



Learning by Doing

The Real Connection
between Innovation,
Wages, and Wealth

JAMES BESSEN





SALADS

Fruit salad

REGULAR \$4.99 \$5.99

SMALL \$3.99 \$4.99

LARGE \$5.99 \$6.99

FRUIT JUICES

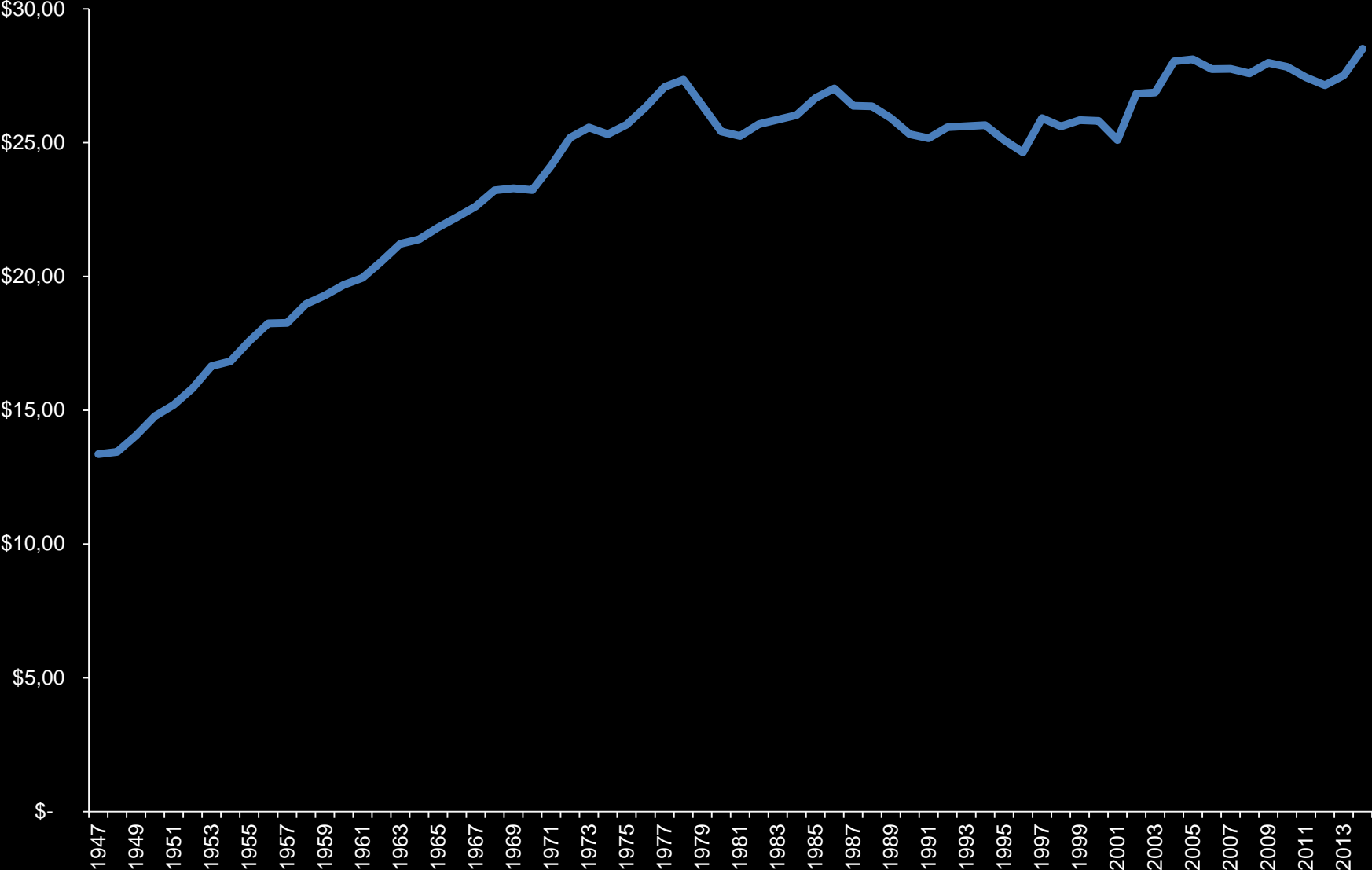
Café Speciale Iced Coffee Gelato Cappuccino

Please pay

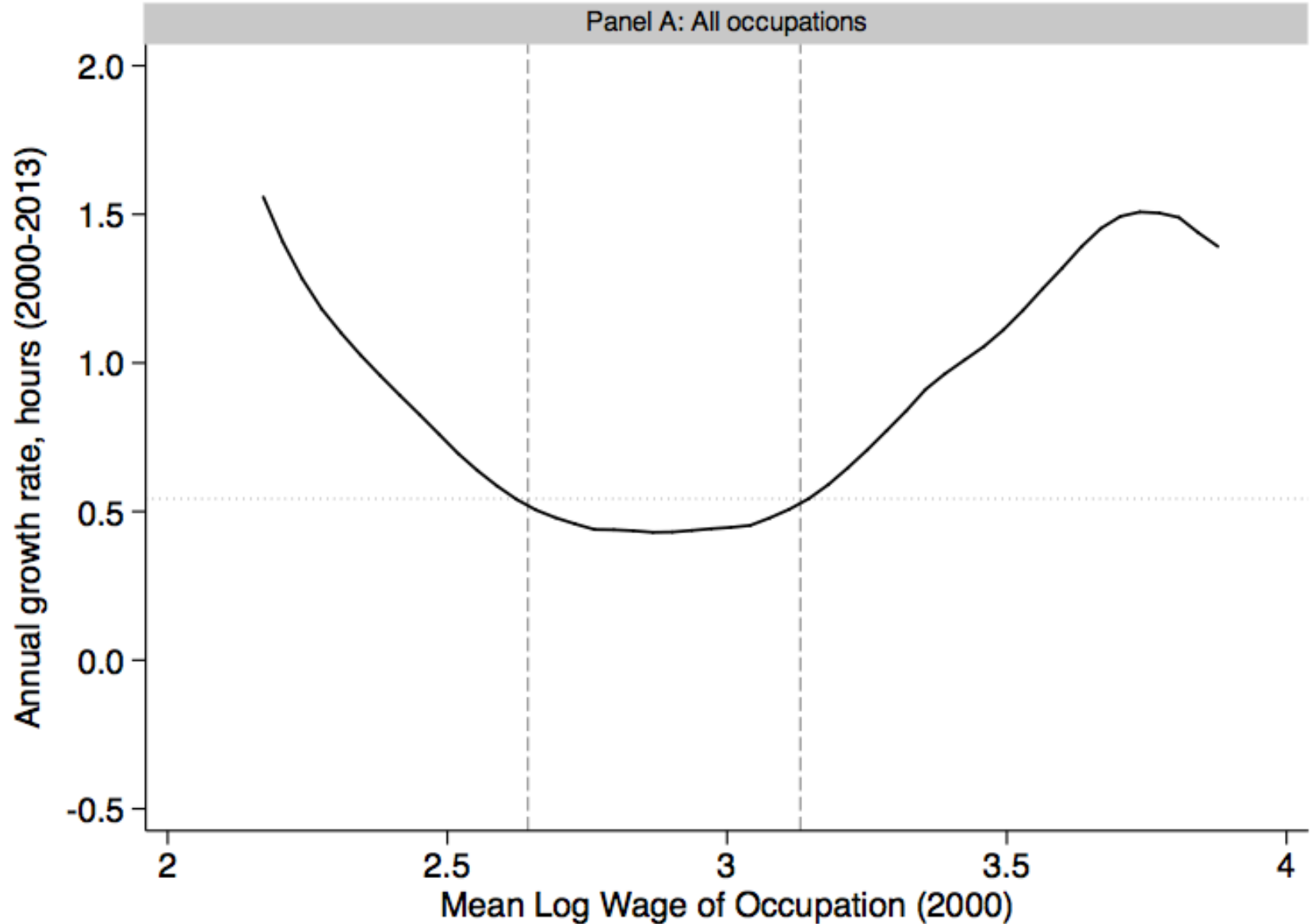
Except...



Hourly Production Wage + Benefits (\$2012)

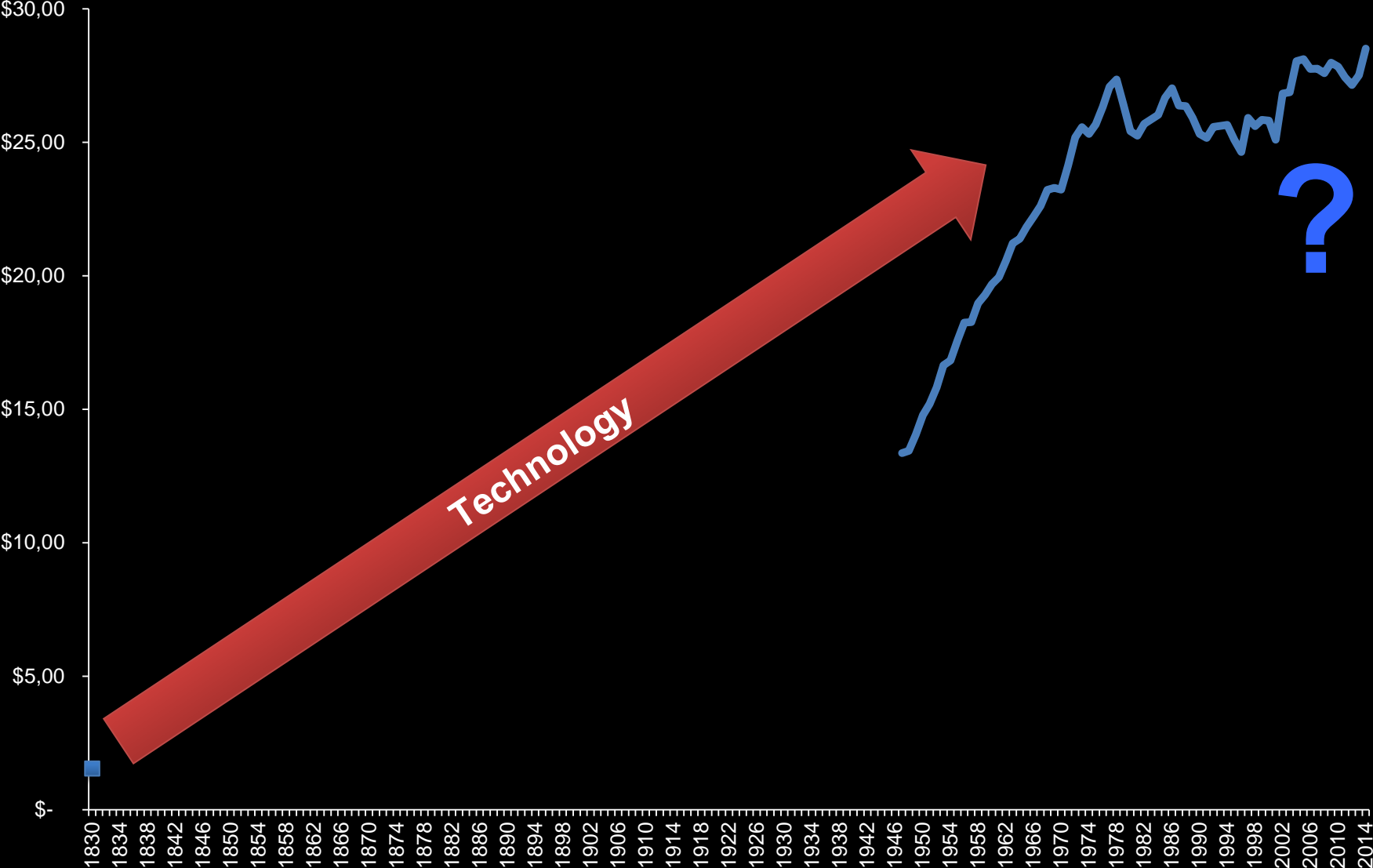


Job Polarization



Break from past?

Hourly Production Wage + Benefits (\$2012)

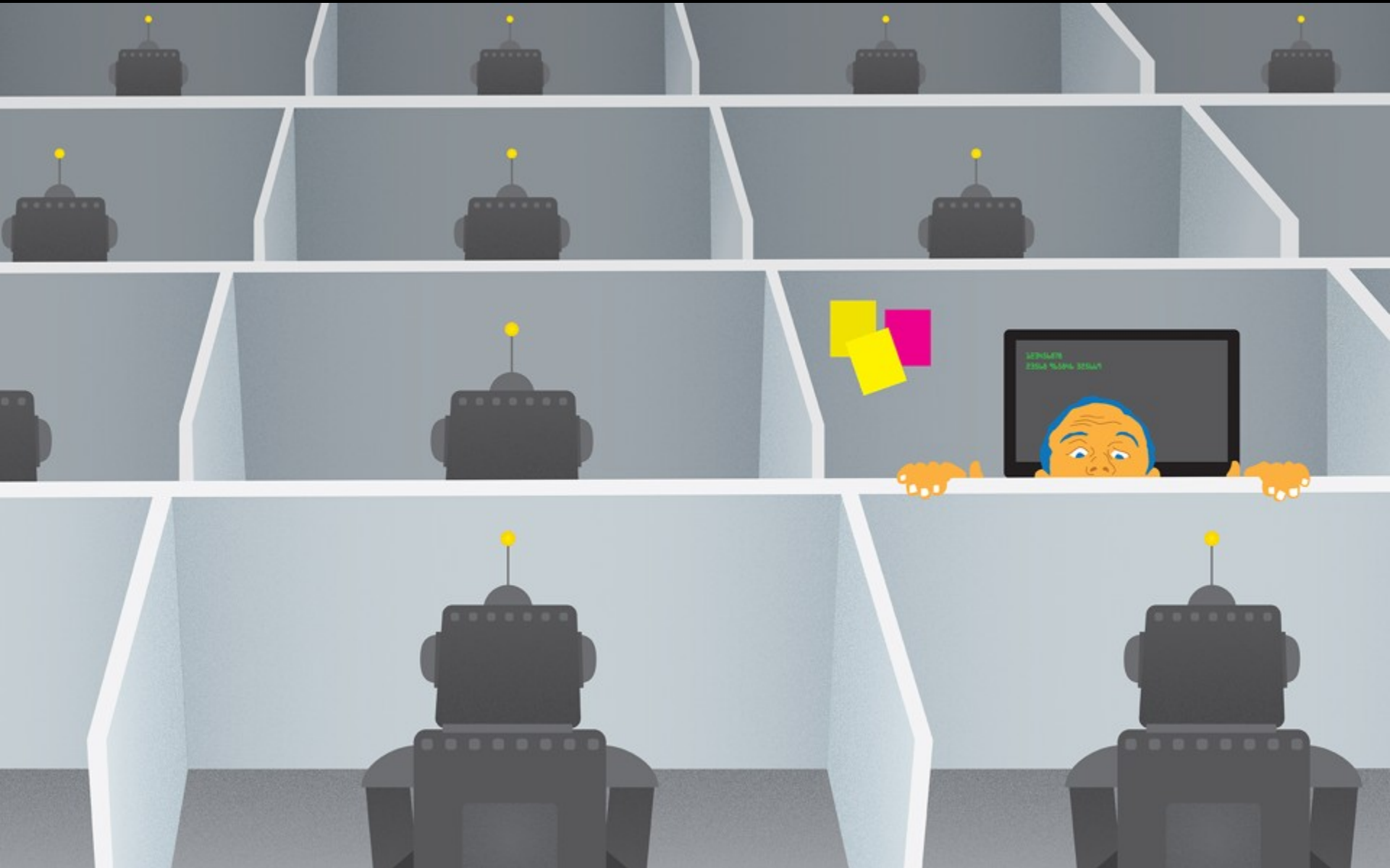


Break from past?

Y: Tech unemployment

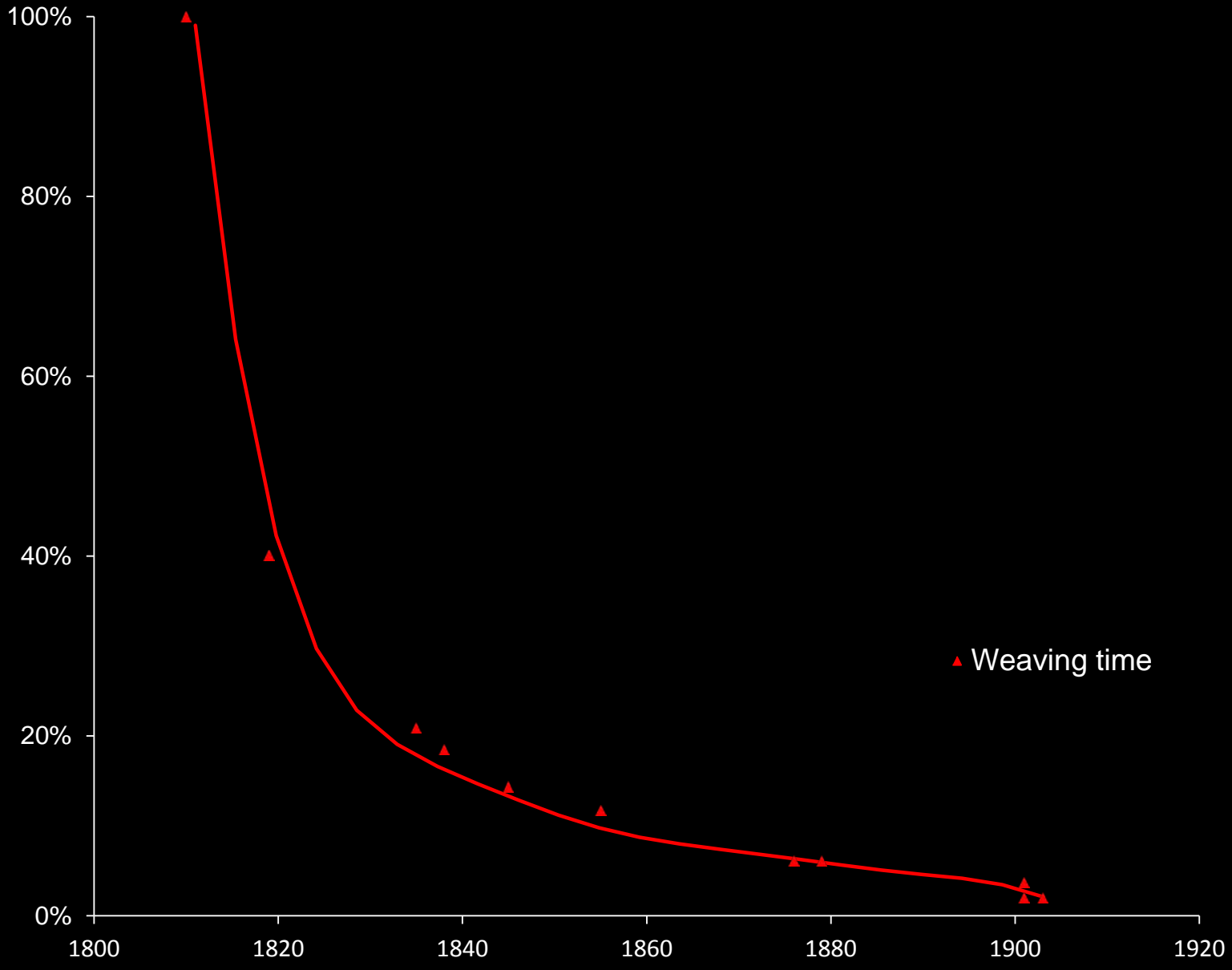
N: Skill gap

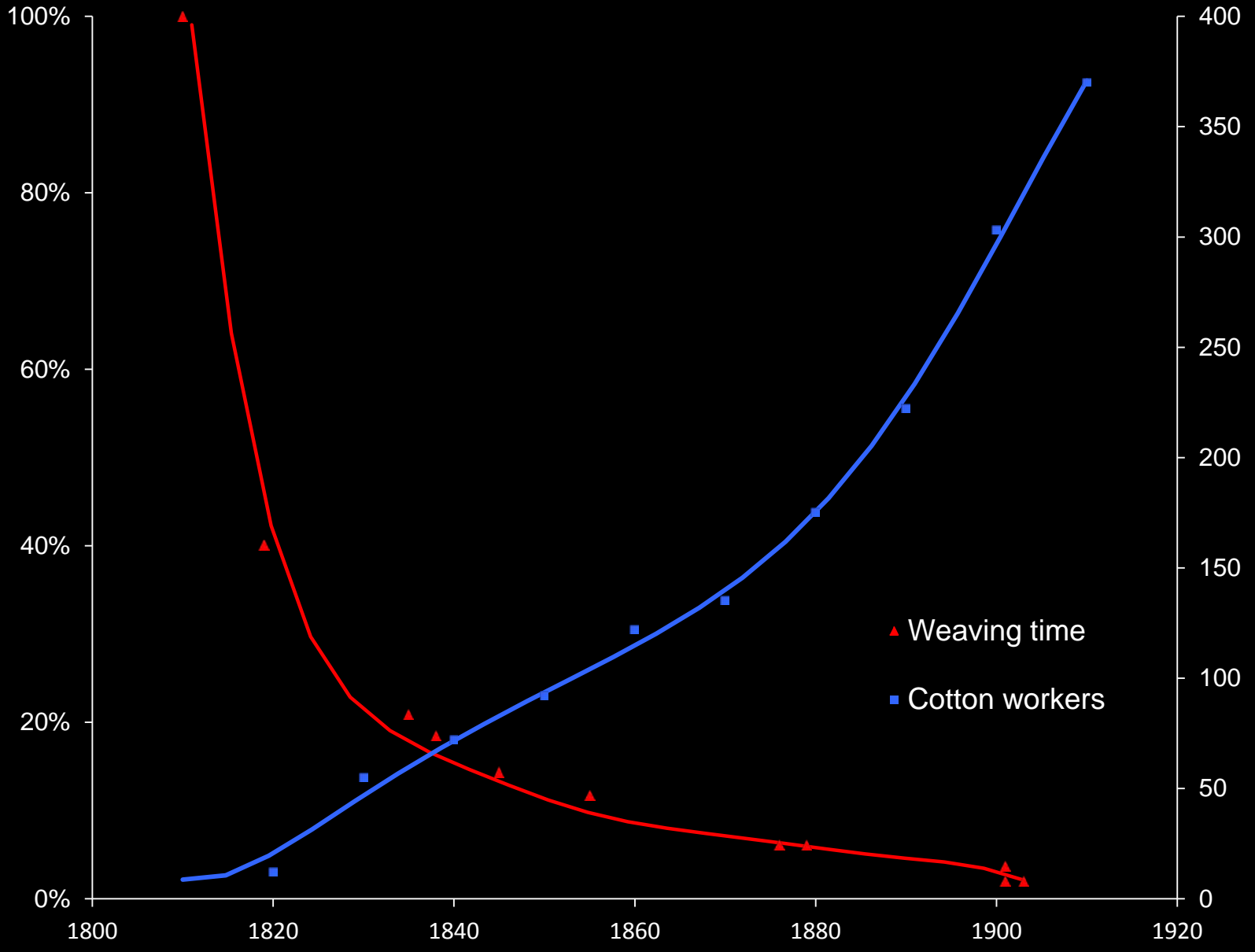
Robots Stealing Jobs?









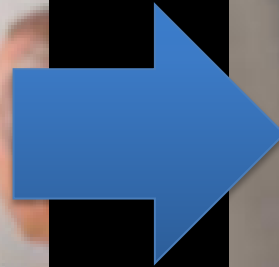


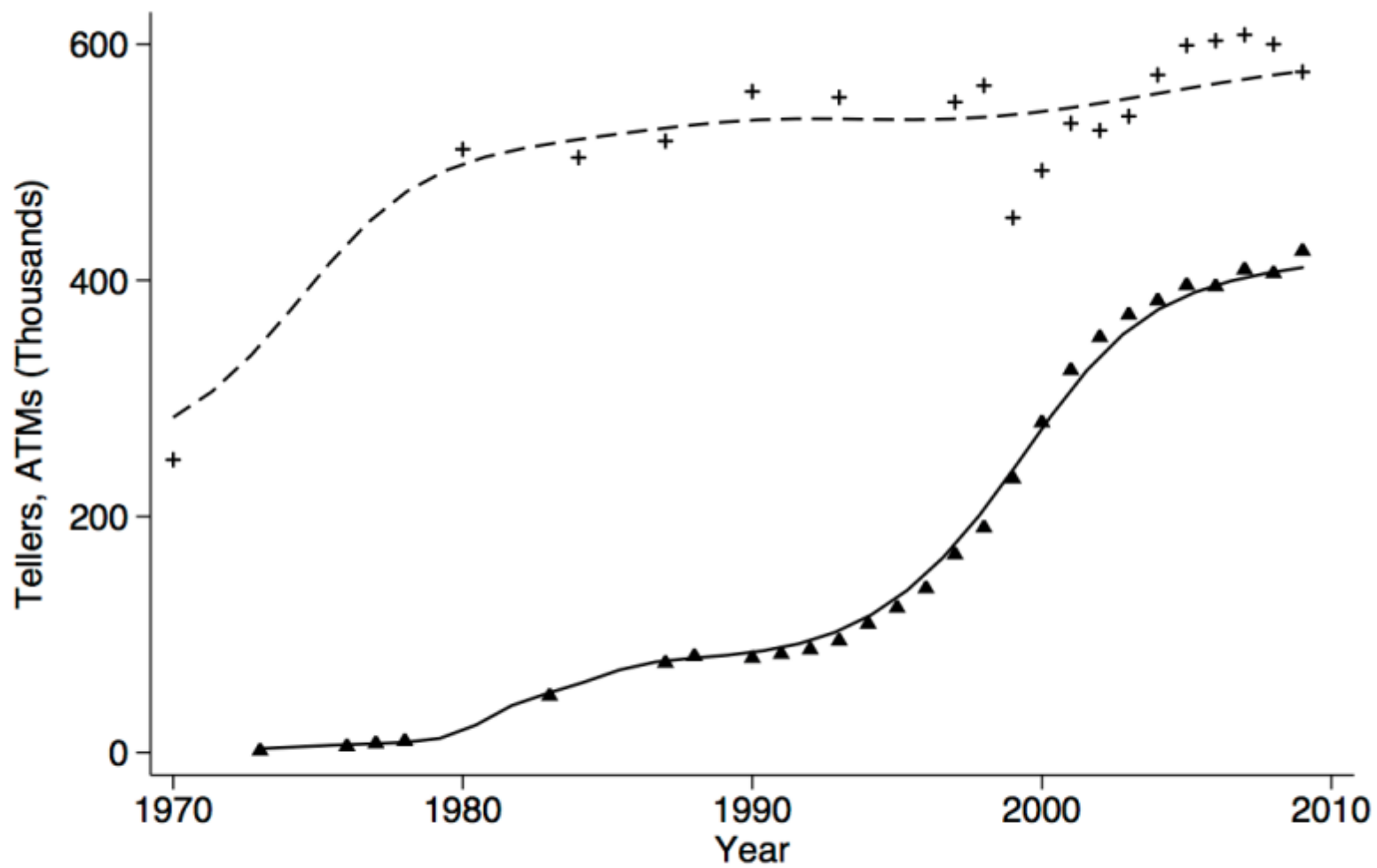
Automation

\Rightarrow

Job Growth

Demand





+ Tellers Employed ▲ ATMs Installed

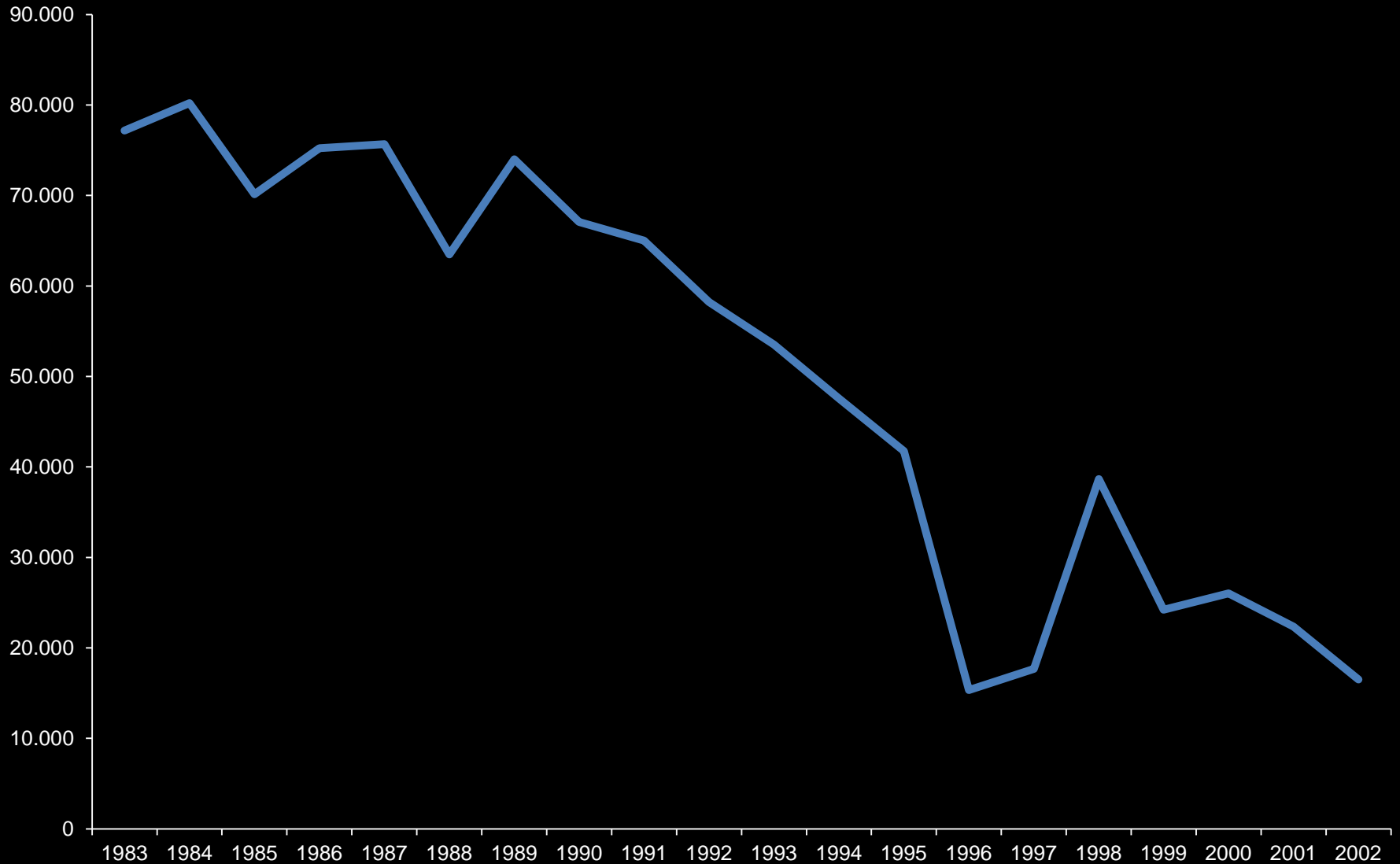
Other examples

- Bar code scanners => **MORE** cashiers
- E-commerce => **MORE** salespeople
- E-discovery => **MORE** paralegals

PLS-9070-E



Number of Typesetters & Compositors

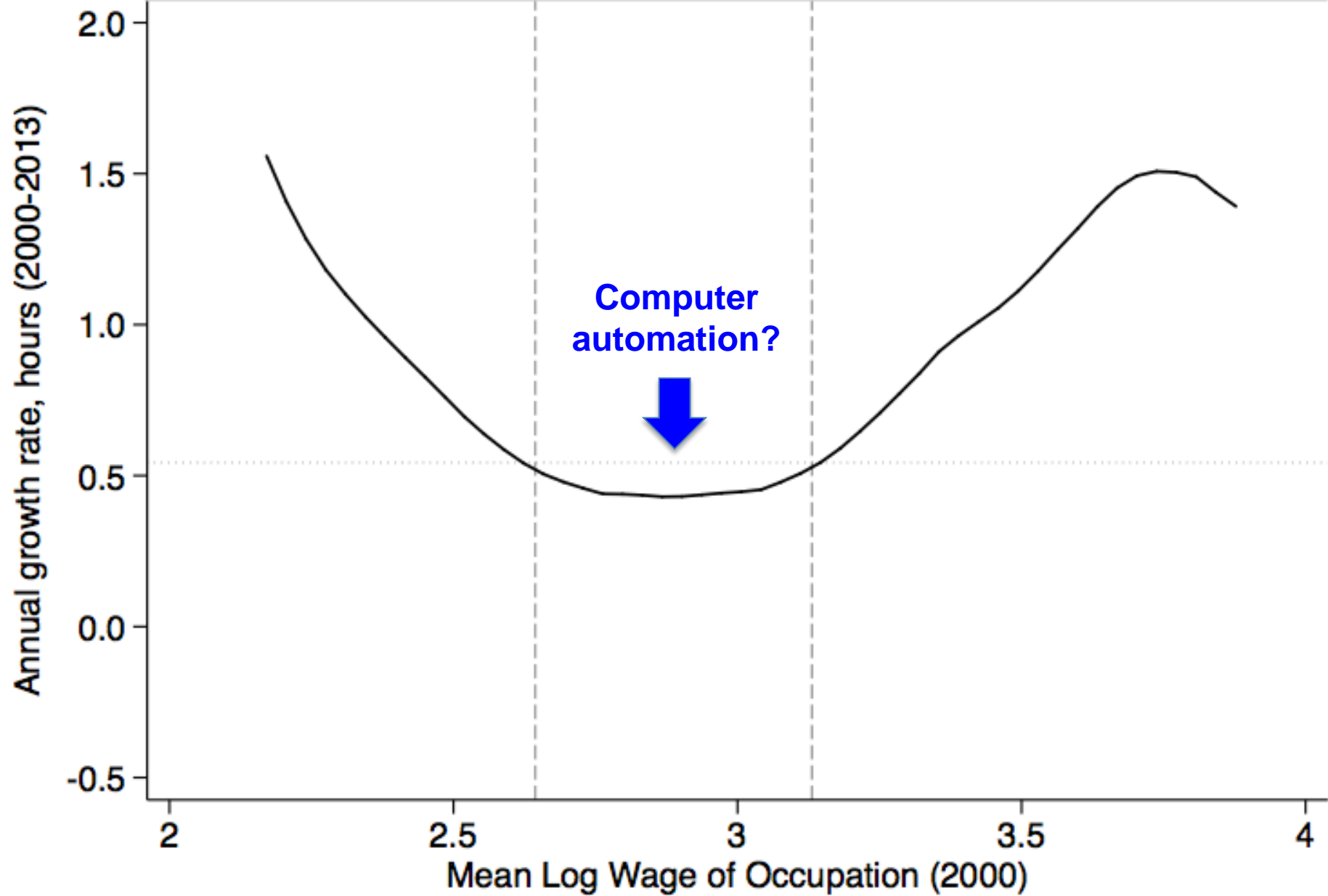




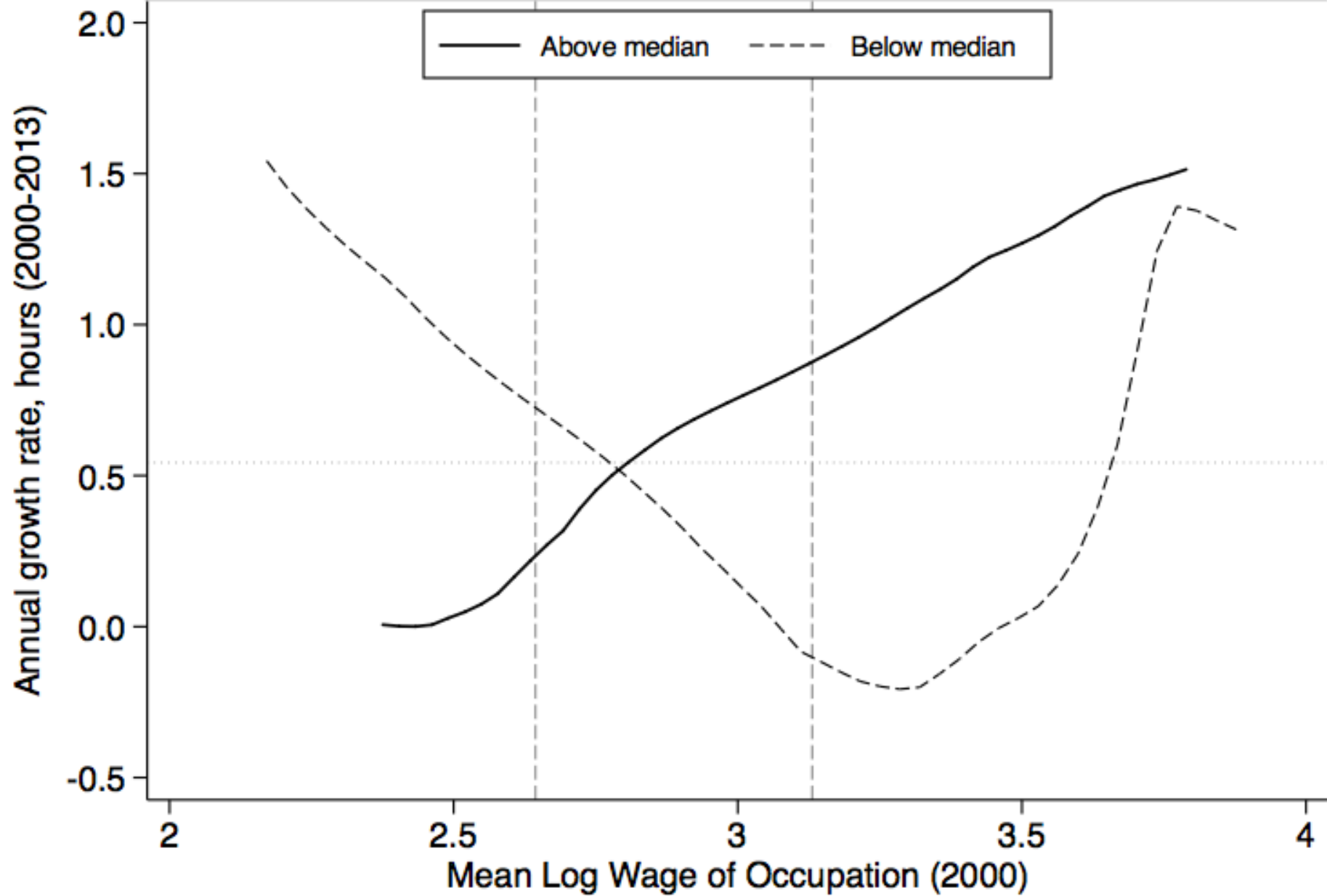
Substitution

Net Effect

Panel A: All occupations



Panel B: Grouped by computer use



Data

- 317 detailed occupations
- Census/ACS 1% samples
 - Decades: 1980-90, 1990-2000, 2000-13
 - Employment growth, wage distribution
- Use computer at work, CPS

Table 2. Employment Growth of Occupations

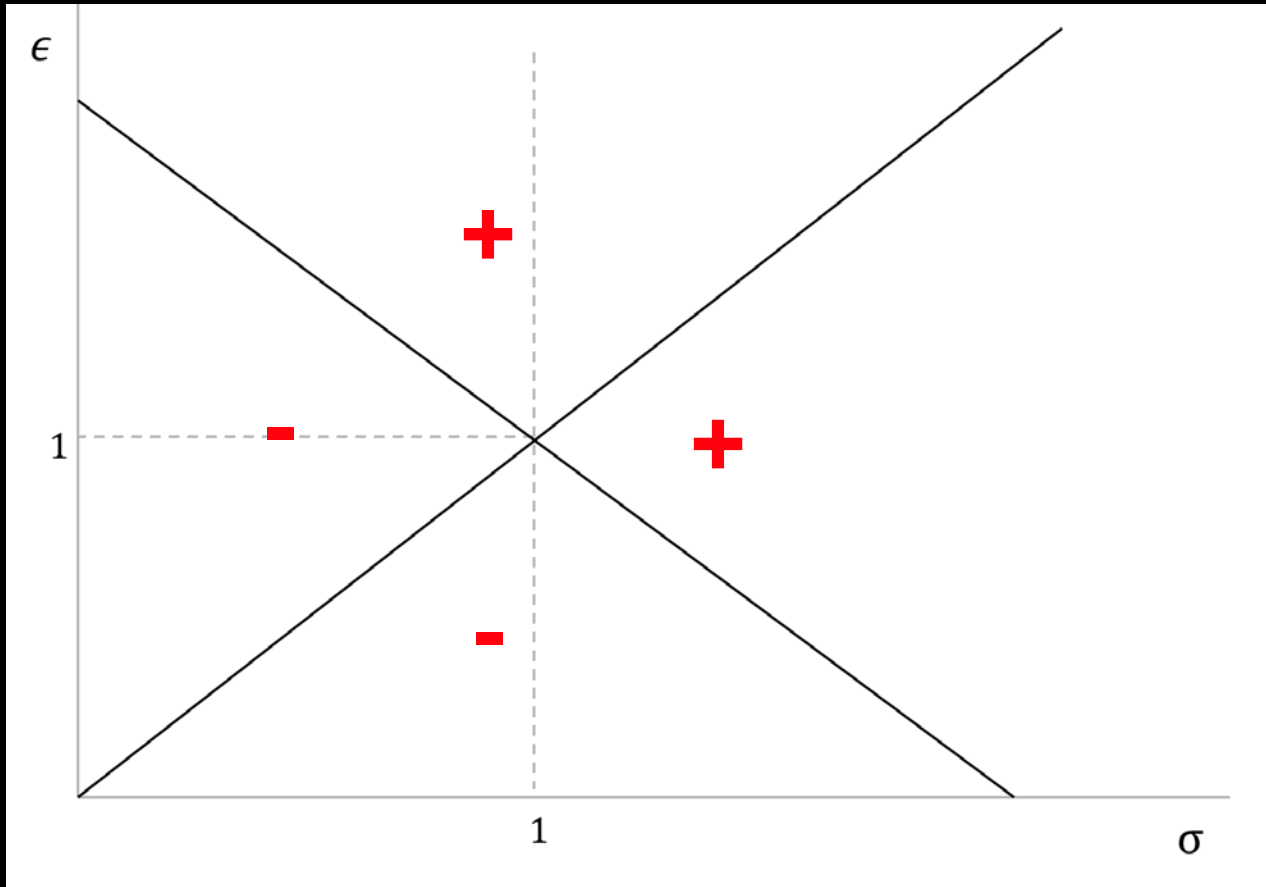
Sample:	All	Routine intensive	Mid wage quartiles
Computer use (share)	.141(.038)**	.136(.048)**	.131 (.062)*
Adjusted R-squared	.035	.073	.053
N	942	453	465
αU_j , computer contribution to growth	.055 (.005)**	.051(.007)**	.050 (.008)**

$$Q = \left(\sum_i (a_i L_i)^\rho \right)^{1/\rho}, \quad \rho \equiv \frac{\sigma - 1}{\sigma}$$

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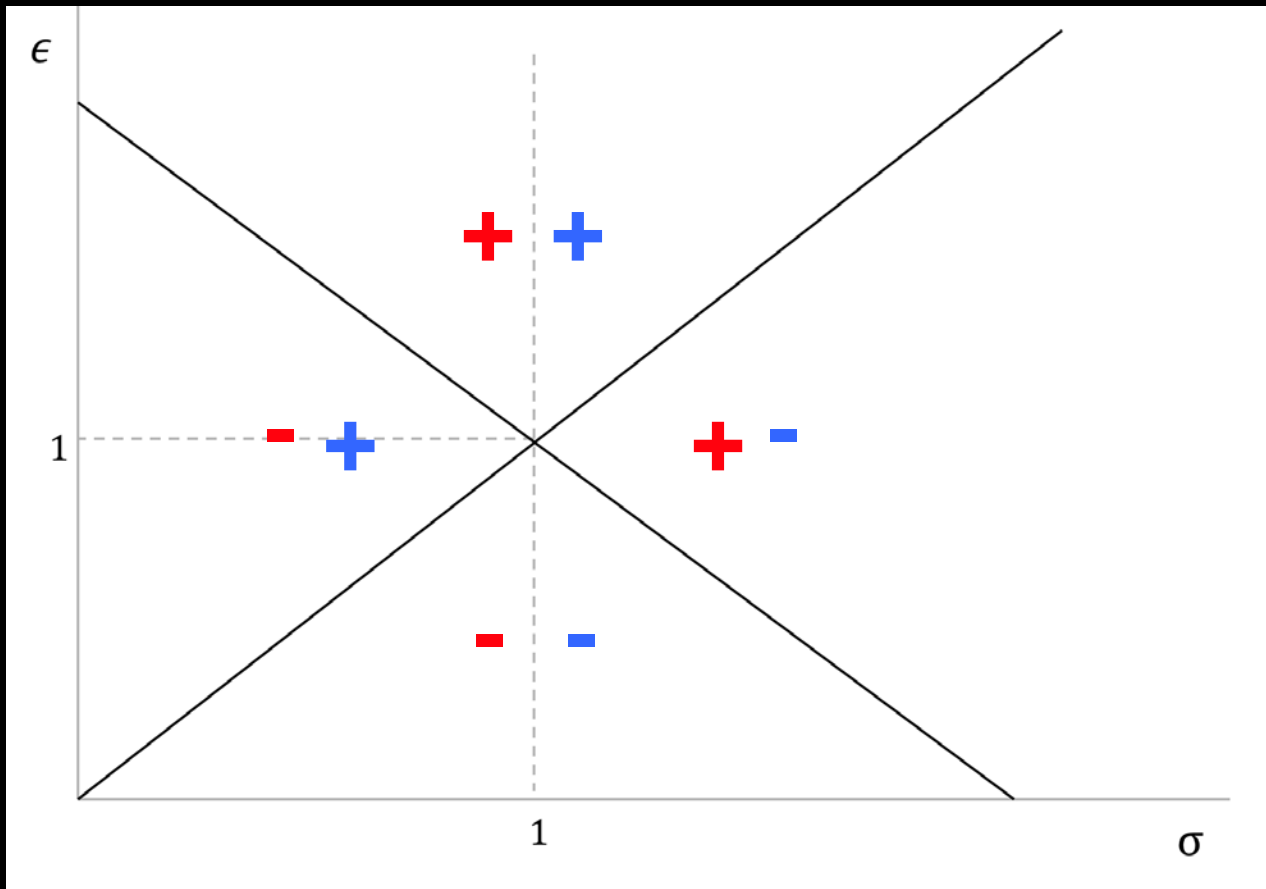
$$\frac{d \ln L_j}{d \ln a_j} = \sigma - 1 + S_j(\epsilon - \sigma), \quad \frac{d \ln L_k}{d \ln a_j} = S_j(\epsilon - \sigma), \quad j \neq k$$

Employment in automated occupation



Employment in automated occupation

Employment in other occupations



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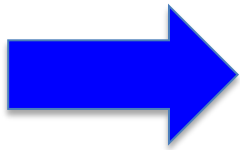
$$d \ln L_j = (\sigma - 1) d \ln a_j + (\epsilon - \sigma) \sum_k S_{kt} \cdot d \ln a_k$$

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$$d \ln L_j = (\sigma - 1)d \ln a_j + (\epsilon - \sigma) \sum_k S_{kt} \cdot d \ln a_k$$

$$d \ln a_j = b U_j$$




$$d \ln L_{jt} = \alpha U_j + \beta X_{jt} + D_{jt} + \mu_{jt}$$


$$\alpha \equiv b(\sigma - 1), \quad \beta \equiv b(\epsilon - \sigma), \quad X_{jt} \equiv \sum_i v_{ij} \sum_k S_{ikt} \cdot U_i$$

Table 3. Employment Growth of Occupations, Model Estimates

Panel A. Weighted Least Squares

	Sample:	All	Routine intensive	Mid wage quartiles
α		.107 (.038)**	.054 (.049)	.143 (.061)*
β		1.000 (.206)**	2.331 (.419)**	1.581 (.339)**
R-squared		.058	.133	.096
N		942	453	465
$\alpha U_j + \beta X_{jt}$, computer contribution to growth		.090 (.018)**	.095 (.023)**	.118 (.027)**

Panel B. Instrumental Variables

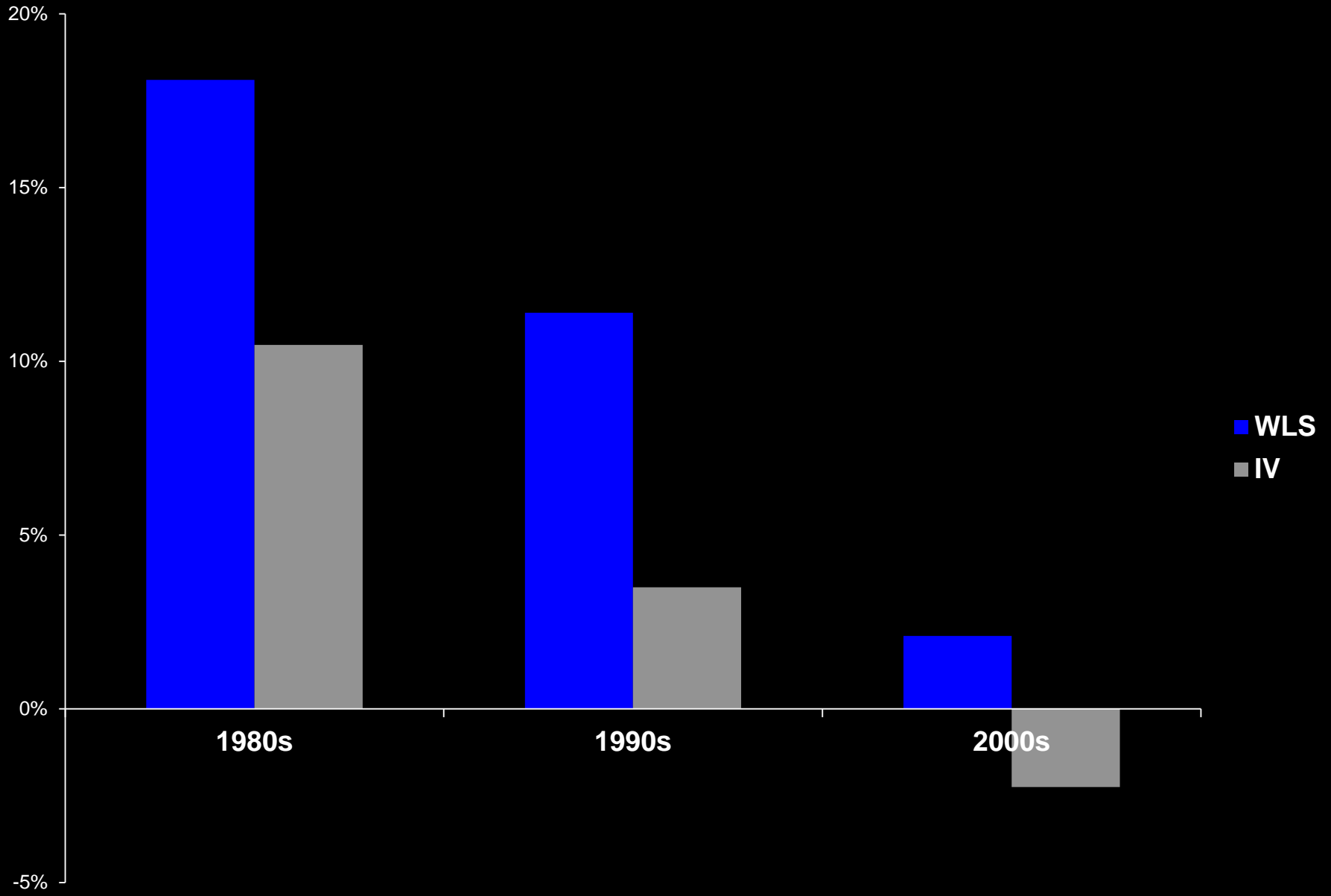
	Sample:	All	Routine intensive	Mid wage quartiles
α		-.210 (.086)*	-.128 (.096)	-.224 (.187)
β		2.172 (.725)**	4.209 (1.050)**	2.245 (1.244)
R-squared		.016	.059	.084
N		936	453	459
Sargan test prob. value		.880	.385	.
$\alpha U_j + \beta X_{jt}$, computer contribution to growth		.022 (.048)	.087 (.049)	.007 (.087)

**Economics
matters**

Declining Growth

	Weighted Least Square			Instrumental Variables - GMM		
	1	2	3	4	5	6
Sample:	1980-90	1990-2000	2000-2013	1980-90	1990-2000	2000-2013
α	.358 (.069)**	.209 (.138)	-.077 (.051)	.137 (.109)	-.301 (.215)	-.357 (.081)**
β	.932 (.349)**	.684 (.797)	1.037 (.266)**	1.091 (.829)	3.393 (2.174)	2.386 (.635)**
R-squared	.113	.011	.048	.084	-.057	-.099
N	314	314	314	312	312	312
Sargan test prob. value				.150	.971	.068
$\alpha \bar{U}_j + \beta \bar{X}_{jt}$, computer contribution to growth	.181 (.031)**	.114 (.066)	.021 (.024)	.105 (.057)	.035 (.131)	-.022 (.045)

Computers: mean contribution to job growth



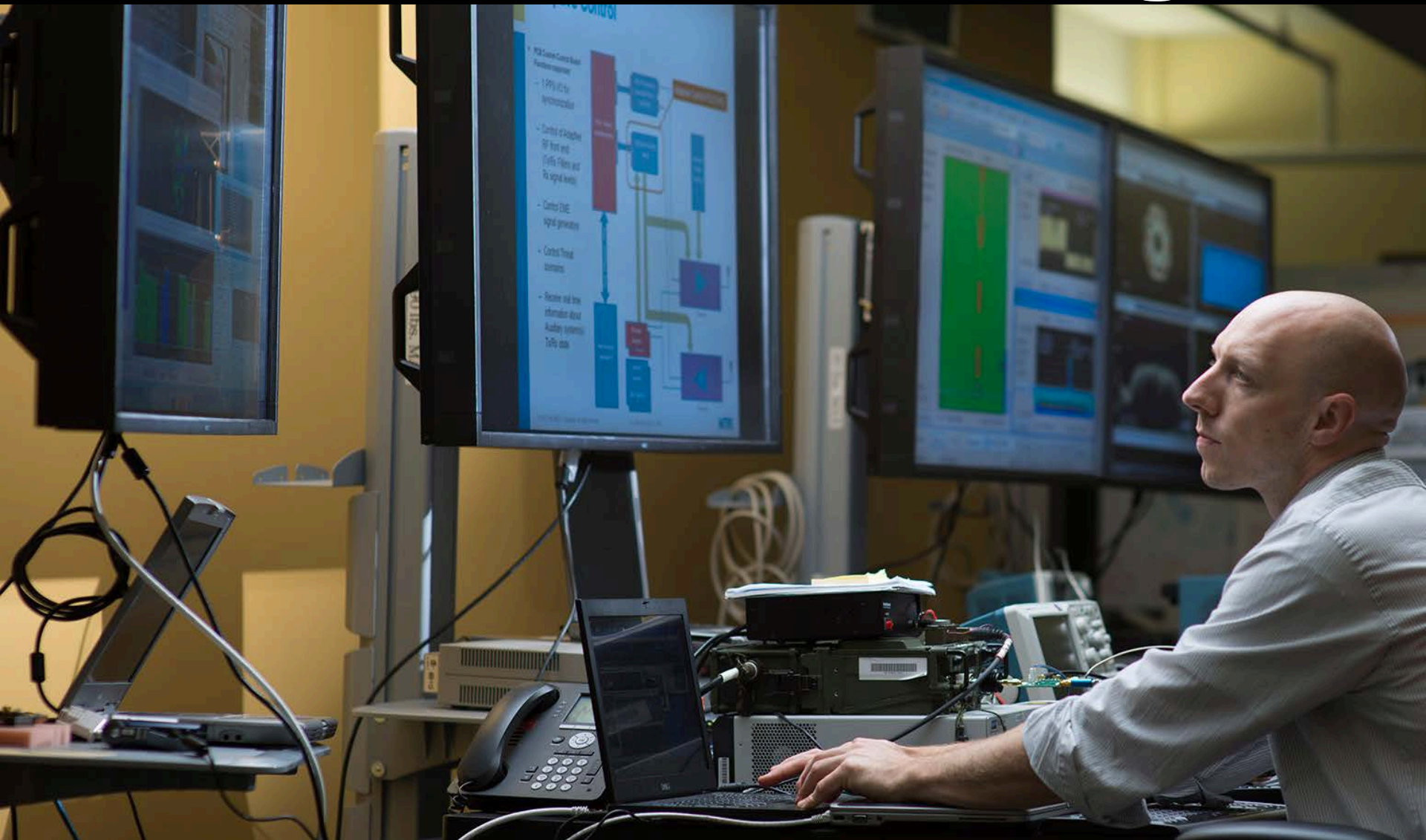
Tech Unemployment



Unemployment

Obsolescence

Skills & Knowledge



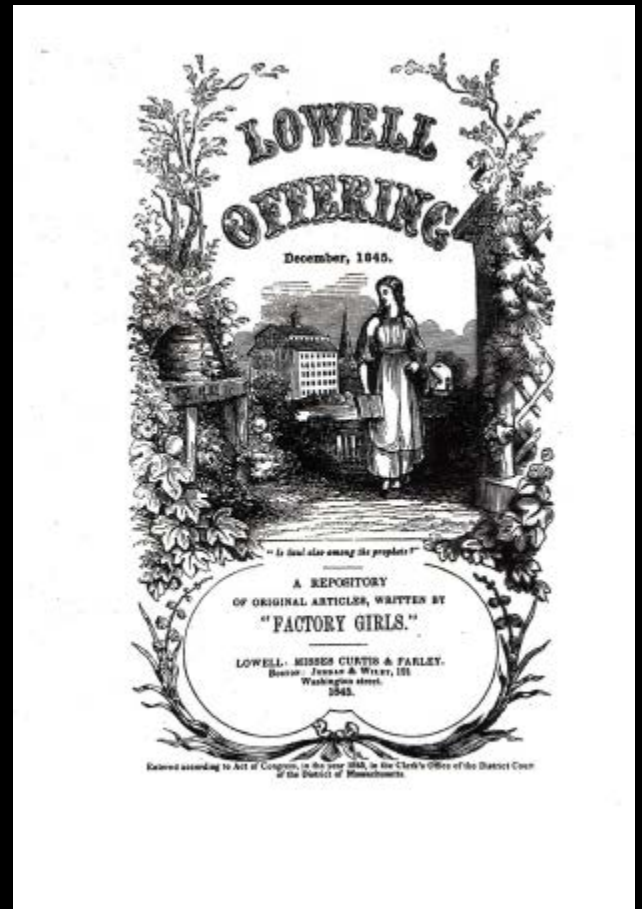








German
Botany
John Quincy Adams
Ralph Waldo Emerson
John Greenleaf Whittier



Learning

Learning

Build

Install

Operate

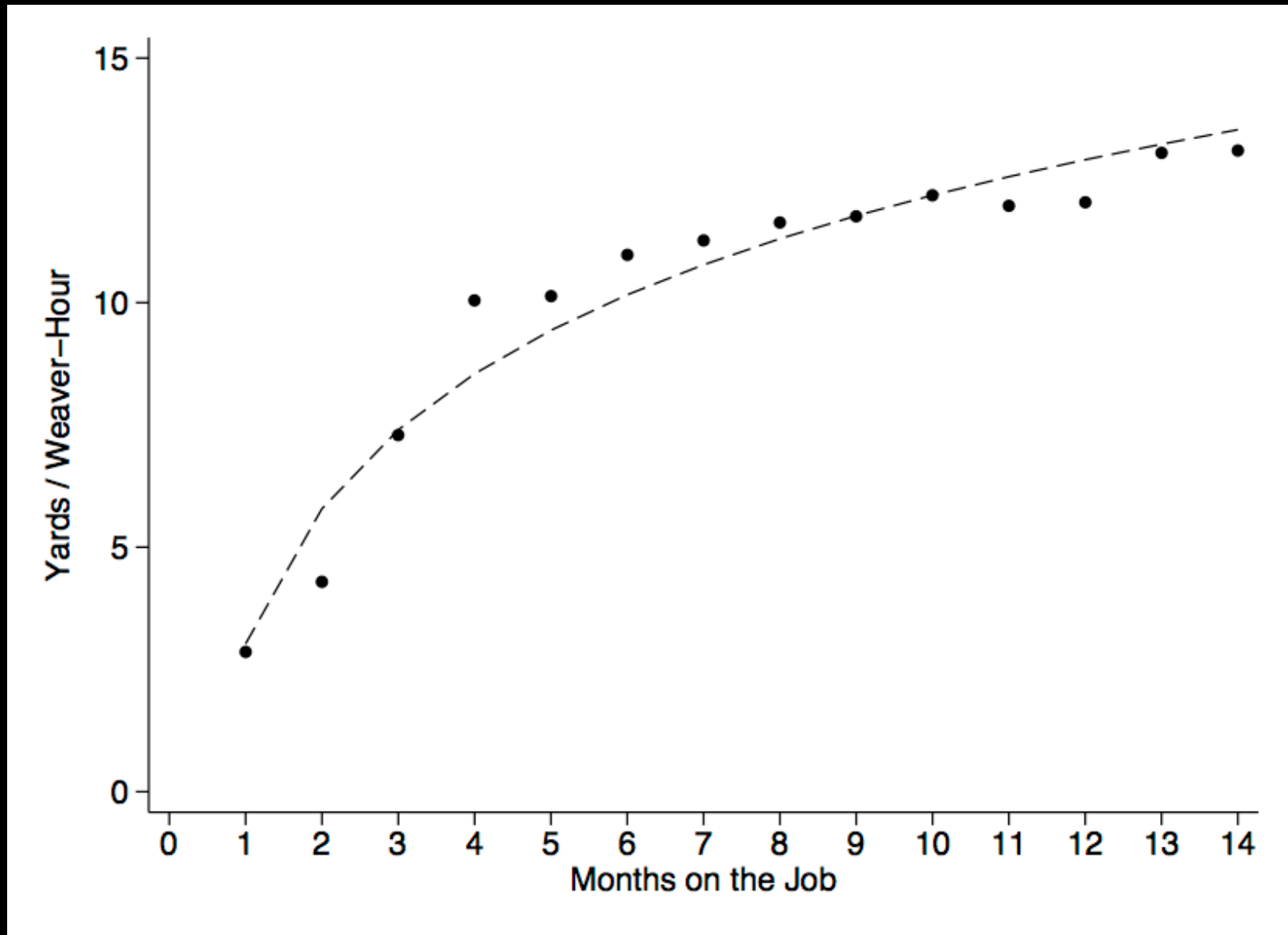
Maintain

Organize

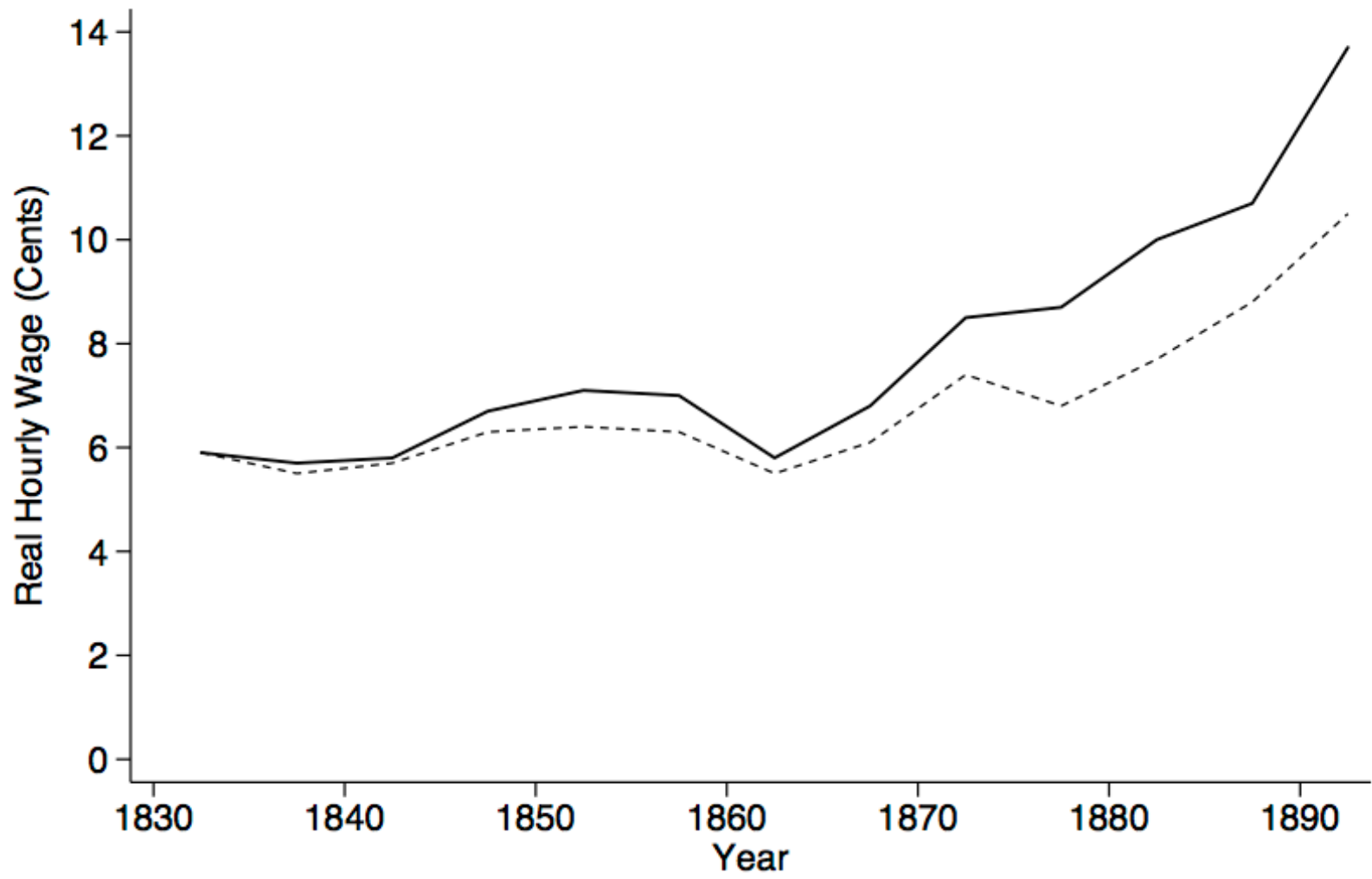
Market

Learning by Doing

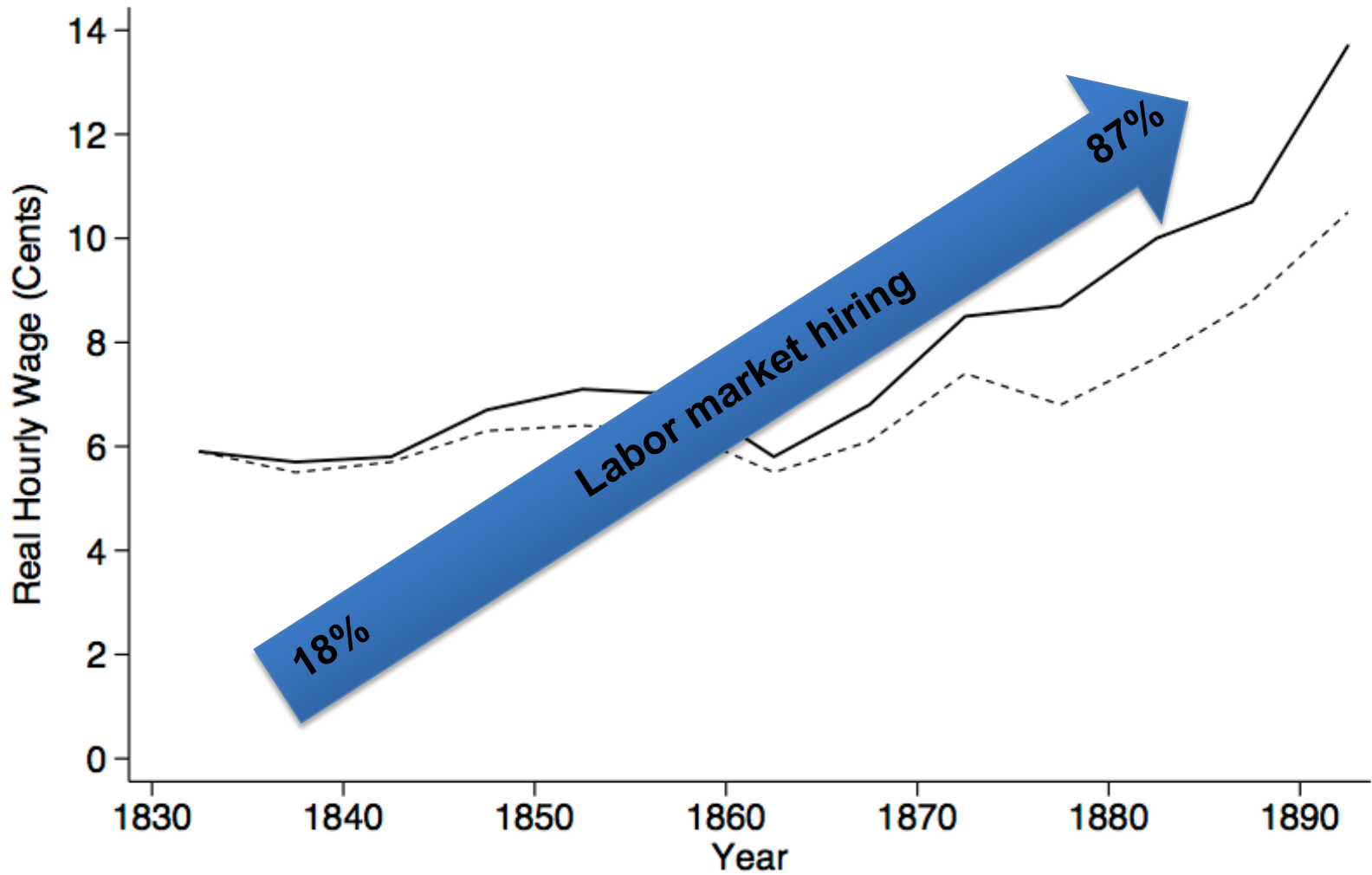
Learning curve of newly hired weavers at the Lawrence Co., 1842-55



Wages?



— Weaving - - - - - Spinning



— Weaving - - - - Spinning

Labor Market

- Standardization
 - Tech
 - Work organization
 - Training
- Employee mobility



Wages?



Median real wage,
1976: **\$19.30**



Median real wage, 2014:
\$20.07

Typesetters & Compositors



Typesetters & Compositors

Print designers & Desktop Publishers



Web Designers

Web Designers

Mobile Designers

“information architects,” “user interaction specialists”...

2012 Flash



2012 Flash

2015 HTML5

Institutions

- Average designer:
 - Schools can't keep up
 - Labor markets don't recognize new skills
- Top designers
 - Teach themselves
 - Develop reputations

Institutions

- Average designer:
 - Schools can't keep up
 - Labor markets don't recognize new skills
 - => Stagnant pay
- Top designers
 - Teach themselves
 - Develop reputations
 - => Rising pay

Costly Learning

$$w_i^t = a^t s_i, \quad t = 0, 1; \quad i = L, H, \quad s_H > s_L$$

$$a^1 > a^0, \quad c = \text{cost of learning tech 1}$$

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Assume:

$$(a^1 - a^0)s_H > c > (a^1 - a^0)s_L$$

and L workers do not leave occupation (e.g., sunk costs)

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Then

$$\frac{w_H^0}{w_L^0} = \frac{s_H}{s_L} < \frac{w_H^1}{w_L^0} = \frac{a^1 s_H}{a^0 s_L}$$

Computers and Rising Within-Occupation Wage Gaps

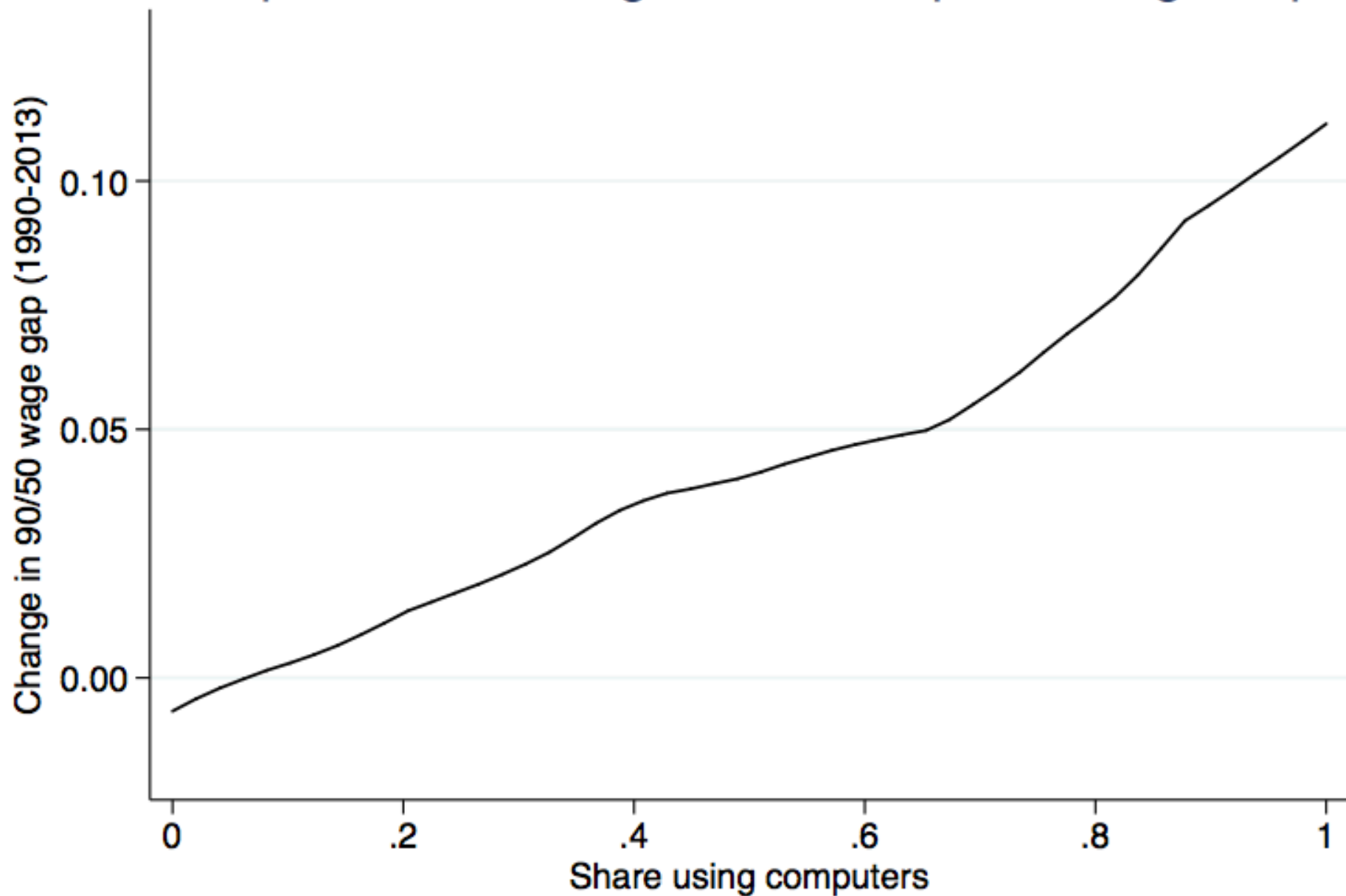
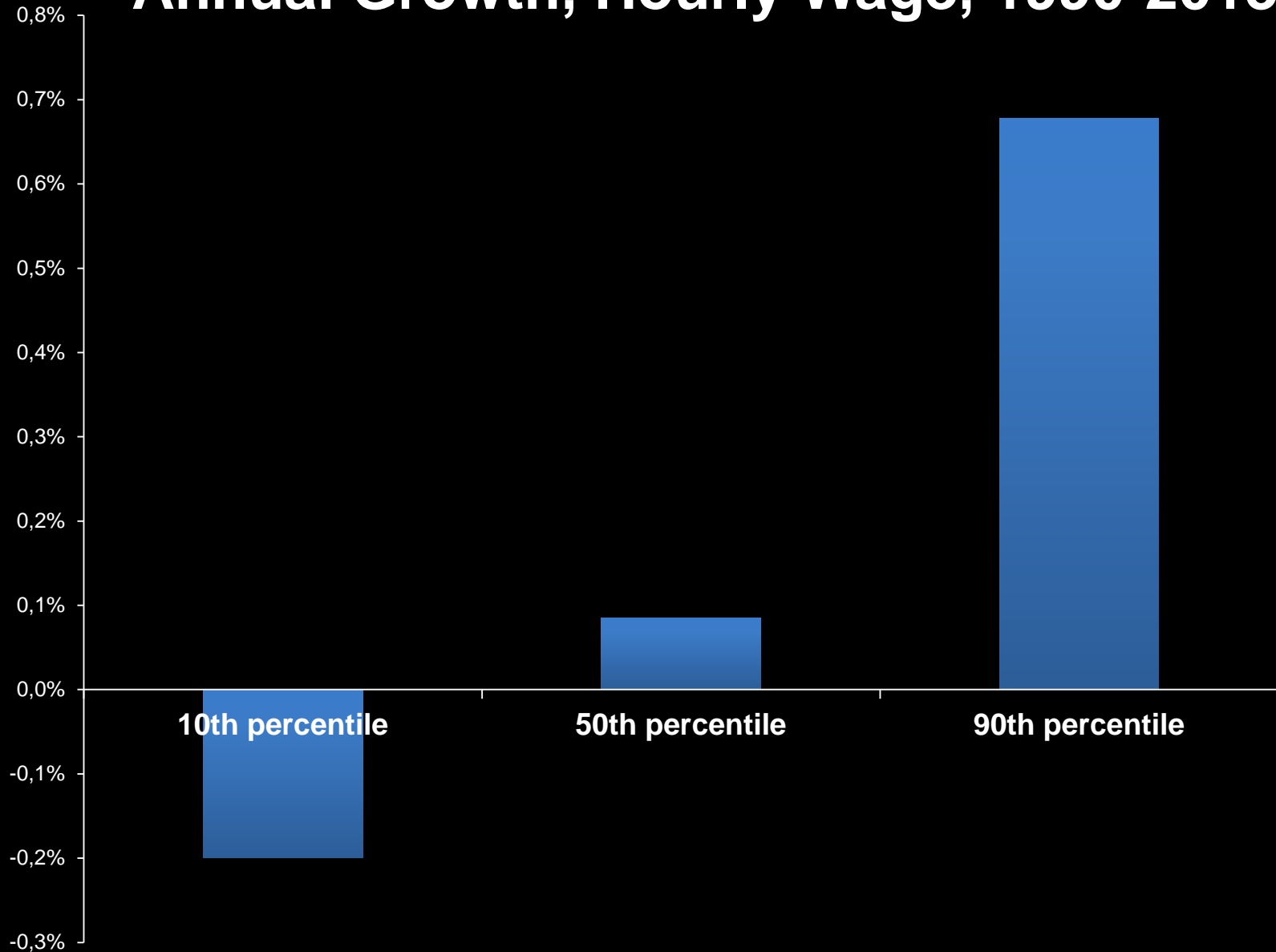


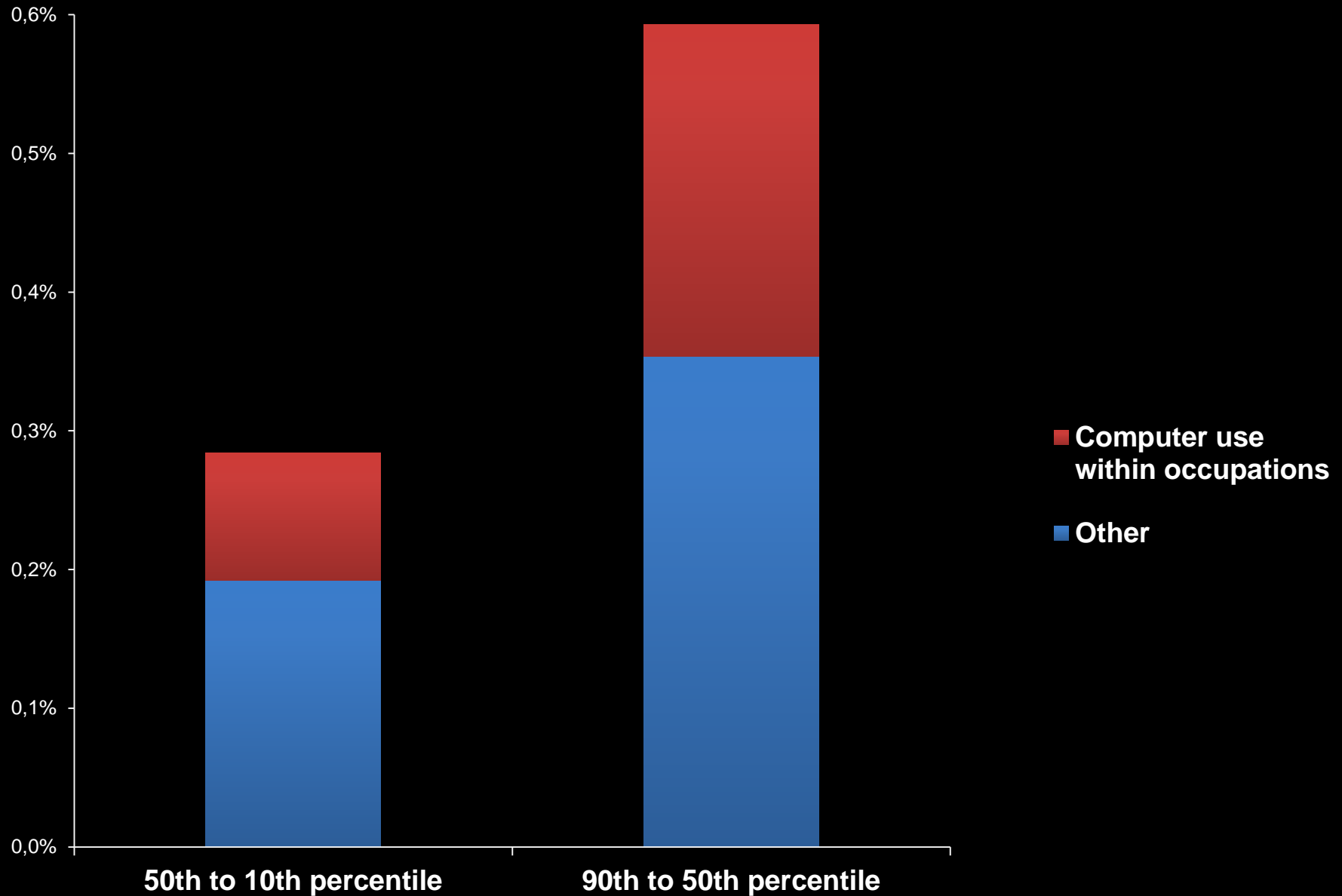
Table 5. Change in Within-Occupation Wage Gaps

	Change between 90 th & 50 th percentiles	Change between 50 th & 10 th percentiles
Share using computers	.039 (.009)**	.048 (.010)**
Education, 2 nd wage quartile	-.008 (.004)	-.001 (.005)
Education, 4 th wage quartile	.005 (.004)	.000 (.005)
Adjusted R-squared	.048	.213
N	942	942

Annual Growth, Hourly Wage, 1990-2013



Annual Growth, Wage Gaps, 1990-2013



Scarce skills,

not

Scarce jobs

**Policy
For
New Skills**

Learning by Doing

- Work-Study
- Apprenticeship
- Certification

Employee Mobility

- Non-compete agreements
- Occupational licensing
- Expansive trade secret law

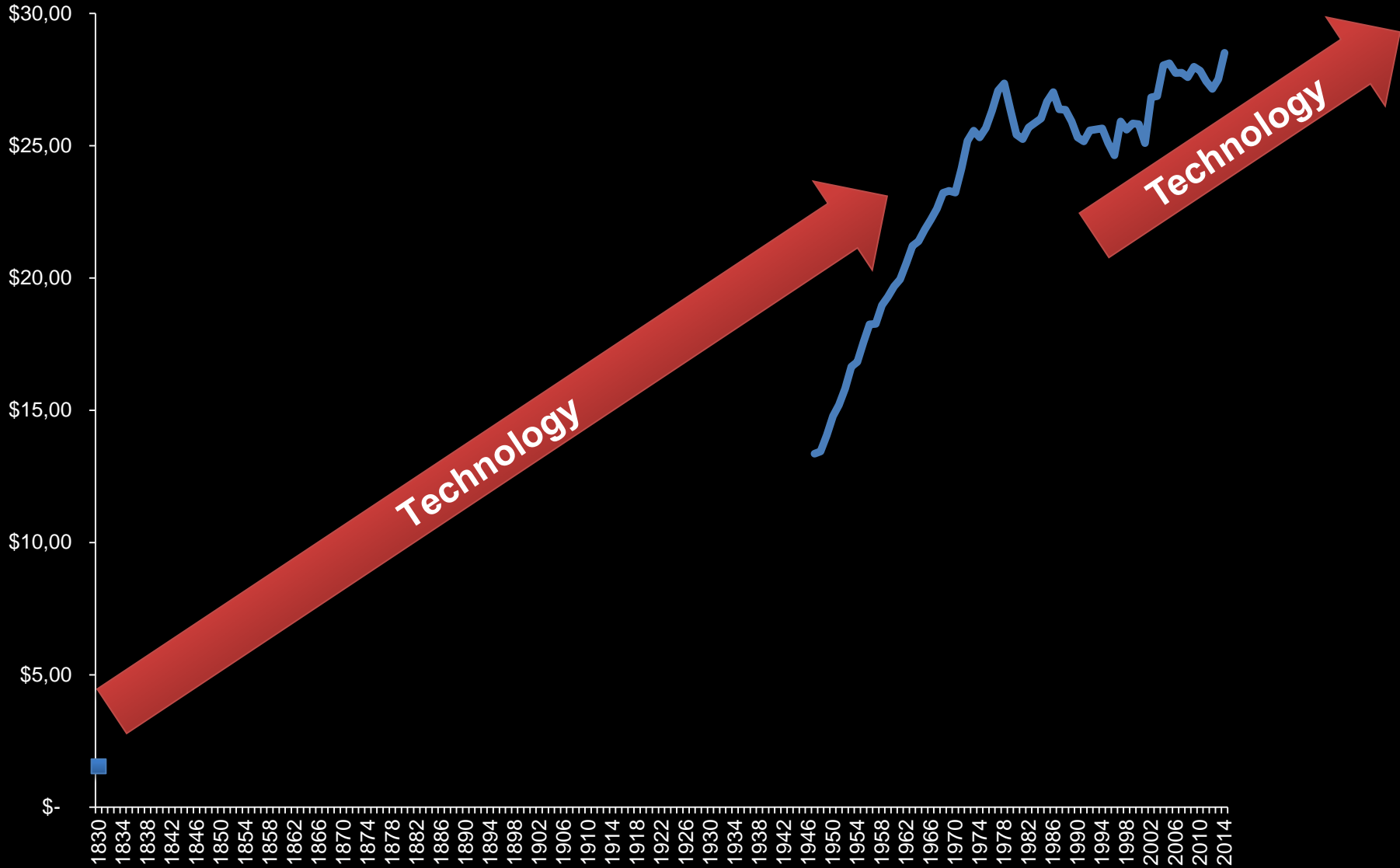
Startups

- Software patent litigation
- Open standards
- Inclusive procurement

Technological determinism

**Economics
matters**

Hourly Production Wage + Benefits (\$2012)



Robots in the US

- Non farm employment = 138m
- Stock of industrial robots = 166,000
 - Ratio = 0.1%
 - Over ½ in automotive industry

Worldwide Shipments of Industrial Robots

