Innovation Booms, Easy Financing, and Human Capital Accumulation

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Motivation

Intense technological change often comes with financial speculation

⇒ Easy financing for innovative firms

... can pay high wages and attract talent

⇒ Reallocation of high-skill workers to booming innovative sector

…exposes their human capital to new technologies

Examples: current AI boom, late 1990s dot-com bubble, etc.

⇒ Matters for aggregate labor productivity

Questions

Effect of innovation booms and easy financing on human capital?

1. Effect of joining a booming new technology sector on skilled workers' human capital?

2. Role of financial capital flows?

Effect on human capital ex ante unclear

- Potential upside: Exposure to new technologies ⇒ workers acquire valuable skills

  // Growth-enhancing tech bubbles (Olivier 2000; Caballero Farhi Hammour 2006)

- Potential downside:

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  - Skills linked to rapidly evolving technology ⇒ vintage-specific human capital (Chari Hopenhayn 1991; Deming Noray 2020)
  - Easy financing ⇒ lower quality projects

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  - Easy financing ⇒ lower quality projects
- Role of financial capital flows?
  - Allocation effect: does capital flow to firms whose effect on workers' HK is >0 or <0?
  - Direct effect of capital flows on a firm's workers' human capital?

Empirical design

- Setup: Information and Communications Technology (ICT) late 1990s boom
  - Large
  - Plausibly accompanied by speculative capital flows
  - Possible to study long-run effects

- Data: Administrative employer-employee panel data for France (1994–2015)

This paper

1. Sizeable reallocation of K and skilled L to ICT sector during boom
   - 1/3 of new cohorts of skilled workers start in ICT during boom

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   - 6% lower
     - Not explained by demand effects
     - Not explained by selection effects
     - ⇒ Lower value of human capital

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     - ⇒ Lower value of human capital
3. Capital flows amplify the effect
4. Mechanism: accelerated skill obsolescence

Literature

1. **Financing cycles and innovation.** Quantity (Kortum Lerner 2000; Brown Fazzari Petersen 2009; Bernstein 2015) Composition (Nanda Rhodes-Kropf 2013, 2017; Townsend 2015; Howell Lerner Nanda Townsend 2021; Bernstein McQuade Nanda Roth 2019) Overvaluation (Fedyk Hodson 2022)

   This paper: Impact on human capital

2. **Impact of financing booms and wage premia on talent allocation and long-run productivity growth.** Rent seeking (Baumol 1990; Philippon 2010; Glode Green Lowery 2012; Gupta Hacamo 2022) Growth enhancing bubbles (Olivier 2000; Caballero Farhi Hammour 2006)

   This paper: Reallocation to, and HK accumulation in technology sector

3. **Sectoral allocation and human capital accumulation.** Mostly low skill sectors (Charles Hurst Notowidigdo 2018; Carrillo 2020; Choi Lou Mukherjee 2022)

   This paper: High-skill, innovative sector

4. **Technology vintages** Chari Hopenhayn 1991; Violante 2002; Deming Noray 2020; Kogan Schmidt Seegmiller 2022; Ma 2022

   This paper: Impact of technology & financing boom

Roadmap

The ICT Boom

Wage Dynamics

Role of Capital Flows

Mechanism

Wrap-up

Data

1. Workers: matched employer-employee data for random $1/24^{th}$ of employees
   - High-skill workers: executives and higher intellectual professions
2. Firms: universe of tax files

The Information and Communication Technology (ICT) Sector

ICT industries	Share of total employment (%)	Share of skilled employment (%)
ICT: Services	**1.9**	**7.8**
IT consultancy	0.7	3.4
Software	0.7	3.2
Data processing	0.3	0.8
Maintenance computers	0.1	0.2
Other data/computer-related services	0.1	0.2
ICT: Telecommunications	**1.4**	**2.2**
Telecommunications	1.4	2.2
ICT: Manufacturing	**1.7**	**3.7**
Electronic/communication equipment	0.8	1.8
Measurement/navigation equipment	0.5	1.2
Accounting/computing equipment	0.2	0.7
Insulated wire and cable	0.1	0.1
ICT: Wholesale	**0.5**	**1.2**
Computers, electronics, telecoms	0.5	1.2
ICT: Total	**5.4**	**14.9**

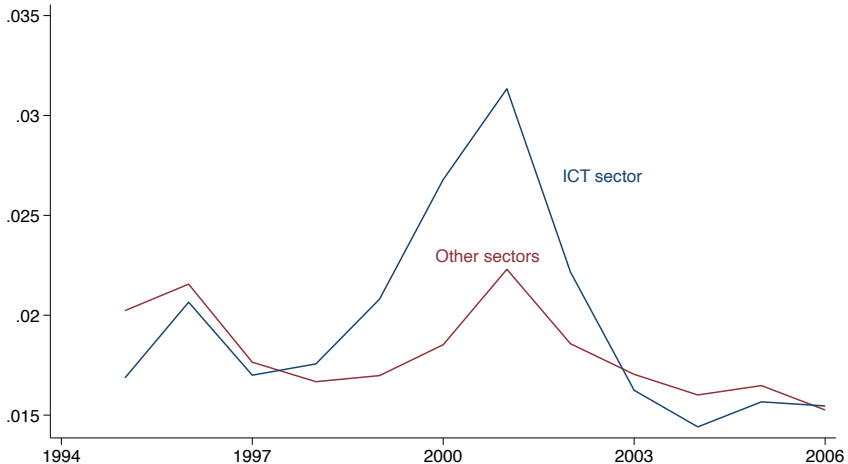
OECD (2002) definition, Universe of matched employer-employee data in France (1994–2008)

ICT boom: equity valuation

- Cumulative stock return: boom → bust → normalization
- (Similar pattern for stock price/sales)

ICT boom: capital reallocation

- Equity issuance/Total assets for universe of listed+private firms
- (Similar pattern for business creation)

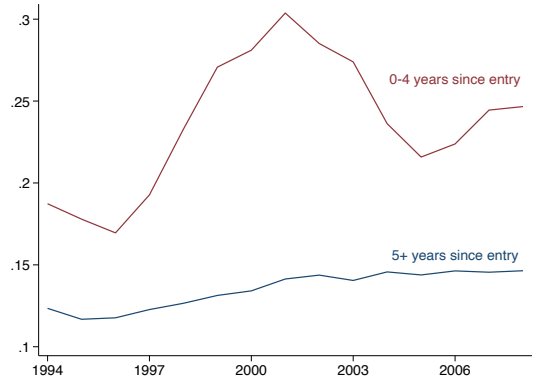


Labor reallocation: the role of the extensive margin

- Reallocation of skilled workers to ICT sector (% skilled employment in ICT)

Labor reallocation: the role of the extensive margin

- Reallocation of skilled workers to ICT sector (% skilled employment in ICT)
- Dynamics driven by workers entering the labor market (= extensive margin)



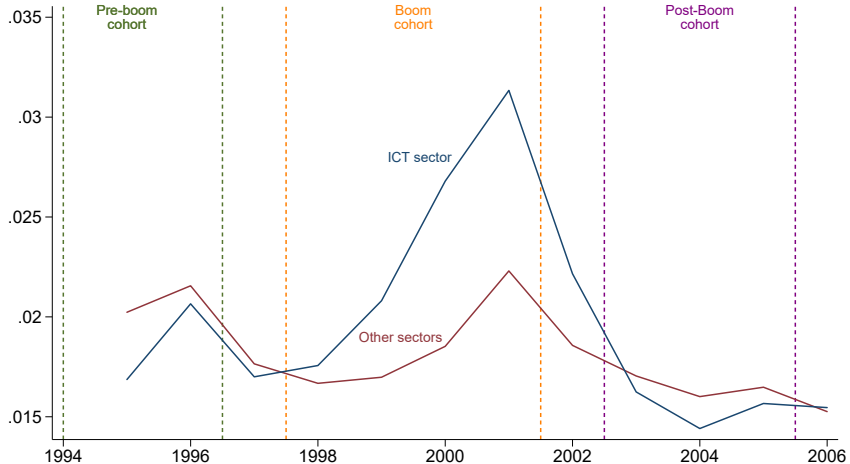
ICT boom: taking stock

1. Large reallocation of capital & skilled labor

2. …that delineates three cohorts of workers: pre-boom, boom, post-boom

Exposure to the boom across cohorts

Equity issuance/Total assets



(Labor market entry)

Roadmap

The ICT Boom

Wage Dynamics

Role of Capital Flows

Mechanism

Wrap-up

Wage dynamics: Across workers within **boom cohort**

- Sample: skilled workers starting between 1998 and 2001

- Baseline regression:

$$\log(wage_{i,t}) = \beta_t \, . \, ICT_{i,0} + \delta_t + \delta_t \times X_i + \epsilon_{i,t}$$

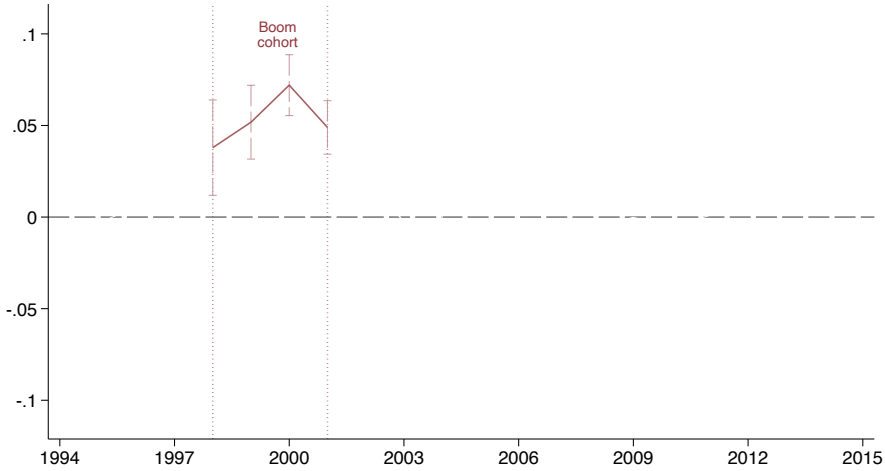
$ICT_{i,0}$ = 1 if worker *i* starts career in ICT sector

→ wage premium can reflect sector reallocation post entry

X_i = entry year, sex, age, age squared, two-digit occupation at entry

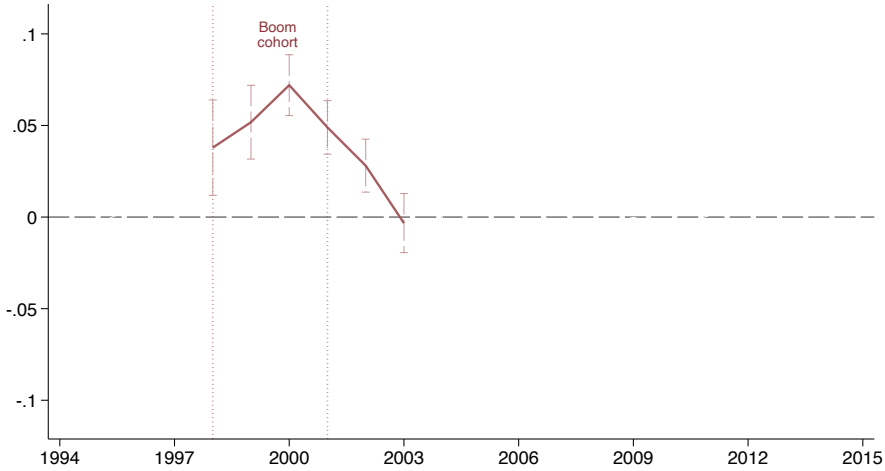
Wage dynamics of boom cohort

– 5% higher entry wage



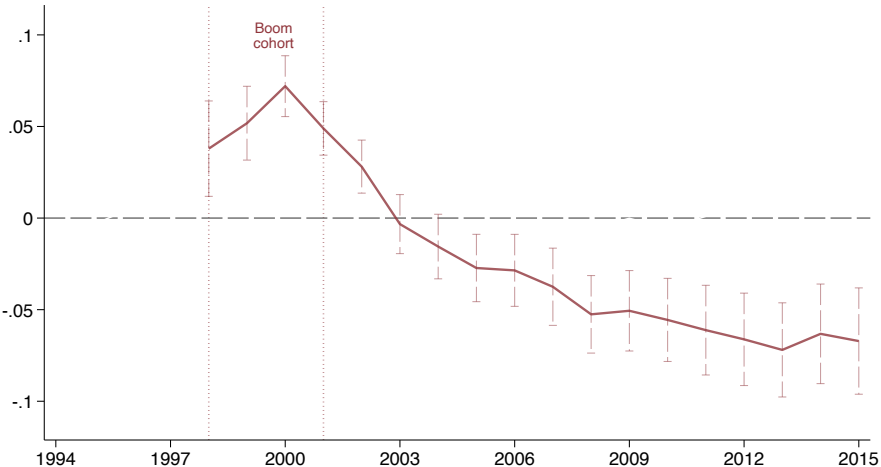
Wage dynamics of boom cohort

– No premium after boom → standard boom-bust



Wage dynamics of boom cohort

– 6% lower wage fifteen years out



Candidate explanations

- **Heterogeneous** workers i (productivity and preferences), overlapping **cohorts** c, choose sector **at entry** k
- **Human capital** has **two** components:
  - **Fixed** component ($\approx$ education, ability): $\theta_{i,k}$
  - **On-the-job** accumulation/depreciation: $dh_{c,k,t}$
- Two types of **sectoral shocks**:
  - **Productivity** shocks in sector k (*all* cohorts)
  - **HK** shocks to $dh_{c,k,t}$ (*sector-**cohort*** specific)

Candidate explanations

- Log wage of individual *i* from cohort *c* in sector *k* at time *t*:

$$w_{i,c,k,t} = w_{k,t} + \theta_{i,k} + \sum_{\tau=c+1}^{t} dh_{c,k,\tau}$$

$w_{k,t}$	$\theta_{i,k}$	$\sum_{\tau=c+1}^{t} dh_{c,k,\tau}$
demand/ supply	worker quality (selection)	accumulated human capital

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demand/ supply | worker quality (selection) | accumulated human capital

⇒ Δ average wage between two sectors for cohort *c* at time *t*:

$$\Delta\overline{w}_{c,t} = \Delta w_t + \Delta\overline{\theta}_c + \sum_{\tau=c+1}^{t} \Delta dh_{c,\tau}$$

Candidate explanations

- Log wage of individual *i* from cohort *c* in sector *k* at time *t*:

$$w_{i,c,k,t} = w_{k,t} + \theta_{i,k} + \sum_{\tau=c+1}^{t} dh_{c,k,\tau}$$

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- Tighter identification (across cohorts) rules out demand/supply and selection

Ruling out labor market imbalance

$$\Delta \overline{w}_{c,t} = \Delta \boldsymbol{w_t} + \Delta \bar{\theta}_c + \sum_{\tau=c+1}^{t} \Delta dh_{c,\tau}$$

demand/ supply

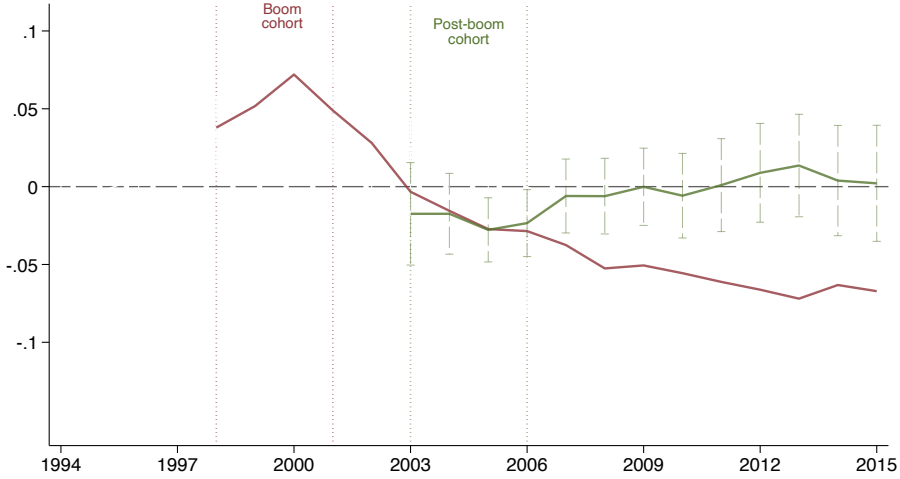
worker quality (selection)

accumulated human capital

- Hypothesis: low labor demand/oversupply of labor in ICT after the boom
- Implication: post-boom cohort should also experience wage decline

Wage dynamics of **post-boom** cohort (2003–2005)

– Inconsistent with labor market imbalance [statistical difference]



Ruling out selection

$$\Delta \overline{w}_{c,t} = \cancel{\Delta w_t} + \Delta \overline{\theta}_c + \sum_{\tau=c+1}^{t} \Delta dh_{c,\tau}$$

demand/ supply

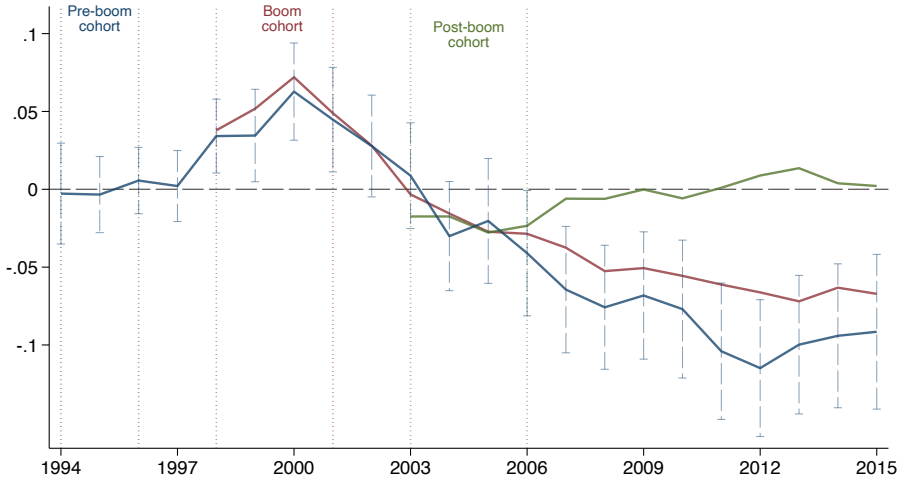
worker quality (selection)

accumulated human capital

- Hypothesis: boom attracts less able workers
- Implication: pre-boom cohort should not display wage decline

Wage dynamics of **pre-boom** cohort (1994–1996)

- Inconsistent with selection [statistical difference]
- Consistent with HK depreciation for all cohorts experiencing the boom



Ruling out selection

Other tests of negative selection:

- No decline in education
- Quantile regressions: not an additional mass of bad outcomes

Taking stock

What explains the wage discount?

$$\Delta \overline{w}_{c,t} = \cancel{\Delta w_t} + \cancel{\Delta \overline{\theta}_c} + \sum_{\tau=c+1}^{t} \Delta dh_{c,\tau}$$

demand/ supply

worker quality (selection)

accumulated human capital

Main specification: across sectors + across cohorts

- Sample: boom cohort (1998–2001) + post-boom cohort (2003–2005)
- Estimating equation

$$\log(wage_{i,c,t}) = \beta_t \, . \, ICT_{i,0} \times BoomCohort_c + \delta_t \times ICT_{i,0} + \alpha_i + \gamma_{c,t} \times X_{i,0} + \epsilon_{i,t}$$

- β_t = wage premium in year t of workers starting

  in ICT sector vs. other sectors

  during the boom vs. after the boom

Long-term wage decline

- Starting in ICT during boom (98–01) ⇒ **7% slower** long-term wage growth from 2003 to 2015

	log(wage)
$ICT_0 \times BoomCohort \times 2003\text{-}05$	0.001
	(0.013)
$ICT_0 \times BoomCohort \times 2006\text{-}10$	-0.035**
	(0.014)
$ICT_0 \times BoomCohort \times 2011\text{-}15$	-0.073***
	(0.019)
$ICT_0 \times$ Year FE	✓
Worker controls × Cohort × Year FE	✓
Worker FE	–
Observations	93,304

Long-term wage decline

- Starting in ICT during boom (98–01) ⇒ **7% slower** long-term wage growth from 2003 to 2015
- Worker FE → control for non-random attrition + selection on levels

	log(wage)	
ICT_0 × BoomCohort × 2003-05	0.001	ref.
	(0.013)	
ICT_0 × BoomCohort × 2006-10	-0.035**	-0.048***
	(0.014)	(0.010)
ICT_0 × BoomCohort × 2011-15	-0.073***	-0.077***
	(0.019)	(0.015)
ICT_0× Year FE	✓	✓
Worker controls × Cohort × Year FE	✓	✓
Worker FE	–	✓
Observations	93,304	92,901

Ruling out other confounding

1. Robust to restricting the sample to US firms (e.g., Microsoft France)
2. Robust to controlling for job termination

   [Alternative check: Job termination ↑ 7pp + Job termination associated with 3.5% long-term wage loss ⇒ Explains <0.3 pp wage loss]

3. Constant effect across the wage distribution in quantile regressions (no winner-take-all)
4. Pattern of attrition is not different for the boom cohort
5. Robust to accounting for profit participation participation in firm profit

Roadmap

The ICT Boom

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Mechanism

Wrap-up

Capital Flows

Do capital flows amplify the negative effect on aggregate HK?

1. Allocative effect: depends on which ICT firms receive the most capital
   - Firms whose workers' HK depreciate the most? The least?
   - → Cov[Capital flow, HK accumulation]?

     (K flow versus L flow)

Allocative effect: Capital flows to firms with largest HK depreciation

- Wage discount only in firms with above-median capital availability
- Cov[Capital flow, HK accumulation]$< 0 \Rightarrow$ aggregate labor productivity $\downarrow$

Proxy of capital availability:	log(Wage)		
	1999 return (Industry level)	1999 P/S (Industry level)	Equity issuance (Industry×geo ×entry-year level)
	(1)	(2)	(3)
ICT_0 × Boom cohort × 2011-15	0.022	0.007	-0.029
	(0.044)	(0.042)	(0.025)
ICT_0 × Capital availability × Boom cohort × 2011-15	-0.129***	-0.113**	-0.081***
	(0.049)	(0.047)	(0.031)
ICT_0× Year FE	✓	✓	✓
Worker controls×Cohort×Year FE	✓	✓	✓
Worker FE	✓	✓	✓
Observations	60,420	60,420	85,128

Direct effect: Does capital flow **cause** faster HK depreciation?

2. Direct effect: easy financing may worsen average project quality and causally accelerates individual-level HK depreciation

   - Alternatively, Cov[Capital flow, HK depreciation] may be driven by omitted factor: technology change $\Rightarrow$ capital flow and HK depreciation

   - Test: re-estimate Cov holding technology fixed $\rightarrow$ within narrow sectors

Direct effect: Capital flow **causes** faster HK depreciation?

– Industry×Cohort×Year FE = within industry, across geography → control for technology shocks

	log(Wage)	
Proxy of capital availability:	Equity issuance (Industry×geo×entry-year level)	
	(3)	(4)
ICT_0 × Boom cohort × 2011-15	-0.029	–
	(0.025)	–
ICT_0 × Capital availability × Boom cohort × 2011-15	-0.081***	-0.083**
	(0.031)	(0.035)
ICT_0× Year FE	✓	✓
Worker controls×Cohort×Year FE	✓	✓
Worker FE	✓	✓
Industry×Cohort×Year FE	–	✓
Observations	85,128	85,128

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What drives human capital depreciation?

Hypothesis: Skill obsolescence

- Skills are vintage specific → made obsolete by technological change
- Test: compare jobs with different level of technological content

Skill obsolescence

- Universe of workers by occupation level: high / middle / low skill
- Wage decline largest in high-skill occupations

	log(Wage)					
	High-skill		Middle-skill		Low-skill	
	(1)	(2)	(3)	(4)	(5)	(6)
ICT_0 × Boom cohort × 2011-15	-0.077***	-0.029	-0.068***	-0.039*	-0.022	-0.027
	(0.015)	(0.025)	(0.014)	(0.023)	(0.020)	(0.040)
ICT_0 × Capital availability × Boom cohort × 2011-15		-0.081***		-0.033		-0.004
		(0.031)		(0.029)		(0.041)
Worker controls×Cohort×Year FE	✓	✓	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓	✓	✓
Observations	92,901	85,128	206,918	186,477	250,620	218,927

Skill obsolescence

- Universe of workers by occupation level: high / middle / low skill
- Wage decline largest in high-skill occupations
- ... particularly so if large inflow of capital

	log(Wage)					
	High-skill		Middle-skill		Low-skill	
	(1)	(2)	(3)	(4)	(5)	(6)
ICT_0 × Boom cohort × 2011-15	-0.077***	-0.029	-0.068***	-0.039*	-0.022	-0.027
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Worker controls×Cohort×Year FE	✓	✓	✓	✓	✓	✓
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Two main results:

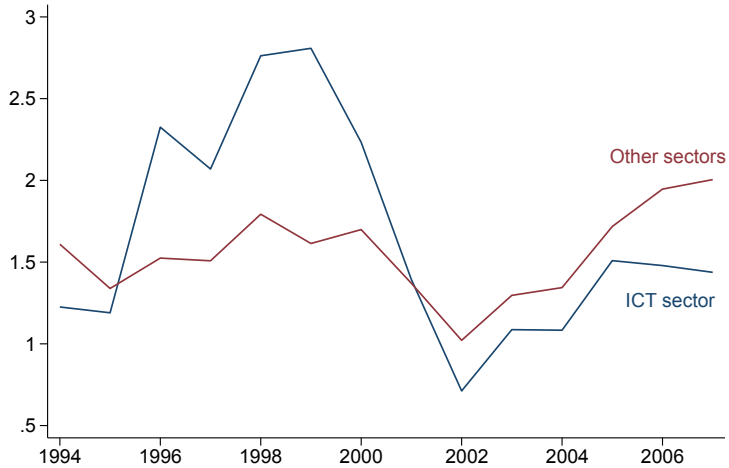
1. Skilled workers starting in booming tech sector eventually lose human capital
   - Wage 6%–8% lower fifteen years out
   - Explained by skill obsolescence not by labor market imbalance and selection
2. Aggregate skill obsolescence amplified by easy financing

Wrap-up

Implications:

- Skill-biased technological change?
  - Our paper: *within* skilled workers, those who develop and implement new technologies (who represent one-third of the boom cohort) lose out
- Growth-enhancing technology bubble?
  - Maybe positive externalities, but
  - Capital allocated to firms that do not enhance their workers' human capital → lower aggregate labor productivity

ICT boom: stock price/sales per share



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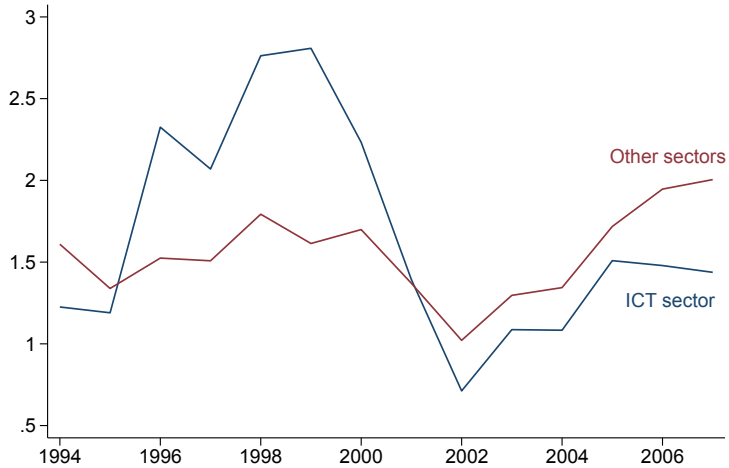
ICT boom: firm entry/stock of firms



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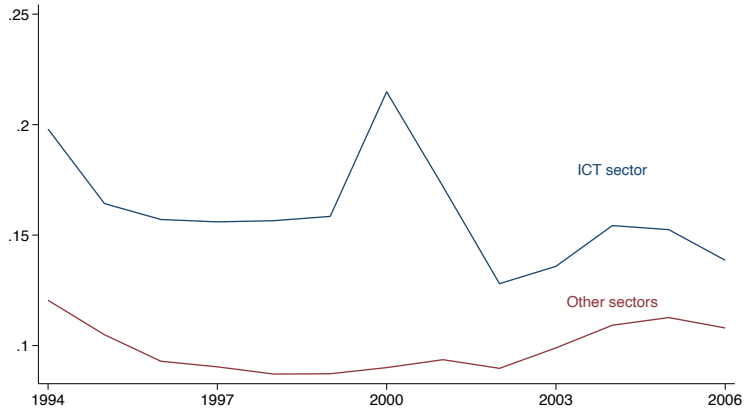
ICT boom: capital reallocation



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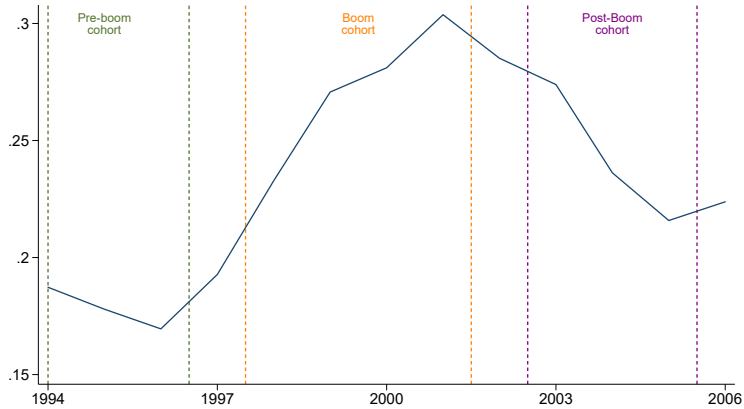
ICT boom: skilled labor market entrants



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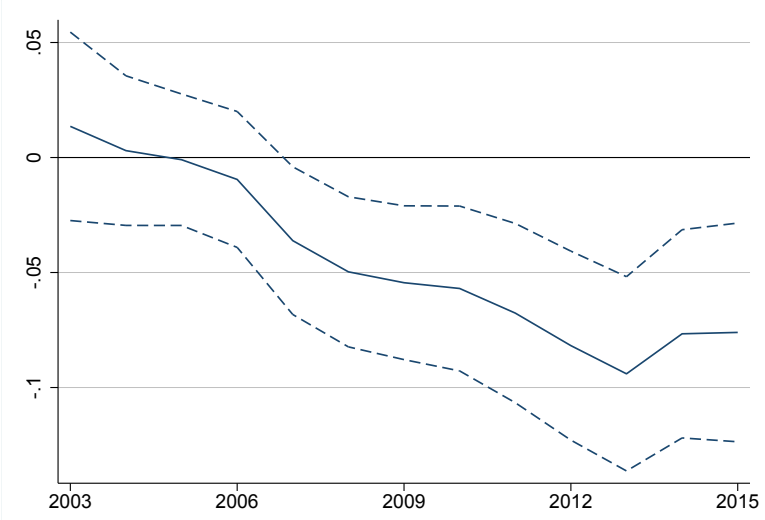
Wage premium: boom cohort vs. post boom cohort



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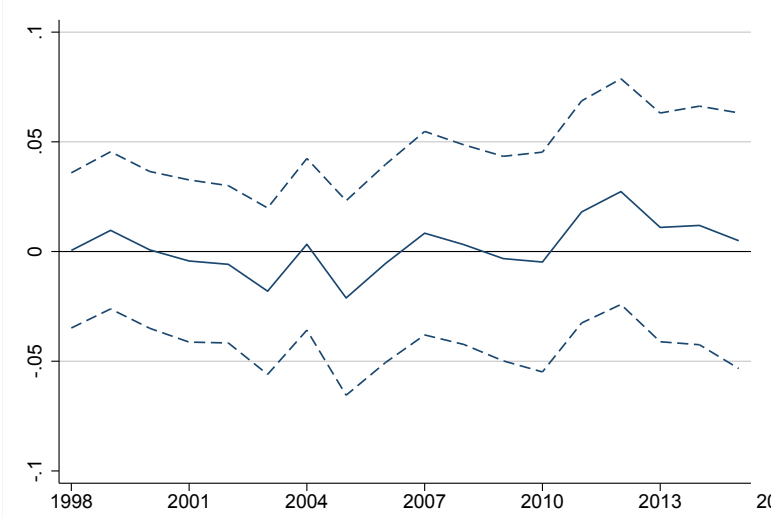
Wage premium: boom cohort vs. pre boom cohort



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Worker controls

	log(Wage)				
	(1)	(2)	(3)	(4)	(5)
ICT_0 × Boom cohort × 2006-10	-0.035**	-0.048***	-0.043***	-0.041***	-0.045***
	(0.014)	(0.010)	(0.010)	(0.011)	(0.013)
ICT_0 × Boom cohort × 2011-15	-0.073***	-0.077***	-0.075***	-0.067***	-0.078***
	(0.019)	(0.015)	(0.015)	(0.016)	(0.019)
Worker controls×Cohort×Year FE	✓	✓	✓	✓	✓
Worker FE	—	✓	✓	✓	✓
Entry wage quintile×Cohort×Year FE	—	—	✓	—	—
Commuting zone×Cohort×Year FE		—	—	✓	—
Four-digit sector×Year FE	—	—	—	—	✓
Observations	93,304	92,901	92,901	92,719	91,343

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Firm controls

- 250 pseudo firms: quintiles of employment, firm age, labor productivity, and whether the firm belongs to a conglomerate ($5 \times 5 \times 5 \times 2 = 250$)
- 5-year growth rate = $[S_{t+5} - S_t]/[(S_{t+5} + S_t) \times 0.5]$

	log(Wage)		
	(1)	(2)	(3)
ICT_0 × Boom cohort × 2011-15	-0.065***	-0.070***	-0.074***
	(0.016)	(0.018)	(0.024)
Worker controls×Cohort×Year FE	✓	✓	✓
Worker FE	✓	✓	✓
Commuting zone×Cohort×Year FE	—	—	✓
Entry wage quintile×Cohort×Year FE	—	—	✓
Four-digit sector×Year FE	—	—	✓
Pseudo firm FE×Year FE	✓	✓	✓
Sales growth ($t \rightarrow t+5$) Quintile FE×Year FE	—	✓	✓
Observations	92,714	90,473	88,586

Back

Job losses explain a tiny part of the wage decline

- Job loss within first four years after entry: employment at initial employer ↓ at least 10% + transition to less-paid job

	log(Wage)		
Control for:	—	Job loss	Job loss ×ICT_0 ×BoomCoh.
	(1)	(2)	(3)
ICT_0 × Boom cohort × 2011-15	-0.077*** (0.015)	-0.076*** (0.015)	-0.069*** (0.017)
ICT_0×Year FE	✓	✓	✓
Worker controls×Cohort×Year FE	✓	✓	✓
Job loss×Year FE	—	✓	—
Job loss×ICT_0×Cohort×Year FE	—	—	✓
Worker FE	✓	✓	✓
Observations	92,901	92,901	92,901

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Robustness: account for “stock options”

- Use net income from tax file, merge with matched employer-employee

	log(Wage)		log(Wage+Cap.income)	
	Excl. finance	US firms	Capital income assigned to CEOs	Capital income assigned to Skilled workers
	(1)	(2)	(3)	(4)
ICT_0 × Boom cohort × 2006-10	-0.049***	-0.033	-0.051***	-0.052***
	(0.010)	(0.032)	(0.011)	(0.011)
ICT_0 × Boom cohort × 2011-15	-0.079***	-0.074*	-0.076***	-0.081***
	(0.015)	(0.044)	(0.015)	(0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓
Observations	87,522	11,359	92,901	92,901

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Robustness: focus on US firms

- Use firm ownership structure → identify US firms

	log(Wage)		log(Wage+Cap.income)	
	Excl. finance	US firms	Capital income assigned to CEOs	Capital income assigned to Skilled workers
	(1)	(2)	(3)	(4)
ICT_0 × Boom cohort × 2006-10	-0.049***	-0.033	-0.051***	-0.052***
	(0.010)	(0.032)	(0.011)	(0.011)
ICT_0 × Boom cohort × 2011-15	-0.079***	-0.074*	-0.076***	-0.081***
	(0.015)	(0.044)	(0.015)	(0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓

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Robustness: remove workers starting in finance

	log(Wage)		log(Wage+Cap.income)	
	Excl. finance	US firms	Capital income assigned to CEOs	Capital income assigned to Skilled workers
	(1)	(2)	(3)	(4)
ICT_0 × Boom cohort × 2006-10	-0.049***	-0.033	-0.051***	-0.052***
	(0.010)	(0.032)	(0.011)	(0.011)
ICT_0 × Boom cohort × 2011-15	-0.079***	-0.074*	-0.076***	-0.081***
	(0.015)	(0.044)	(0.015)	(0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓

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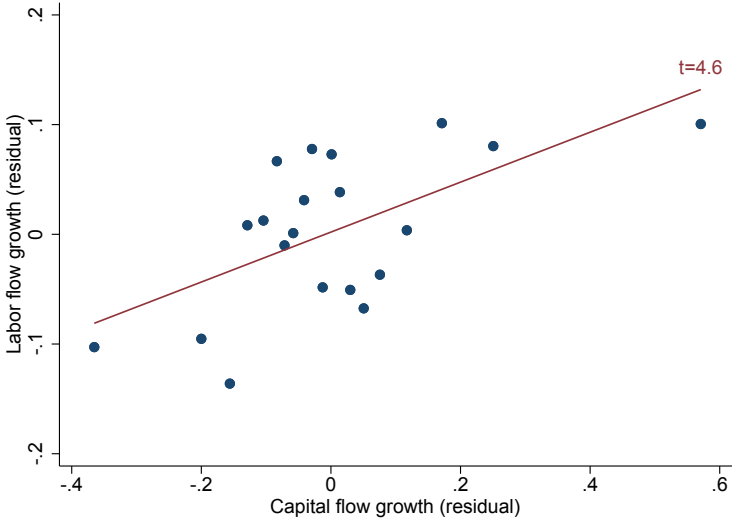
Capital flow versus labor flow



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Winner-take-all?

- Quantile regressions
- Entire wage distribution shifts to the left

	Wage quantiles				
	P10	P25	P50	P75	P90
ICT_0 × Capital availability × Boom cohort × 2011-15	-0.056	-0.065**	-0.077***	-0.089***	-0.098***
	(0.036)	(0.026)	(0.018)	(0.023)	(0.032)
Worker controls	✓	✓	✓	✓	✓
Cohort × Year FE	✓	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓	✓
Observations	93,306	93,306	93,306	93,306	93,306

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