# 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 tech 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?</li>
  - 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 ⇒ workers acquire valuable skills
    - ≈ Growth-enhancing tech bubbles (Olivier 2000; Caballero Farhi Hammour 2006)
- Potential downside

#### Effect on human capital ex ante unclear

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

# Empirical design

- Episode: 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

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  - 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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- 3. Capital flows amplify the effect
- 4. Mechanism: accelerated skill obsolescence

#### Contribution to the Literature

- Financing cycles and trajectory of innovation. Quantity (Kortum and Lerner, 2000; Brown, Fazzari, and Petersen, 2009; Bernstein, 2015) Composition and risk (Nanda and Rhodes-Kropf 2013, 2017; Townsend 2015; Howell, Lerner, Nanda, and Townsend 2021; Bernstein, McQuade, Nanda, and Roth 2019) human capital overvaluation (Fedyk and Hodson, 2022)
- 2. Role of financing booms and wage premia across sectors on the talent allocation and long-run productivity growth. (Baumol, 1990; Philippon, 2010; Gupta and Hacamo, 2022) Growth enhancing bubbles (Olivier, 2000; Caballero, Farhi, and Hammour, 2006)
- 3. Sectoral allocation and human capital accumulation. Mostly low skill sectors (Charles, Hurst, and Notowidigdo, 2018 Carrillo, 2020; Choi, Lou, and Mukherjee, 2022)
- Technological vintages Chari and Hopenhayn, 1991; Violante, 2002; Deming and Noray, 2020; Kogan, Schmidt, and Seegmiller, 2022; Ma, 2022

# Roadmap

#### The ICT Boom

Wage Dynamics

Role of Financial Capita

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Wrap-up

#### Data

- 1. Workers: matched employer-employee data for random 1/24<sup>th</sup> of employees
  - → High-skill workers: executives and higher intellectual professions
- 2. Firms: universe of tax files
- ICT sector defined by industry

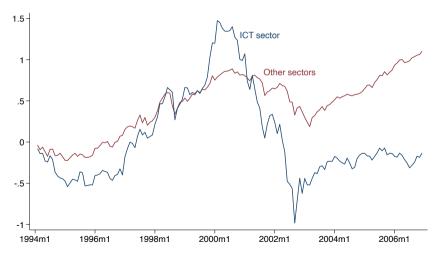
# The Information and Communication Technology (ICT) Sector

ICT industries	Share of	Share of
	total employment	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)

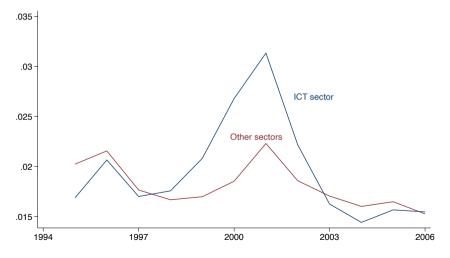
#### ICT boom: equity valuation

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



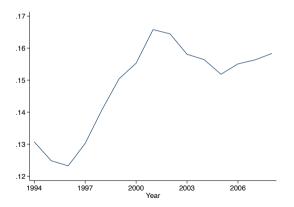
#### ICT boom: capital reallocation

- Equity issuance/Total assets for universe of listed+private firms
- Similar pattern for firm creation rate



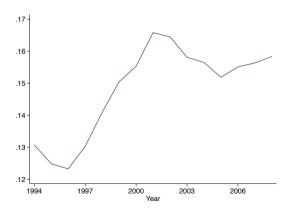
# Labor reallocation: the role of extensive margin

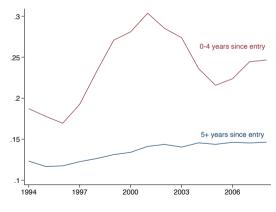
Reallocation of skilled workers to ICT sector (% skilled employment in ICT)



## Labor reallocation: the role of extensive margin

- Reallocation of skilled workers to ICT sector (% skilled employment in ICT)
- Dynamics driven by workers starting their career (= extensive margin)





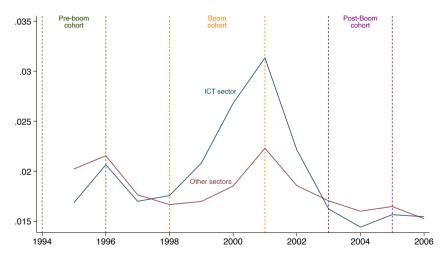
# ICT boom: taking stock

1. Large reallocation of capital & skilled labor

2. Three distinct cohorts of workers: pre-boom, boom, post-boom

# Different exposure to the boom across cohorts

#### Equity issuance/Total assets



# Roadmap

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Graphical evidence
Regressions & robustness

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# Wage differences: across workers within boom cohort

- Sample: Skilled workers starting between 1998 and 2001

Baseline regression:

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

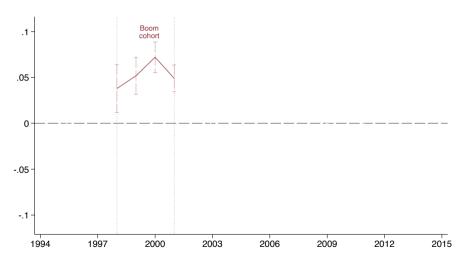
 $ICT_{i,0} = 1$  if worker i starts career in ICT sector

→ wage premium can reflect sector reallocation post entry

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

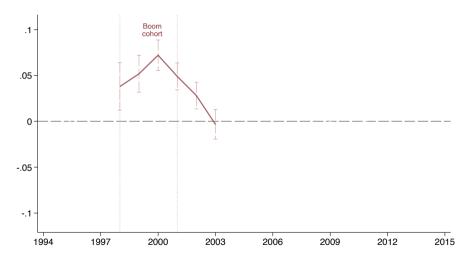
# Wage dynamics of boom cohort

- 5% higher entry wage



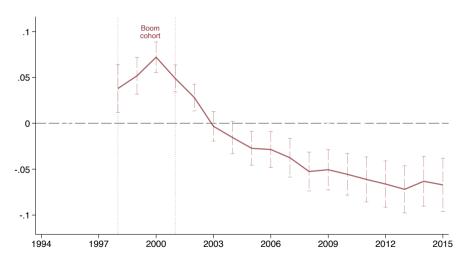
# Wage dynamics of boom cohort

- 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 (productivity and preferences) choose sector at entry
- Human capital has two components:
  - Fixed component (≈ education, ability)
  - On-the-job accumulation / depreciation (sector specific)
- Two types of sectoral shocks:
  - Demand shocks ⇒ sector specific (all cohorts)
  - Technological shocks ⇒ sector-cohort specific

#### Wage Dynamics Differential

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

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

## Wage Dynamics Differential

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

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 $\Rightarrow \Delta$  average wage between two sectors for cohort c at time t:

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

Tighter identification (across cohorts) rules out demand and selection

# Ruling out labor market demand / supply shocks

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

accumulated demand / supply shock worker quality (selection)

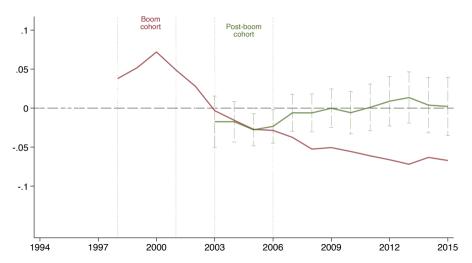
- Hypothesis: low labor demand/high labor supply in ICT after the boom
- Implication: post-boom cohort should also experience wage decline

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

Inconsistent with labor supply / demand shock

Test

Test statistical difference



# Ruling out selection

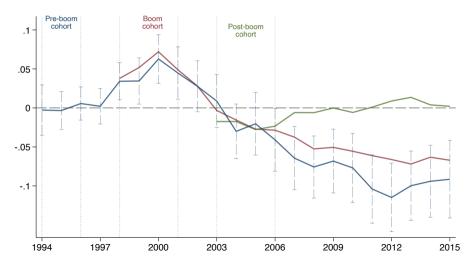
$$\Delta \overline{W}_{c,t} = \sum_{\tau=c+1}^{t} \Delta dh_{c,\tau} + \Delta W_t + \Delta \overline{\theta}_c$$

accumulated demand / supply shock worker quality (selection)

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

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

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



#### Taking stock

What explains the wage discount?

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

accumulated demand / supply shock worker quality (selection)

# Roadmap

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Wage Dynamics

Graphical evidence

Regressions & robustness

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### Main specification: across sectors + across cohorts

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

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

 $-\beta_t$  = wage premium in year t

... of workers starting in ICT sector vs. in other sectors (first difference)

... of workers starting during the boom vs. after boom ends (second difference)

### Main specification: across sectors + across cohorts

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

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

- $\delta_t \times ICT_{i,0}$  = ICT specific shocks (labor supply/demand)
- $\delta_t \times \gamma_c \times X_{i,0}$  = Cohort & worker characteristics time-varying shocks

## Long-term wage decline

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

	log(wage)
$ICT_0 \times BoomCohort \times 2003-05$	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)
Worker controls ICT <sub>0</sub> × Year FE Cohort × Year FE Worker FF	√ √ √
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)			
$ICT_0 \times BoomCohort \times 2003-05$	0.001 (0.013)	ref.		
$ICT_0 \times BoomCohort \times 2006\text{-}10$	-0.035** (0.014)	-0.048*** (0.010)		
$ICT_0 \times BoomCohort \times 2011\text{-}15$	-0.073*** (0.019)	-0.077*** (0.015)		
Worker controls ICT <sub>0</sub> × Year FE Cohort × Year FE Worker FE Observations	√ √ √ − 93,304	√ √ √ 92,901		

## Robustness to possible confounding factors

- Robust to:
  - Controlling for workers' characteristics: city, education
  - Controlling for job termination
  - Controlling for firm characteristics: productivity, age, size, future growth
  - Measurement of earnings: account for participation in firm profit
  - Restricting the sample to US firms (e.g., Microsoft France) → not a French firm phenomenon

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If 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?
  - → Cov[Capital flow, HK accumulation]?

(K flow versus L flow)

- 2. Direct effect: easy financing may worsen average project quality
  - Reduces individual-level HK accumulation?

## 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 ⇒ aggregate labor productivity ↓</li>

	log(Wage)				
Proxy of capital availability:	1999 return (Industry level)	1999 P/S (Industry level)	Equity issuance (Industry×geo ×entry year level)		
	(1)	(2)	(3)		
$ICT_0 \times Boom \ cohort \times 2011-15$	0.022 (0.044)	0.007 (0.042)	-0.029 (0.025)		
$ICT_0 \times Capital \ availability \times Boom \ cohort \times 2011\text{-}15$	-0.129*** (0.049)	-0.113** (0.047)	-0.081*** (0.031)		
ICT <sub>0</sub> × 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?

- Cov[Capital flow, HK depreciation] may reflect causal relation
- ...or both are driven by omitted factor: technology change ⇒ capital flow and HK depreciation
- Test: re-estimate correlation holding technology fixed (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:		y issuance oxentry year level)		
	(3)	(4)		
ICT <sub>0</sub> × Boom cohort × 2011-15	-0.029 (0.025)	- -		
$ICT_0 \times Capital \ availability \times Boom \ cohort \times 2011-15$	-0.081*** (0.031)	-0.083** (0.035)		
ICT <sub>0</sub> × 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?

#### - 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 <sub>0</sub> × 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)
$ICT_0 \times Capital \ availability \times Boom \ cohort \times 2011\text{-}15$		-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)
$ICT_0 \times Boom \ cohort \times 2011-15$	-0.077*** (0.015)	-0.029 (0.025)	-0.068*** (0.014)	-0.039* (0.023)	-0.022 (0.020)	-0.027 (0.040)
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## What drives human capital depreciation?

- Winner-take-all
  - VC/tech-specialized investors prefer projects with small probability of large success
     ⇒ right-skewed outcomes
  - Test: quantile regressions

### Winner-take-all?

- Quantile regressions
- Entire wage distribution shifts to the left

	Wage quantiles				
	P10	P25	P50	P75	P90
$ICT_0 \times Capital \ availability \times Boom \ cohort \times 2011-15$	-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	✓	$\checkmark$	<b>✓</b>	✓	✓
Observations	93,306	93,306	93,306	93,306	93,306

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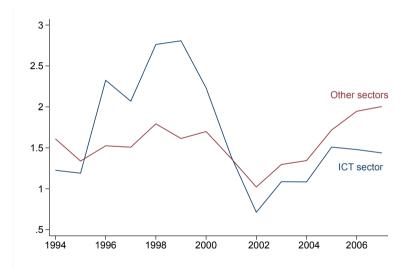
#### Two main results:

- 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

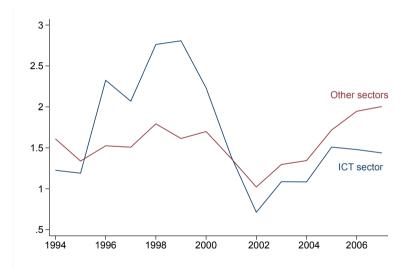
#### Implications:

- 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

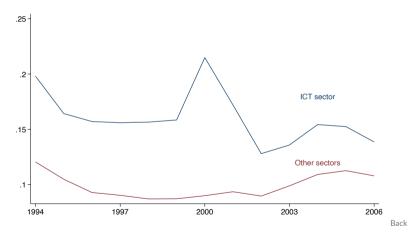
# ICT boom: stock price/sales per share



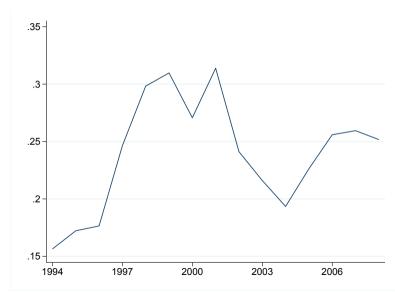
## ICT boom: firm entry/stock of firms



# ICT boom: capital reallocation

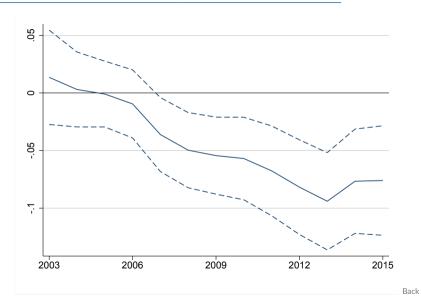


### ICT boom: skilled labor market entrants

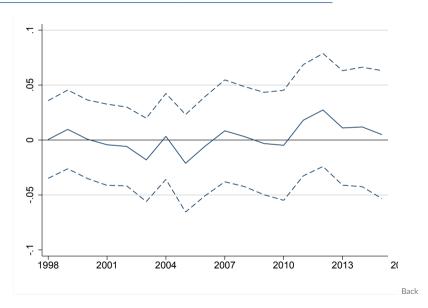


Back

# 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)	
$\overline{ICT_0 \times Boom \; cohort \times 2006\text{-}10}$	-0.035** (0.014)	-0.048*** (0.010)	-0.043*** (0.010)	-0.041*** (0.011)	-0.045*** (0.013)	
$ICT_0 \times Boom\ cohort \times 2011-15$	-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	✓	✓	✓	✓	<b>√</b>	
Worker FE	_	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	
Entry wage quintile×Cohort×Year FE	_	_	$\checkmark$	_	_	
Commuting zone×Cohort×Year FE		_	_	✓	_	
Four-digit sector×Year FE	_	_	_	_	$\checkmark$	
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)	
$ICT_0 \times Boom cohort \times 2011-15$	-0.065*** (0.016)	-0.070*** (0.018)	-0.074*** (0.024)	
Worker controls×Cohort×Year FE	✓	✓	<b>√</b>	
Worker FE	$\checkmark$	$\checkmark$	$\checkmark$	
Commuting zone×Cohort×Year FE	_	_	$\checkmark$	
Entry wage quintile×Cohort×Year FE	_	_	$\checkmark$	
Four-digit sector×Year FE	_	_	$\checkmark$	
Pseudo firm FE×Year FE	$\checkmark$	$\checkmark$	$\checkmark$	
Sales growth $(t \rightarrow t + 5)$ Quintile FE×Year FE	_	$\checkmark$	$\checkmark$	
Observations	92,714	90,473	88,586	

## Job losses explain a tiny part of the wage decline

- Control for forced job loss within first four years after entry → wage discount constant
  - (i)  $\downarrow$  employment at initial employer > 10% (ii) transition to next job  $\rightarrow$  wage cut

		log(Wage)	
Control for:	_	Job loss	
	(1)	(2)	
ICT <sub>0</sub> × Boom cohort × 2011-15	-0.029	-0.026	
	(0.025)	(0.025)	
$ICT_0 \times Capital$ availability $\times$ Boom cohort $\times$ 2011-15	-0.081***	-0.082***	
	(0.031)	(0.031)	
Worker controls×Cohort×Year FE	✓	✓	
Job loss×Year FE	_	$\checkmark$	
Job loss×Cohort×Year FE	_	_	
Worker FE	$\checkmark$	$\checkmark$	
Observations	85,128	85,128	

## Job losses explain a tiny part of the wage decline

- Control for forced job loss within first four years after entry → wage discount constant
  - (i)  $\downarrow$  employment at initial employer > 10% (ii) transition to next job  $\rightarrow$  wage cut
- Same if job loss during a sectoral bust

		log(Wage)	
Control for:	-	Job loss	
	(1)	(2)	(3)
$ICT_0 \times Boom cohort \times 2011-15$	-0.029 (0.025)	-0.026 (0.025)	-0.019 (0.028)
$ICT_0 \times Capital \ availability \times Boom \ cohort \times 2011-15$	-0.081*** (0.031)	-0.082*** (0.031)	-0.083** (0.035)
Worker controls×Cohort×Year FE	<b>√</b>	<b>√</b>	✓
Job loss×Year FE	_	$\checkmark$	_
Job loss×Cohort×Year FE	_	_	$\checkmark$
Worker FE	✓	✓	$\checkmark$
Observations	85,128	85,128	85,128

## 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 inco CEOs	me assigned to Skilled workers
	(1)	(2)	(3)	(4)
$ICT_0 \times Boom \ cohort \times 2006-10$	-0.049***	-0.033	-0.051***	-0.052***
	(0.010)	(0.032)	(0.011)	(0.011)
$ICT_0 \times Boom\ cohort \times 2011\text{-}15$	-0.079***	-0.074*	-0.076***	-0.081***
	(0.015)	(0.044)	(0.015)	(0.016)
Worker controls×Cohort×Year FE	√	√	92,901	√
Worker FE	√	√		√
Observations	87,522	11,359		92,901

### Robustness: focus on US firms

- Use firm ownership structure → identify US firms

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

# Robustness: remove workers starting in finance

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

# Capital flow versus labor flow

