

Innovation Booms, Easy Financing, and Human Capital Accumulation

Johan Hombert
HEC Paris

Adrien Matray
Princeton University

Wharton, April 5 2023

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.

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**?
 - **Allocative effect**: does capital flow to firms whose effect on its workers' human capital is >0 or <0 ?
 - **Direct effect** of capital flows on a firm's workers' human capital?
- Matters for **aggregate labor productivity**

Effect on human capital ex ante unclear

- Potential **upside**
 - Exposure to new technologies \Rightarrow workers acquire **valuable skills**
 - \approx Growth-enhancing tech bubbles (Olivier 2000; Caballero Farhi Hammour 2006)
- Potential **downside**

Effect on human capital ex ante unclear

- Potential **upside**
 - Exposure to new technologies \Rightarrow workers acquire **valuable skills**
 - \approx Growth-enhancing tech bubbles (Olivier 2000; Caballero Farhi Hammour 2006)
- Potential **downside**
 - Skills rapidly **lose value**
 - Skills linked to **rapidly evolving technology** \Rightarrow “vintage-specific human capital”
(Chari Hopenhayn 1991; Deming Noray 2020)
 - Easy financing \Rightarrow **lower quality projects**

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)
 - Track workers from when they start in a sector
 - Compare cohorts of workers starting in ICT sector vs. other sectors

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

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

2. Wage pattern for these workers fifteen years out:

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

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
2. Wage pattern for these workers fifteen years out:
 - 6% lower
 - Not explained by demand effects
 - Not explained by selection effects
 - ⇒ Lower value of human capital
3. Capital flows **amplify** the effect

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
2. Wage pattern for these workers fifteen years out:
 - **6% lower**
 - **Not** explained by **demand effects**
 - **Not** explained by **selection effects**
 - ⇒ 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; 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 1/24th of employees
 - High-skill workers: executives and higher intellectual professions
2. Firms: universe of tax files

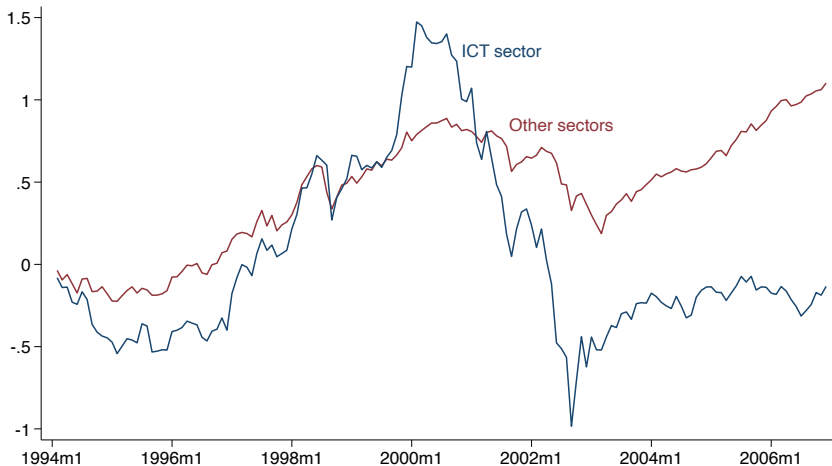
The Information and Communication Technology (ICT) Sector

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)

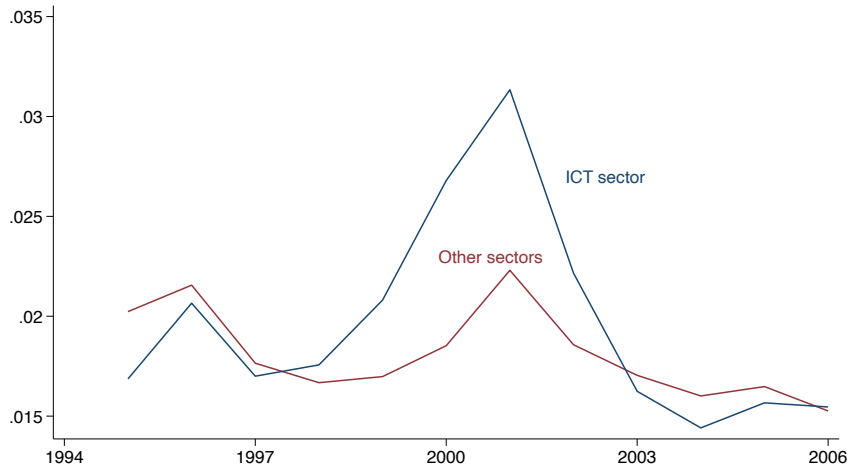
ICT boom: equity valuation

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



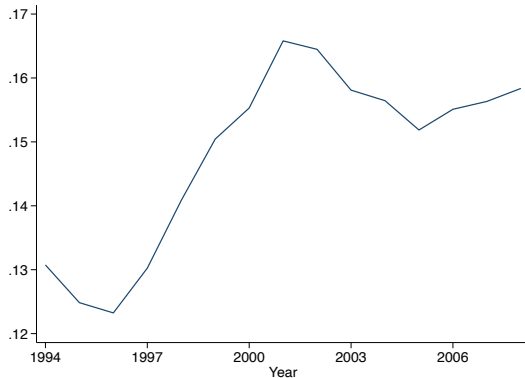
ICT boom: capital reallocation

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



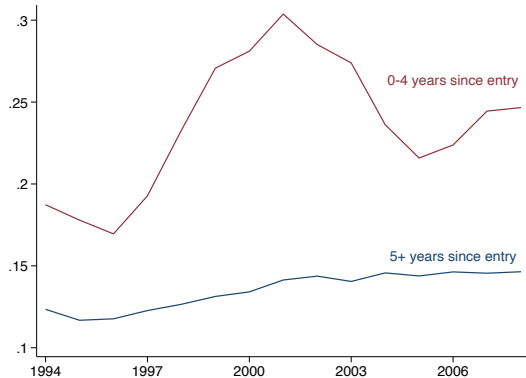
Labor reallocation: the role of the extensive margin

- 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)

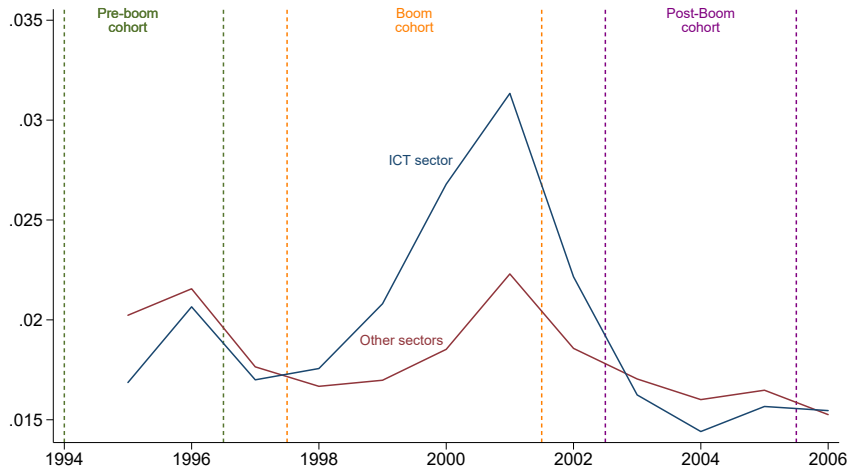


ICT boom: taking stock

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:

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

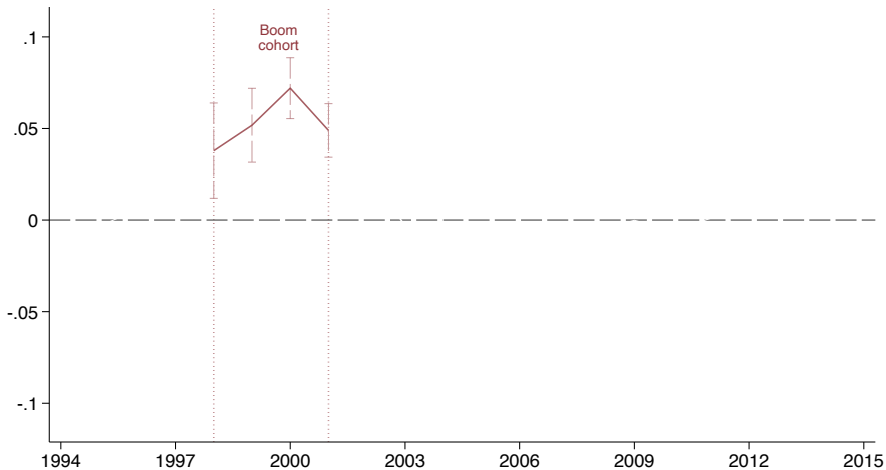
$ICT_{i,0} = 1$ if worker i starts career in ICT sector

→ wage premium can reflect sector reallocation post entry

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

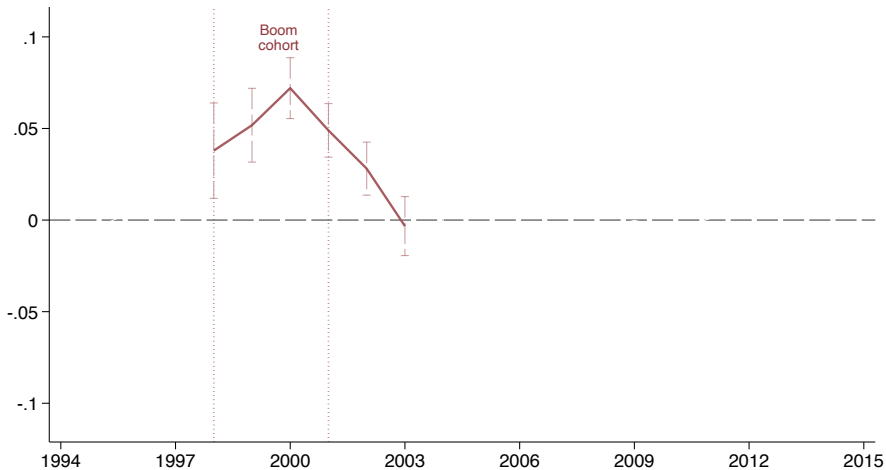
Wage dynamics of boom cohort

- 5% higher entry wage



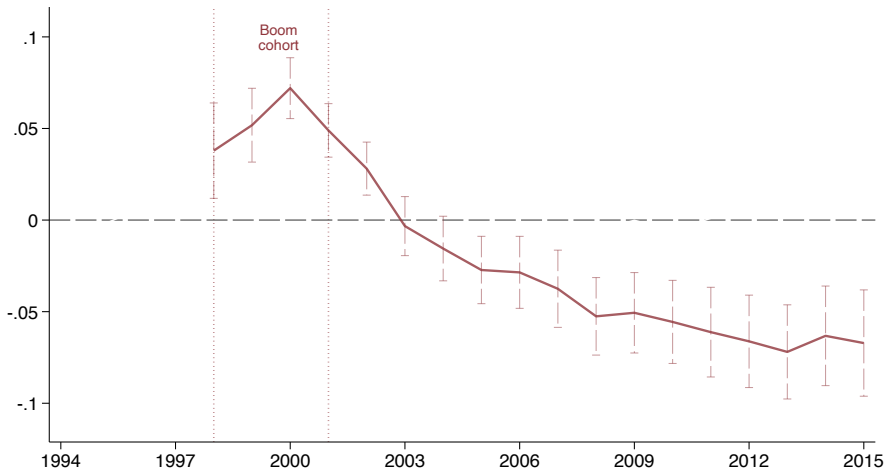
Wage dynamics of boom cohort

- No premium after boom → standard boom-bust



Wage dynamics of boom cohort

- 6% lower wage fifteen years out



Candidate explanations

Key ingredients of the model

- **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: $dh_{c,k,t}$
- Final good produced from intermediate goods k with CES
- Two types of **sectoral shocks**:
 - **Productivity** shocks in sector k (*all cohorts*)
 - **Human capital** accumulation/depreciation shocks to $dh_{c,k,t}$ (*sector-cohort specific*)

Wage dynamics differential

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

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

demand/
supply

worker quality
(selection)

accumulated
human capital

Wage dynamics differential

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

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

demand/
supply

worker quality
(selection)

accumulated
human capital

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

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

Wage dynamics differential

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

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

demand/
supply

worker quality
(selection)

accumulated
human capital

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

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

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

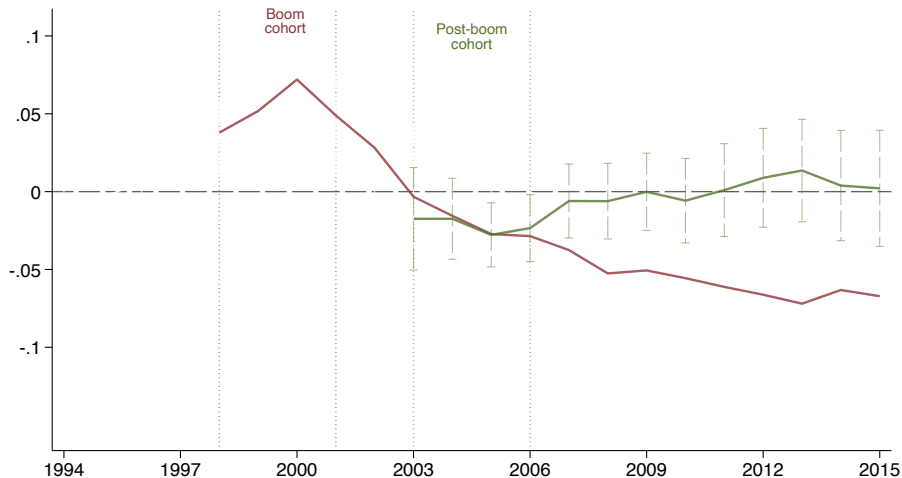
Ruling out labor market imbalance

$$\Delta \bar{w}_{c,t} = \underbrace{\Delta \mathbf{w}_t}_{\text{demand/supply}} + \underbrace{\Delta \bar{\theta}_c}_{\text{worker quality (selection)}} + \underbrace{\sum_{\tau=c+1}^t \Delta dh_{c,\tau}}_{\text{accumulated human capital}}$$

- **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

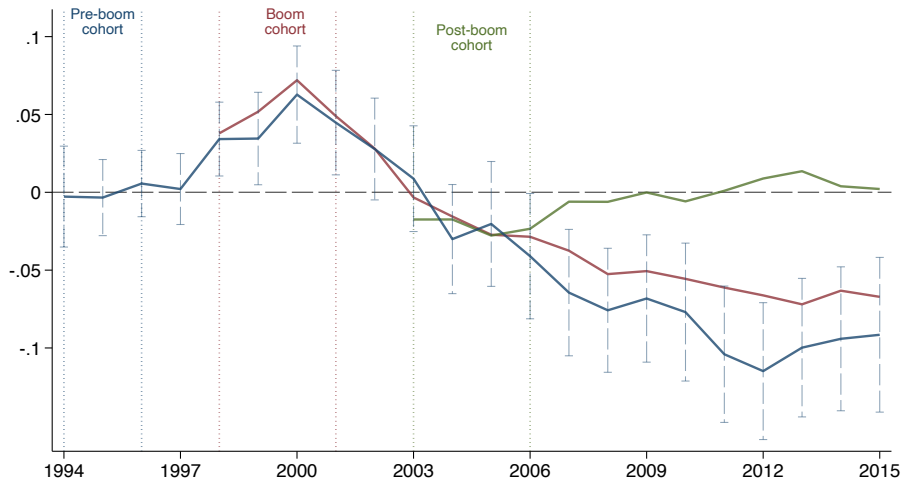
$$\Delta \bar{w}_{c,t} = \cancel{\Delta w_t} + \Delta \bar{\theta}_c + \sum_{\tau=c+1}^t \Delta dh_{c,\tau}$$

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



Taking stock

What explains the wage discount?

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

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

$$\log(\text{wage}_{i,c,t}) = \beta_t \cdot \text{ICT}_{i,0} \times \text{BoomCohort}_c + \delta_t \times \text{ICT}_{i,0} + \alpha_i + \gamma_{c,t} \times X_{i,0} + \epsilon_{i,t}$$

- 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) \Rightarrow **7% slower** long-term wage growth from 2003 to 2015

	log(wage)
ICT ₀ × BoomCohort × 2003-05	0.001 (0.013)
ICT ₀ × BoomCohort × 2006-10	-0.035** (0.014)
ICT ₀ × BoomCohort × 2011-15	-0.073*** (0.019)
ICT ₀ × Year FE	✓
Worker controls × Cohort × Year FE	✓
Worker FE	—
Observations	93,304

Long-term wage decline

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

	log(wage)	
ICT ₀ \times BoomCohort \times 2003-05	0.001 (0.013)	ref.
ICT ₀ \times BoomCohort \times 2006-10	-0.035** (0.014)	-0.048*** (0.010)
ICT ₀ \times BoomCohort \times 2011-15	-0.073*** (0.019)	-0.077*** (0.015)
ICT ₀ \times Year FE	✓	✓
Worker controls \times Cohort \times 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 \uparrow 7pp + job termination associated with 3.5% long-term wage loss \Rightarrow explains <0.3 pp wage loss]
3. Constant effect across the wage distribution in **quantile regressions** (no winner-take-all)
4. No decline in **education**
5. Robust to accounting for profit participation **participation in firm profit**

Roadmap

The ICT Boom

Wage Dynamics

Role of Capital Flows

Mechanism

Wrap-up

Is easy financing making things worse?

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?

→ $\text{Cov}[\text{Capital flow}, \text{HK accumulation}]?$

(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
- $\text{Cov}[\text{Capital flow, HK accumulation}] < 0 \Rightarrow \text{aggregate labor productivity} \downarrow$

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)
$\text{ICT}_0 \times \text{Boom cohort} \times 2011-15$	0.022 (0.044)	0.007 (0.042)	-0.029 (0.025)
$\text{ICT}_0 \times \text{Capital availability} \times \text{Boom cohort} \times 2011-15$	-0.129*** (0.049)	-0.113** (0.047)	-0.081*** (0.031)
$\text{ICT}_0 \times \text{Year FE}$	✓	✓	✓
$\text{Worker controls} \times \text{Cohort} \times \text{Year FE}$	✓	✓	✓
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, $\text{Cov}[\text{Capital flow, HK depreciation}]$ 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

Proxy of capital availability:	log(Wage)	
	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*** (0.031)	-0.083** (0.035)
ICT ₀ × Year FE	✓	✓
Worker controls×Cohort×Year FE	✓	✓
Worker FE	✓	✓
Industry×Cohort×Year FE	—	✓
Observations	85,128	85,128

Roadmap

The ICT Boom

Wage Dynamics

Role of Capital Flows

Mechanism

Wrap-up

What drives human capital depreciation?

Hypothesis: Skill obsolescence

- Skills are **vintage** specific → made obsolete by technological change
- Worsened by easy financing if lower quality technologies are funded
- 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*** (0.015)	-0.029 (0.025)	-0.068*** (0.014)	-0.039* (0.023)	-0.022 (0.020)	-0.027 (0.040)
ICT ₀ × Capital availability × Boom cohort × 2011-15		-0.081*** (0.031)		-0.033 (0.029)		-0.004 (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*** (0.015)	-0.029 (0.025)	-0.068*** (0.014)	-0.039* (0.023)	-0.022 (0.020)	-0.027 (0.040)
ICT ₀ × Capital availability × Boom cohort × 2011-15		-0.081*** (0.031)		-0.033 (0.029)		-0.004 (0.041)
Worker controls×Cohort×Year FE	✓	✓	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓	✓	✓
Observations	92,901	85,128	206,918	186,477	250,620	218,927

Roadmap

The ICT Boom

Wage Dynamics

Role of Capital Flows

Mechanism

Wrap-up

Wrap-up

Two main results:

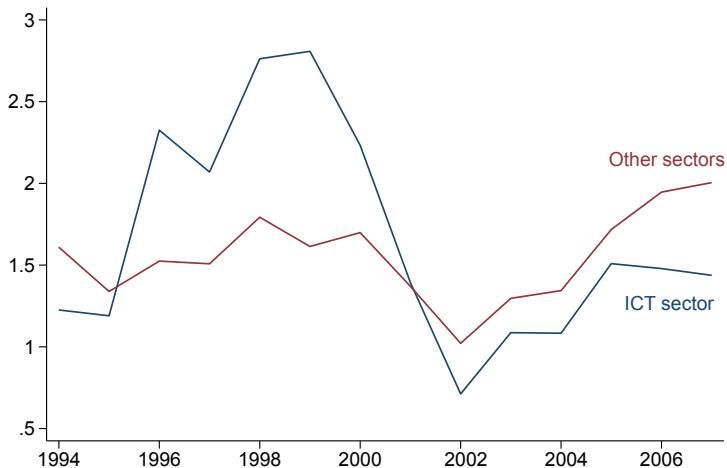
1. Skilled workers starting in booming tech sector eventually **lose human capital**
 - Wage **6%–8% lower fifteen years out**
 - Explained by **skill obsolescence** not by labor market imbalance and selection
2. Aggregate skill obsolescence **amplified by easy financing**

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 financial speculation?
 - Maybe positive externalities, **but**
 - Capital allocated to firms that do not enhance their workers' human capital → lower aggregate labor productivity

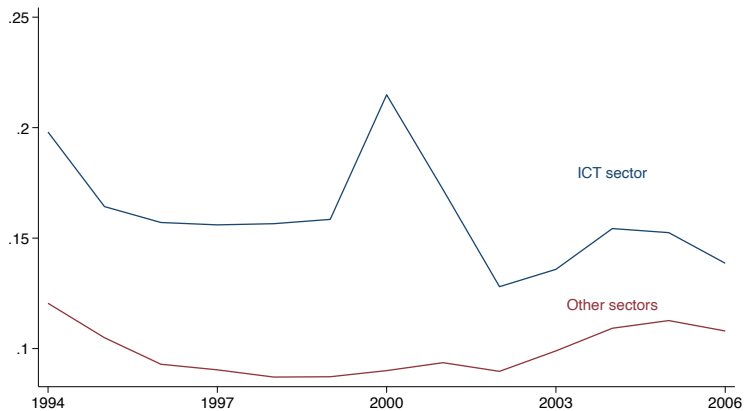
ICT boom: stock price/sales per share



ICT boom: firm entry/stock of firms

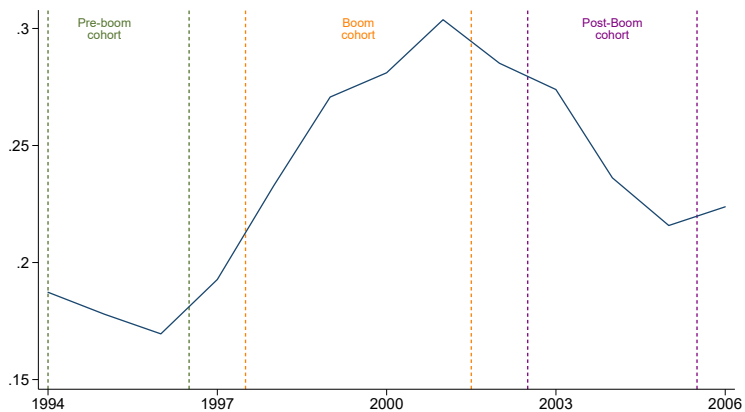


ICT boom: capital reallocation



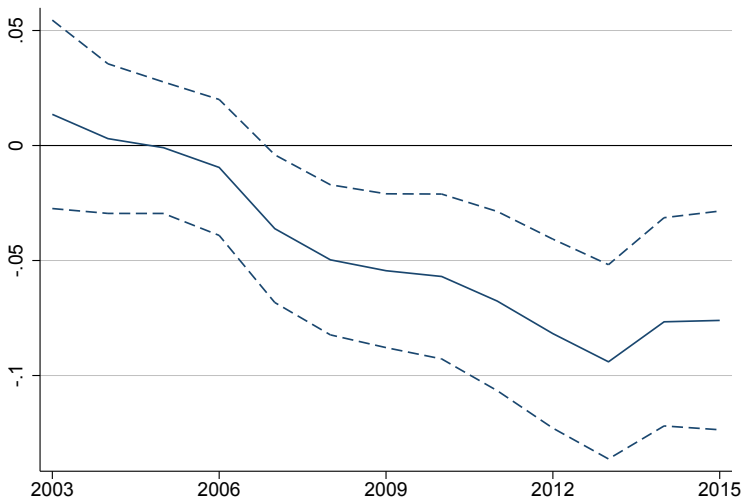
[Back](#)

ICT boom: skilled labor market entrants

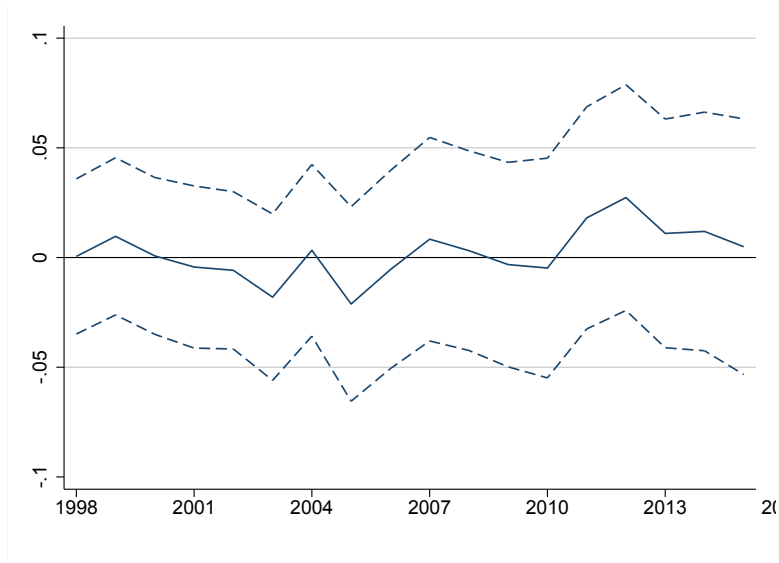


[Back](#)

Wage premium: boom cohort vs. post boom cohort



Wage premium: boom cohort vs. pre boom cohort



Worker controls

	log(Wage)				
	(1)	(2)	(3)	(4)	(5)
$ICT_0 \times \text{Boom cohort} \times 2006-10$	-0.035** (0.014)	-0.048*** (0.010)	-0.043*** (0.010)	-0.041*** (0.011)	-0.045*** (0.013)
$ICT_0 \times \text{Boom cohort} \times 2011-15$	-0.073*** (0.019)	-0.077*** (0.015)	-0.075*** (0.015)	-0.067*** (0.016)	-0.078*** (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

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*** (0.016)	-0.070*** (0.018)	-0.074*** (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

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

Control for:	log(Wage)		
	—	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

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	Skilled workers
	(1)	(2)	(3)	(4)
ICT ₀ × Boom cohort × 2006-10	-0.049*** (0.010)	-0.033 (0.032)	-0.051*** (0.011)	-0.052*** (0.011)
ICT ₀ × Boom cohort × 2011-15	-0.079*** (0.015)	-0.074* (0.044)	-0.076*** (0.015)	-0.081*** (0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓
Observations	87,522	11,359	92,901	92,901

Robustness: focus on US firms

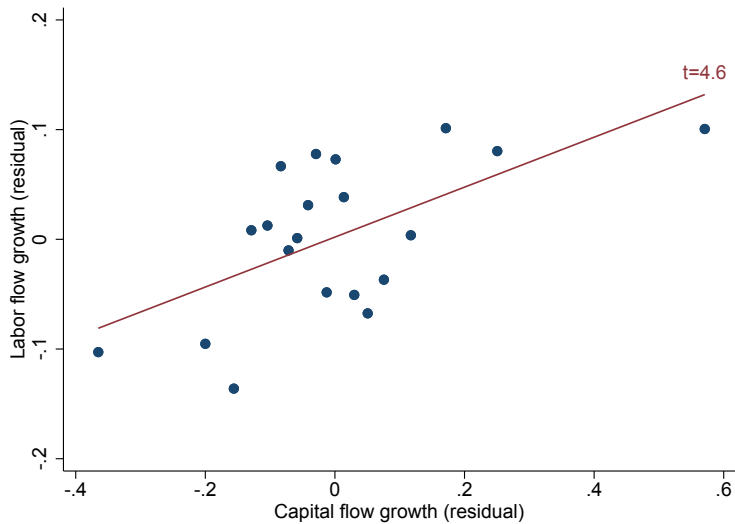
- Use firm ownership structure → identify US firms

	log(Wage)		log(Wage+Cap.income)	
	Excl. finance	US firms	Capital income assigned to CEOs	Skilled workers
	(1)	(2)	(3)	(4)
ICT ₀ × Boom cohort × 2006-10	-0.049*** (0.010)	-0.033 (0.032)	-0.051*** (0.011)	-0.052*** (0.011)
ICT ₀ × Boom cohort × 2011-15	-0.079*** (0.015)	-0.074* (0.044)	-0.076*** (0.015)	-0.081*** (0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓

Robustness: remove workers starting in finance

	log(Wage)		log(Wage+Cap.income)	
	Excl. finance	US firms	Capital income assigned to CEOs	Skilled workers
	(1)	(2)	(3)	(4)
ICT ₀ × Boom cohort × 2006-10	-0.049*** (0.010)	-0.033 (0.032)	-0.051*** (0.011)	-0.052*** (0.011)
ICT ₀ × Boom cohort × 2011-15	-0.079*** (0.015)	-0.074* (0.044)	-0.076*** (0.015)	-0.081*** (0.016)
Worker controls×Cohort×Year FE	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓

Capital flow versus labor flow



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 (0.036)	-0.065** (0.026)	-0.077*** (0.018)	-0.089*** (0.023)	-0.098*** (0.032)
Worker controls	✓	✓	✓	✓	✓
Cohort × Year FE	✓	✓	✓	✓	✓
Worker FE	✓	✓	✓	✓	✓
Observations	93,306	93,306	93,306	93,306	93,306

Back