported in parentheses. In the third column, SEs clustered by year and establishments are reported. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Z = Mean Wage (j$= 1 \sim 5$) back

	$\log(Z_{et+j}) - \log(Z_{et})$				
	j=1	j=2	j=3	j=4	j=5
$log(N_{et})$	.005***	.008***	.008***	.008***	.008***
	(.001)	(.001)	(.001)	(.001)	(.001)
J_{Het}	.0000	.0001	.0001	.0002	.0004
	(.0001)	(.0002)	(.0002)	(.0002)	(.0002)
Const.	1.404***	2.206***	2.745***	3.162***	3.453***
	(.10)	(.12)	(.13)	(.13)	(.13)
Control	√	√	√	√	√
FE	√	√	√	√	√
Observations	105,326	102,223	98,707	94,909	89,977

Notes: Z_{et} is the mean daily wage of the full-time employees in the establishment e in year t. J_{Het} is the number of inventors who moved from the establishment with a higher mean wage. SEs clustered by establishment and year are reported in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Z = Mean Wage (j= $6 \sim 10$)

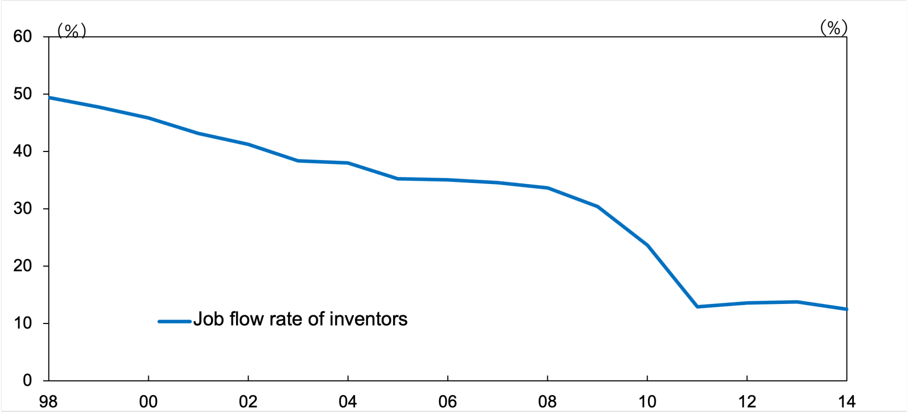
	$\log(Z_{et+j}) - \log(Z_{et})$				
	j=6	j=7	j=8	j=9	j=10
$log(N_{et})$	.007***	.007***	.008***	.008***	.008***
	(.001)	(.002)	(.002)	(.002)	(.002)
J_{Het}	.0006***	.0006***	.0007***	.0008***	.0008***
	(.0002)	(.0002)	(.0002)	(.0002)	(.0003)
Const.	3.679***	3.901***	4.047***	4.205***	4.351***
	(.13)	(.12)	(.11)	(.09)	(.10)
Control	√	√	√	√	√
FE	√	√	√	√	√
Observations	84,455	78,690	72,937	67,355	61,906

Z = Size (j= $1 \sim 5$)

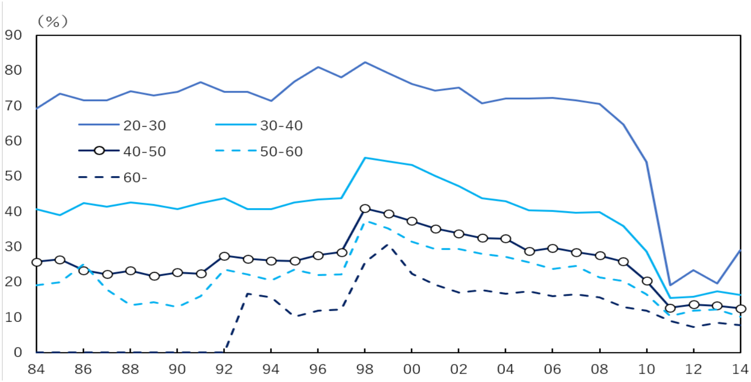
	$\log(Z_{et+j}) - \log(Z_{et})$				
	j=1	j=2	j=3	j=4	j=5
$log(N_{et})$	.006**	.0001	-.007	-.0118**	-.015**
	(.003)	(.004)	(.005)	(.006)	(.006)
J_{Het}	-.0001	.0003	.0004	.0004	-.0004
	(.0004)	(.0006)	(.0008)	(.0009)	(.001)
Const.	1.042***	1.606***	2.078***	2.490***	2.886***
	(.11)	(.14)	(.16)	(.18)	(.20)
Control	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
FE	$\surd$	$\surd$	$\surd$	$\surd$	$\surd$
Observations	105,493	102,379	98,860	95,046	90,101

Notes: Z_{et} is the number of employees in the establishment e in year t. J_{Het} is the number of inventors who moved from the establishment with a higher mean wage. SEs clustered by establishment and year are reported in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Inventor Job Flow Rate in Germany back



Job Flow by Age



Average N of inventors for each category (84-14):
(20-30) 1189, (30-40) 7053, (40-50) 6451, (50-60) 4177, (60-) 583

Density of Firms log f(z,n): A = 0.05 v.s. 0.15 back