Aalto University
School of Business

Topics in Labor Economics II

Ability Rents, Scale of Operations, and Matching

Marko Terviö (Aalto University)

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Helsinki GSE

Introduction

How do differences in abilities and tastes translate into wage differences?

1. How much you produce depends on who/what you produce with
   - Ability rents*
   - Scale effects (scale of operations, span of control)
   - Matching workers with co-workers (team production)
   - Matching workers and firms/jobs
   - Superstar effects
2. (Dis)Amenities and compensating differentials

Introduction to Matching and Scale Effects

In the canonical model (each type of) labor is a divisible cardinal-scale input $\rightarrow$ tendency to wage = MPL

Indivisible qualities $\leftrightarrow$ ordinal scale

How do differences in indivisible inputs translate to differences in cardinal outputs? How do ability dispersion and technological change affect wage dispersion?

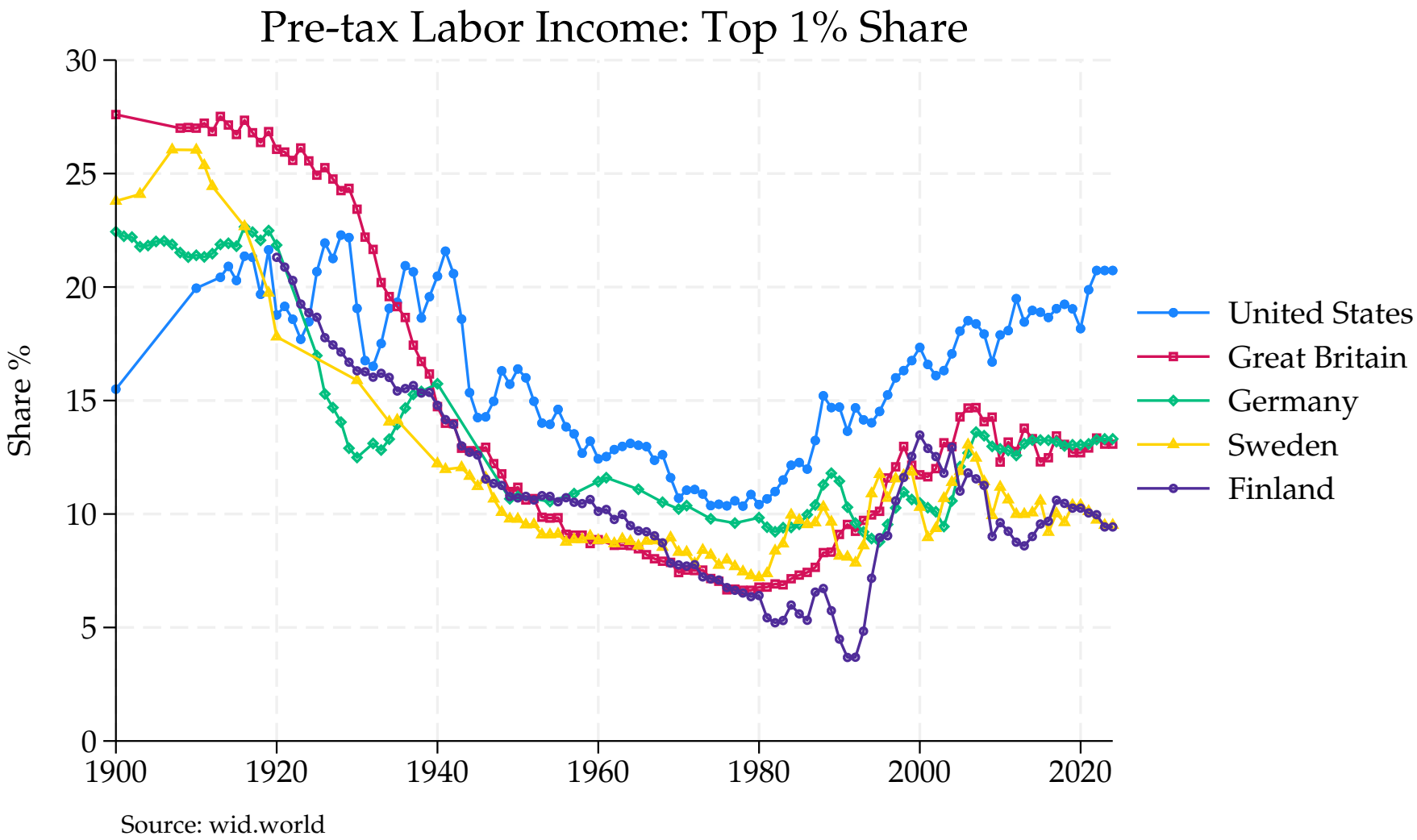
We have tractable models with results that can be understood!

One indivisible factor $\rightarrow$ Scale effects
More than one indivisible factor $\rightarrow$ Matching (aka Assignment)

A recurring theme is winner-take-more economics. Intuitive assumptions tend to lead to right-skewed wage distributions.

Evolution of Top 1% Labor Income Share

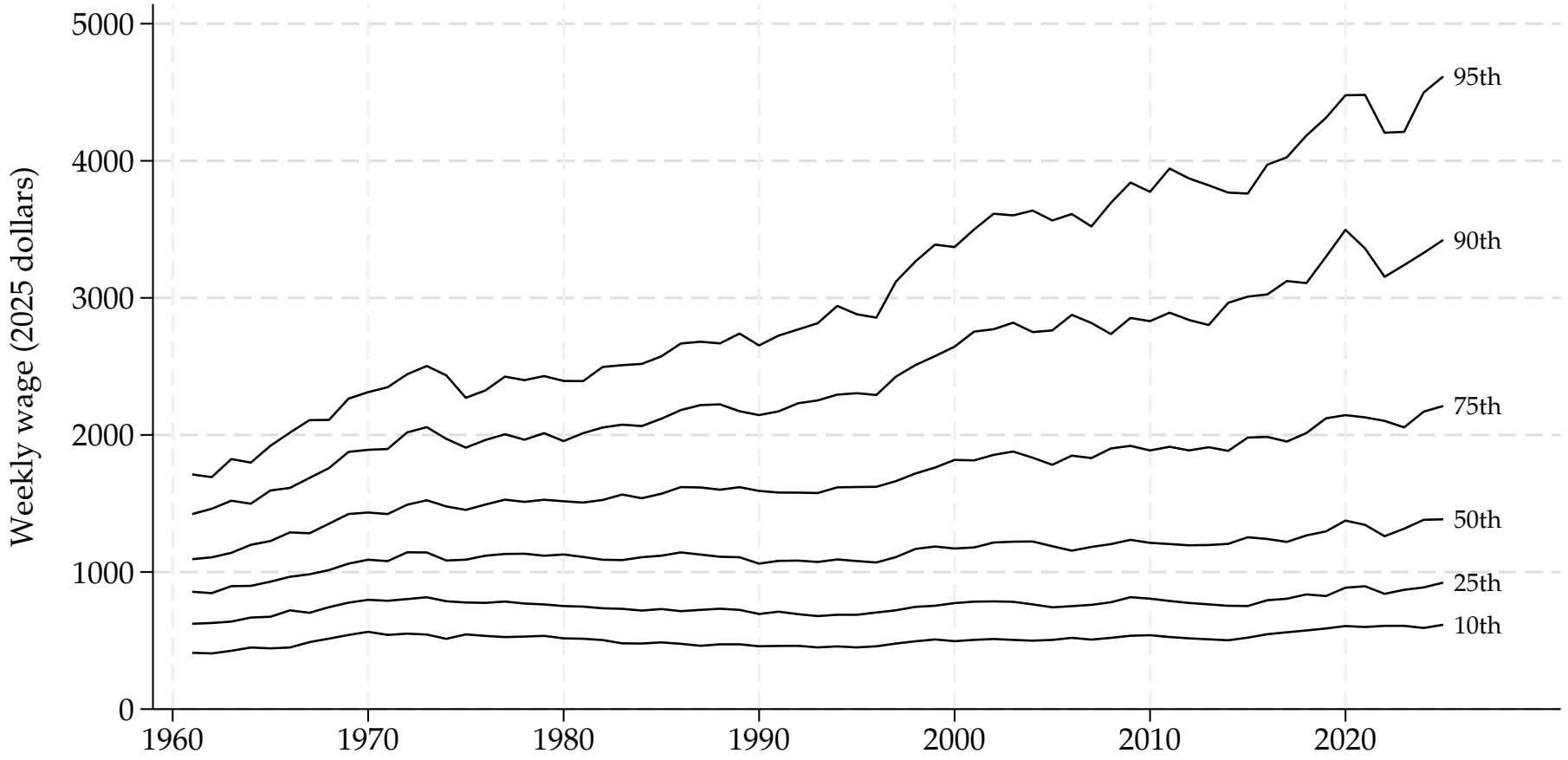
World Inequality Database



Source: wid.world

Evolution of Wage Distribution (US Men)

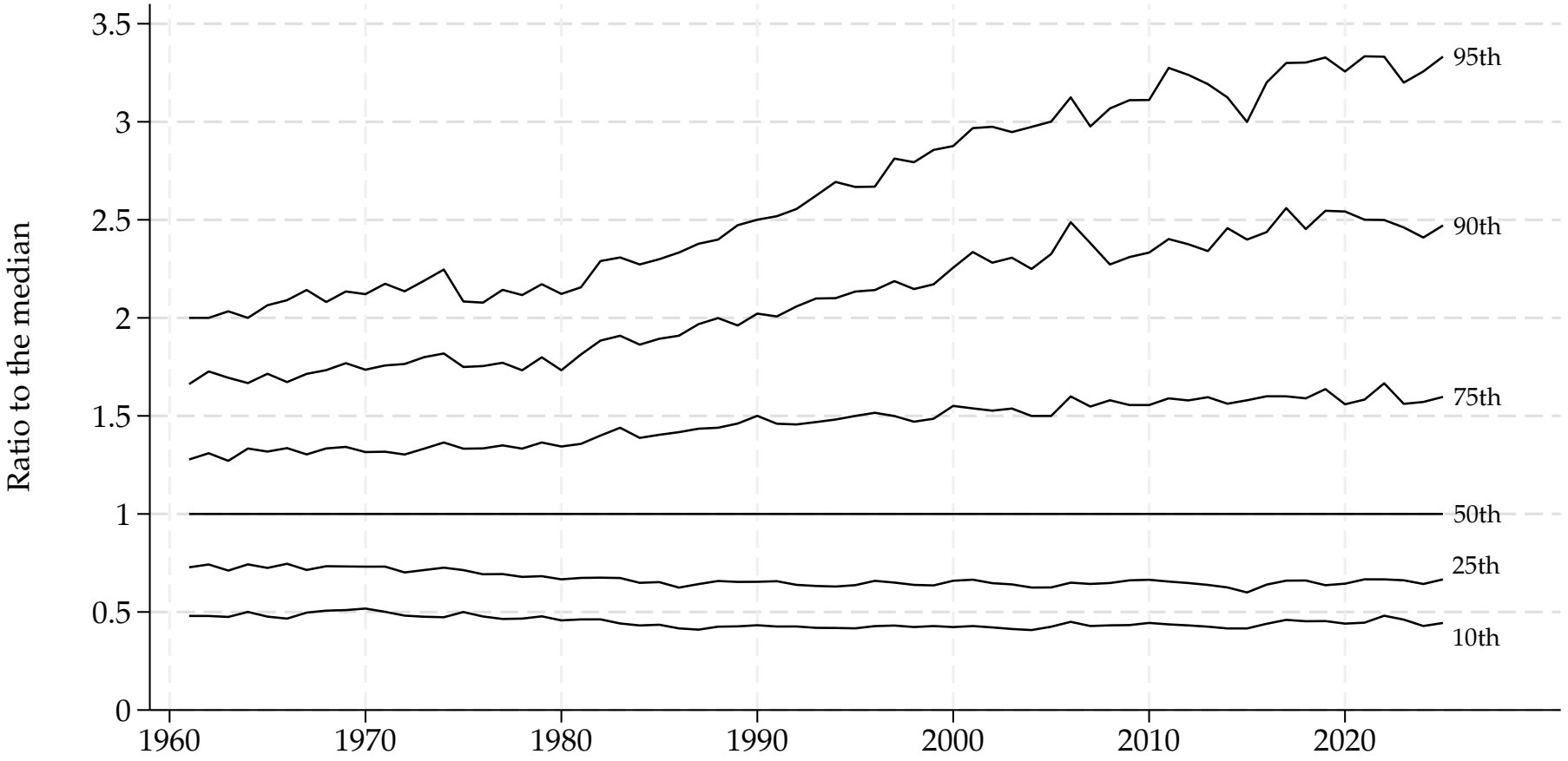
Weekly wage percentiles



US men 18-64, wage and salary workers, 27+ weeks, full time (35+ hours).
Earnings year; deflated by the PCE price index. Source: IPUMS CPS ASEC.

Evolution of Wage Distribution (US Men)

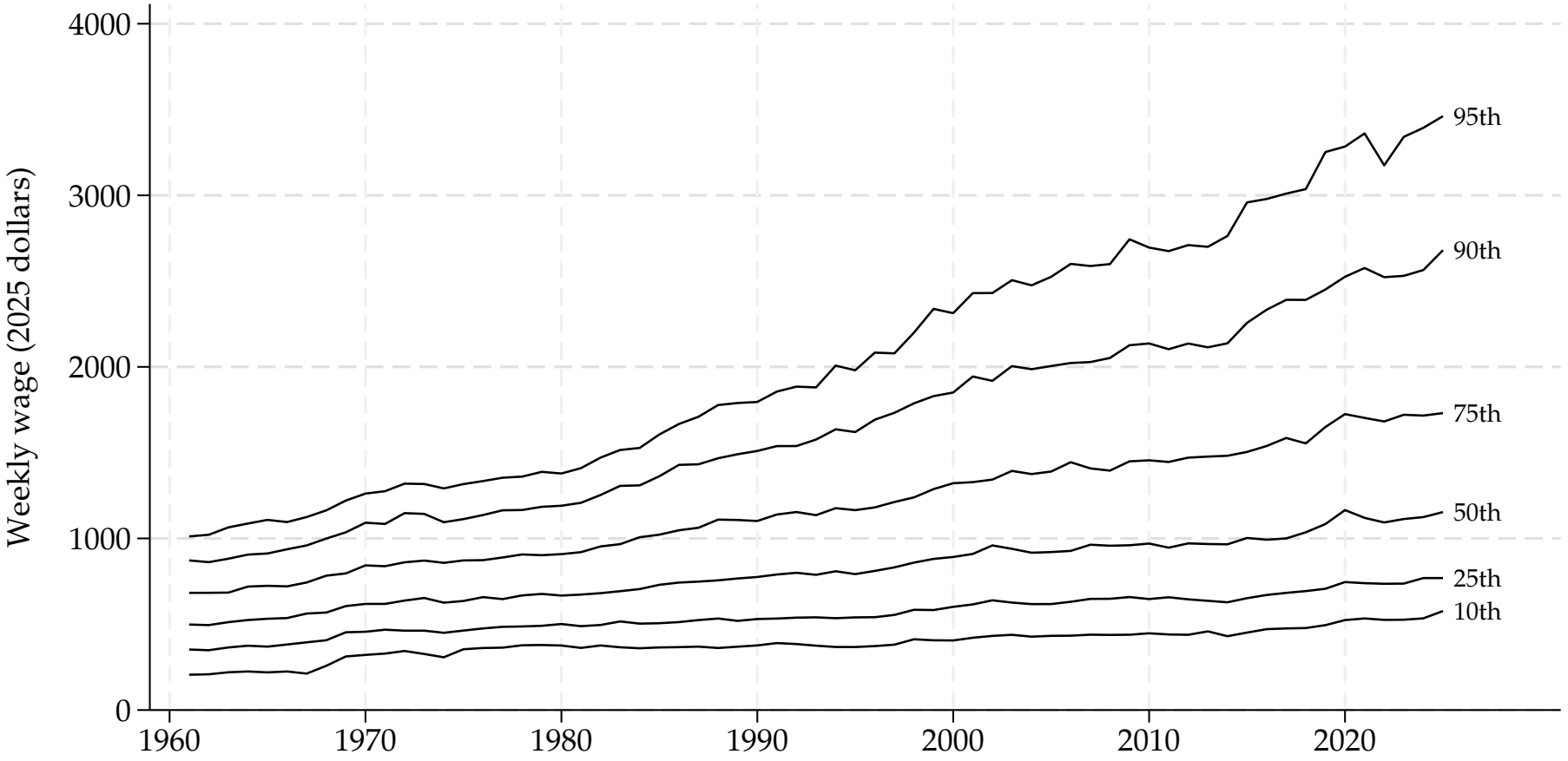
Weekly wage percentiles, as ratios to median



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Evolution of Wage Distribution (US Women)

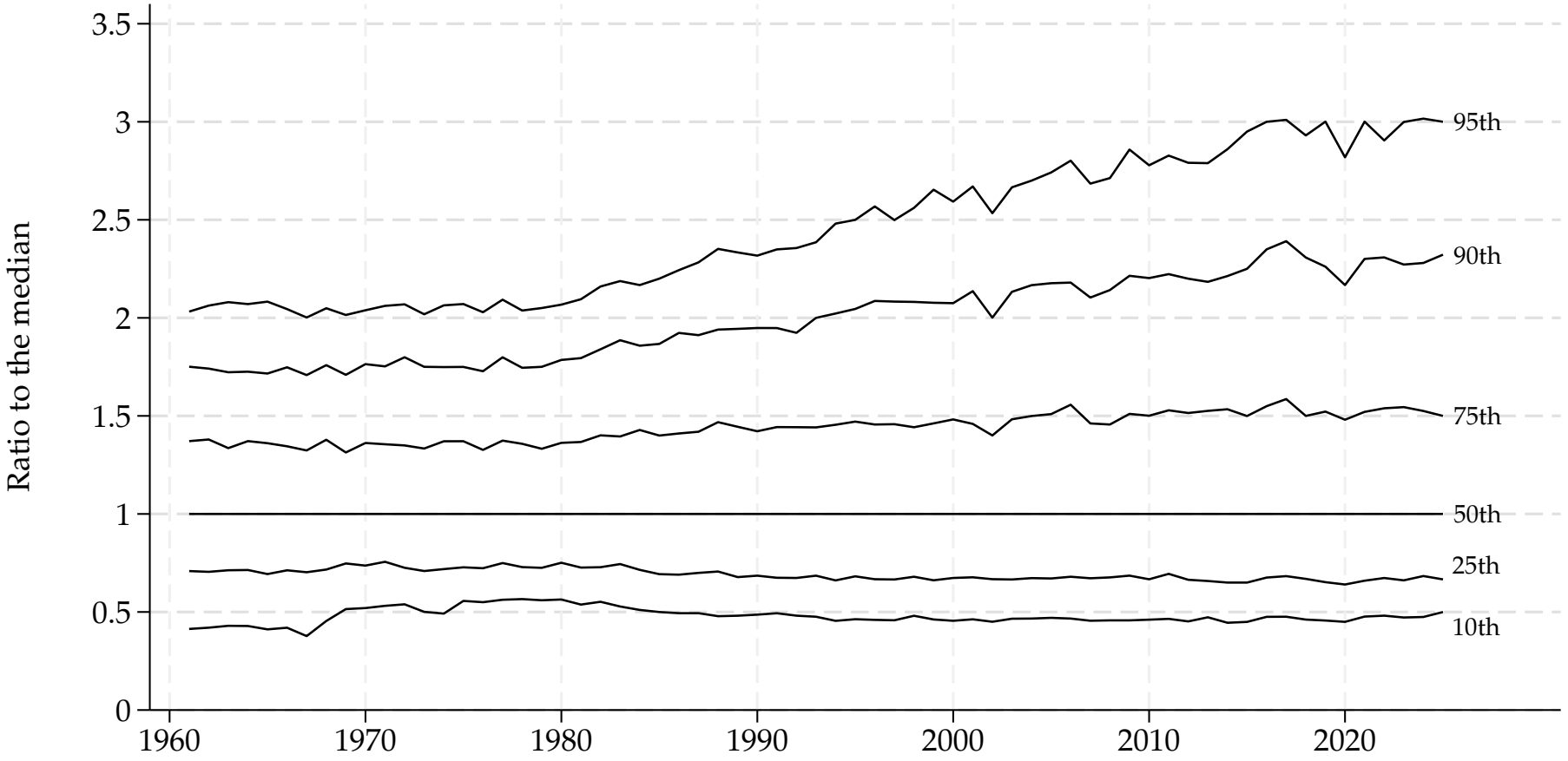
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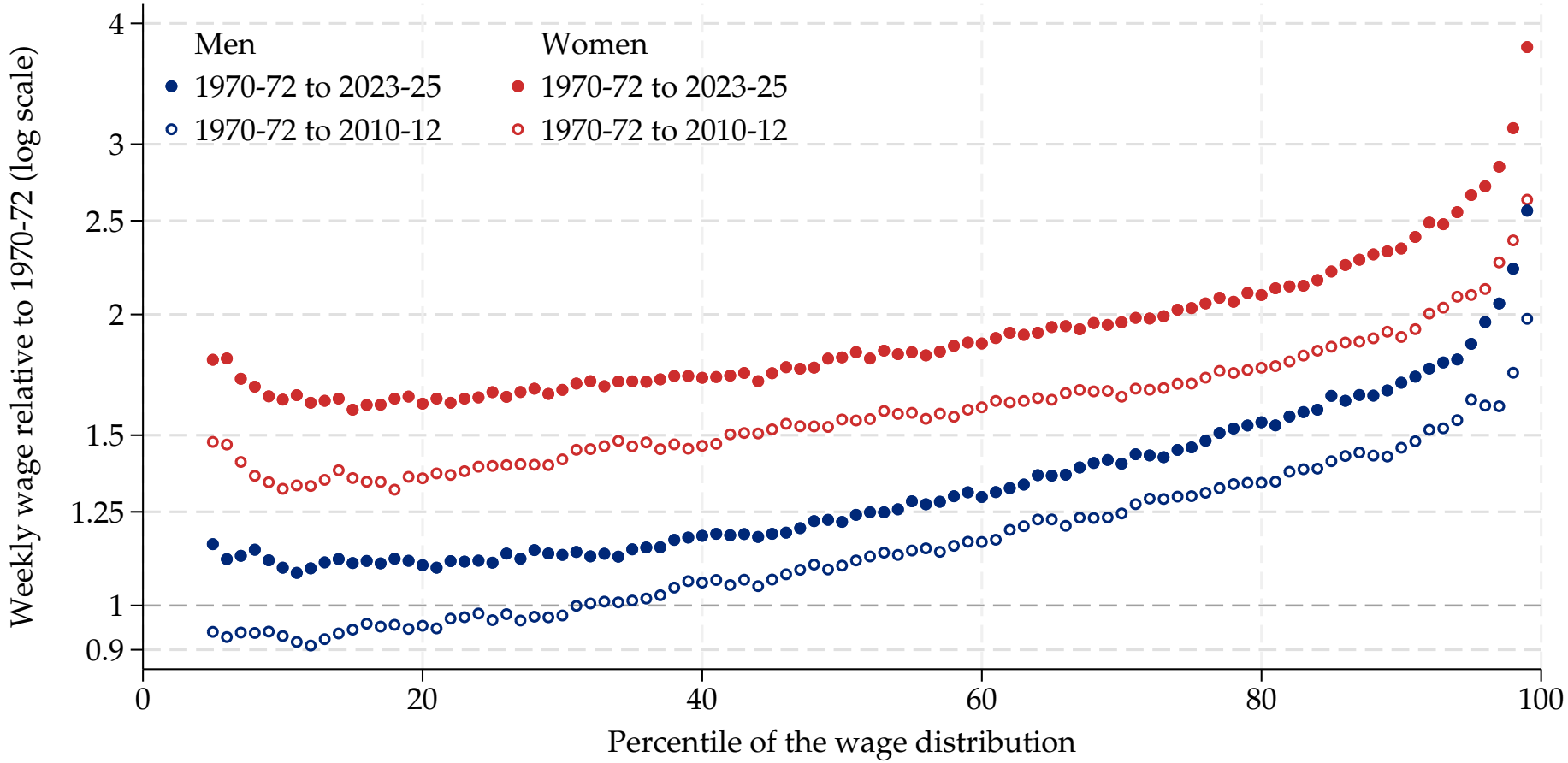
Weekly wage percentiles, as ratios to median



US women 18-64, wage and salary workers, 27+ weeks, full time (35+ hours).
Earnings year. Source: IPUMS CPS ASEC.

Change in Wage by Percentile since 1970–72 (US)

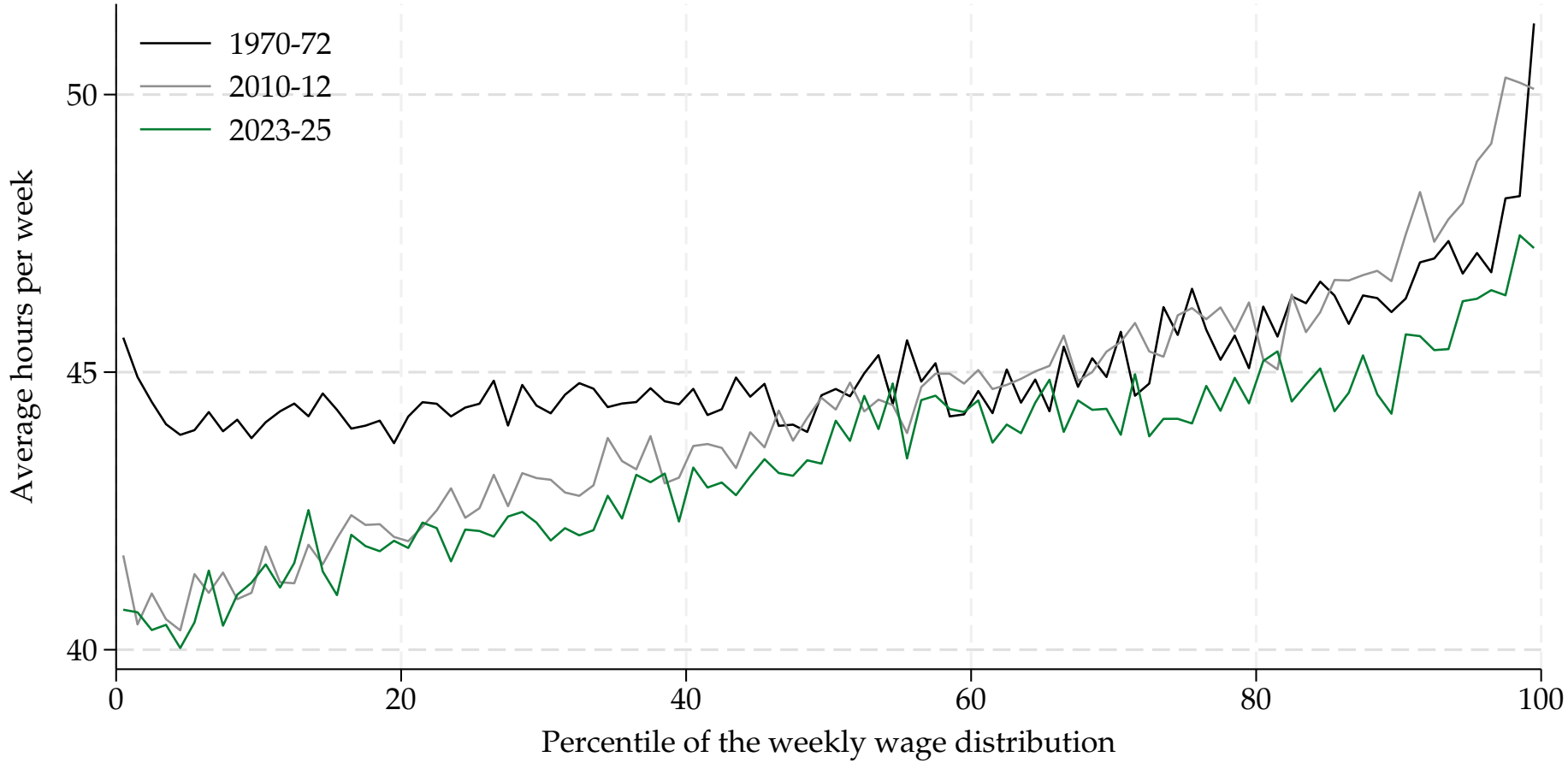
Murphy and Topel (2016) compared 1970–72 and 2010–12



US men and women 18-64, wage and salary workers, 27+ weeks, full time (35+ hours).
Weekly wage deflated by the PCE price index; 3 earnings years pooled. Source: IPUMS CPS ASEC.

Change in Hours Worked (US Men)

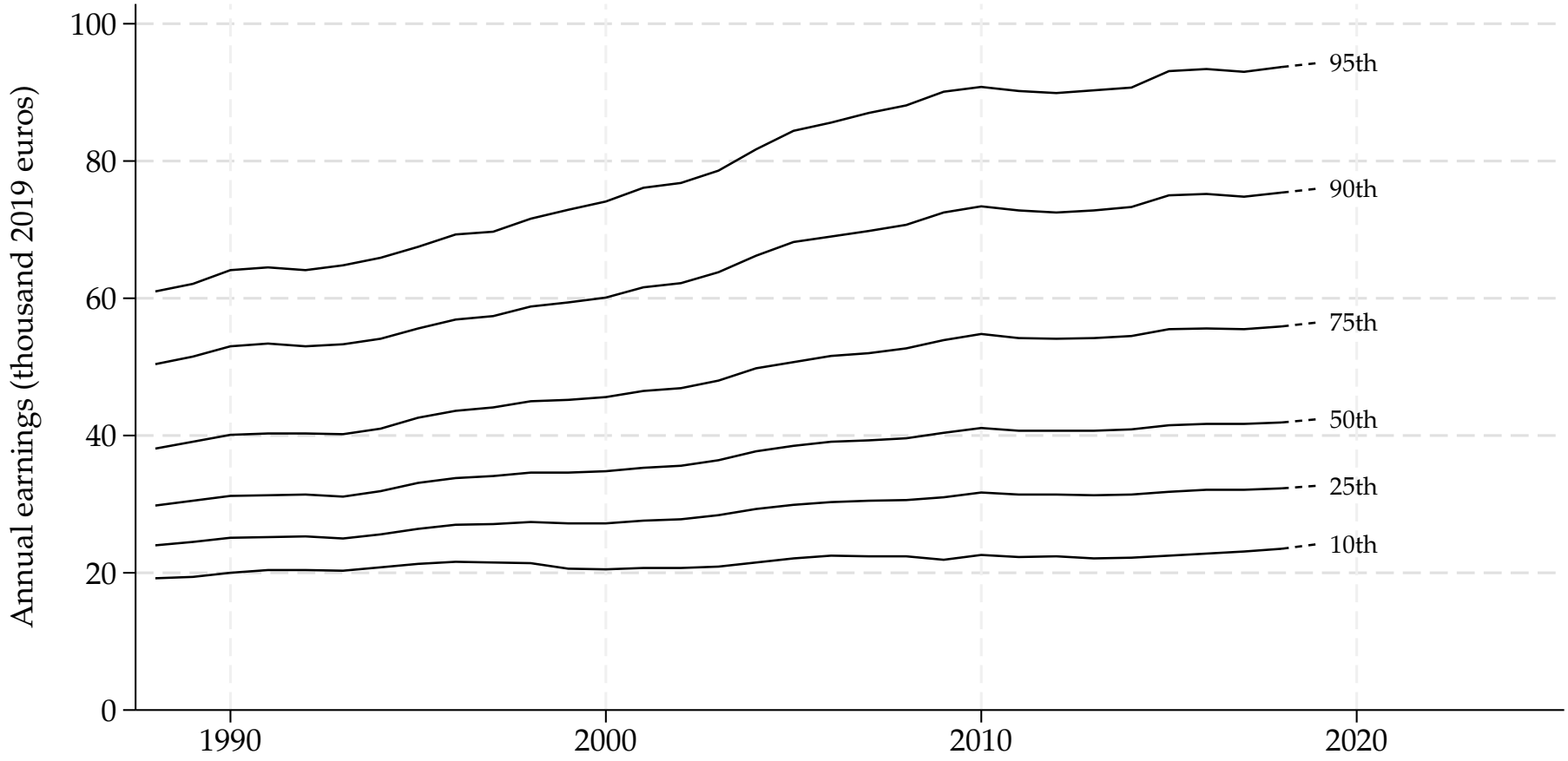
Hours by percentile of weekly wage



US men 18-64, wage and salary workers with over 30 weeks (before 1976: 27+) and over 30 hours in the survey week (March of the next year); hours of that week; 3 earnings years pooled. Source: IPUMS CPS ASEC.

Evolution of Wage Distribution (Finland, Men)

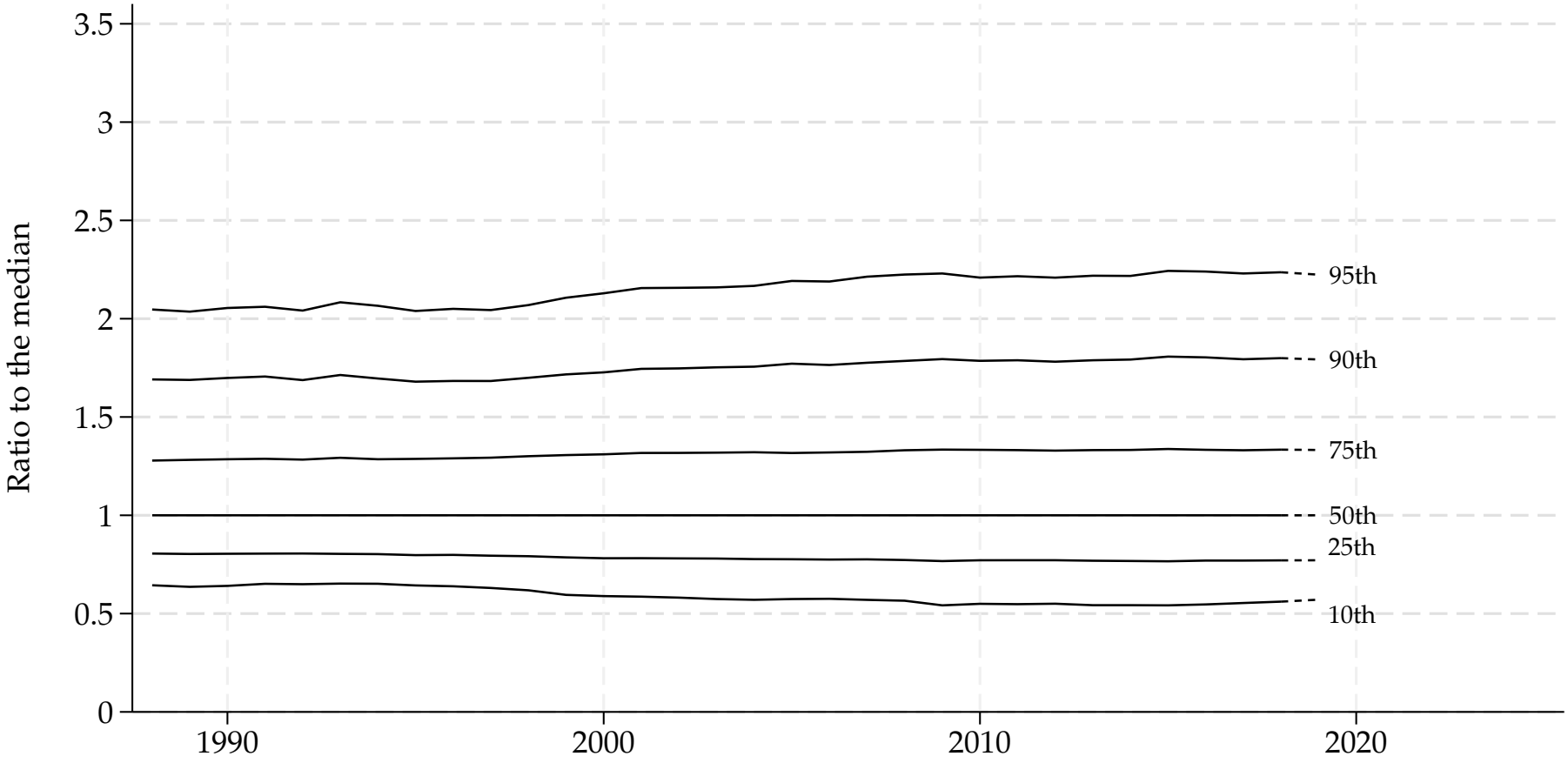
Annual wage earnings percentiles of full-year wage and salary earners



Finland, men 18-64, wage and salary earners at the end of the year and the previous one, no unemployment in the year. Annual wage income deflated by the CPI; dashed: 2019 break in the register. Source: Statistics Finland, FOLK.

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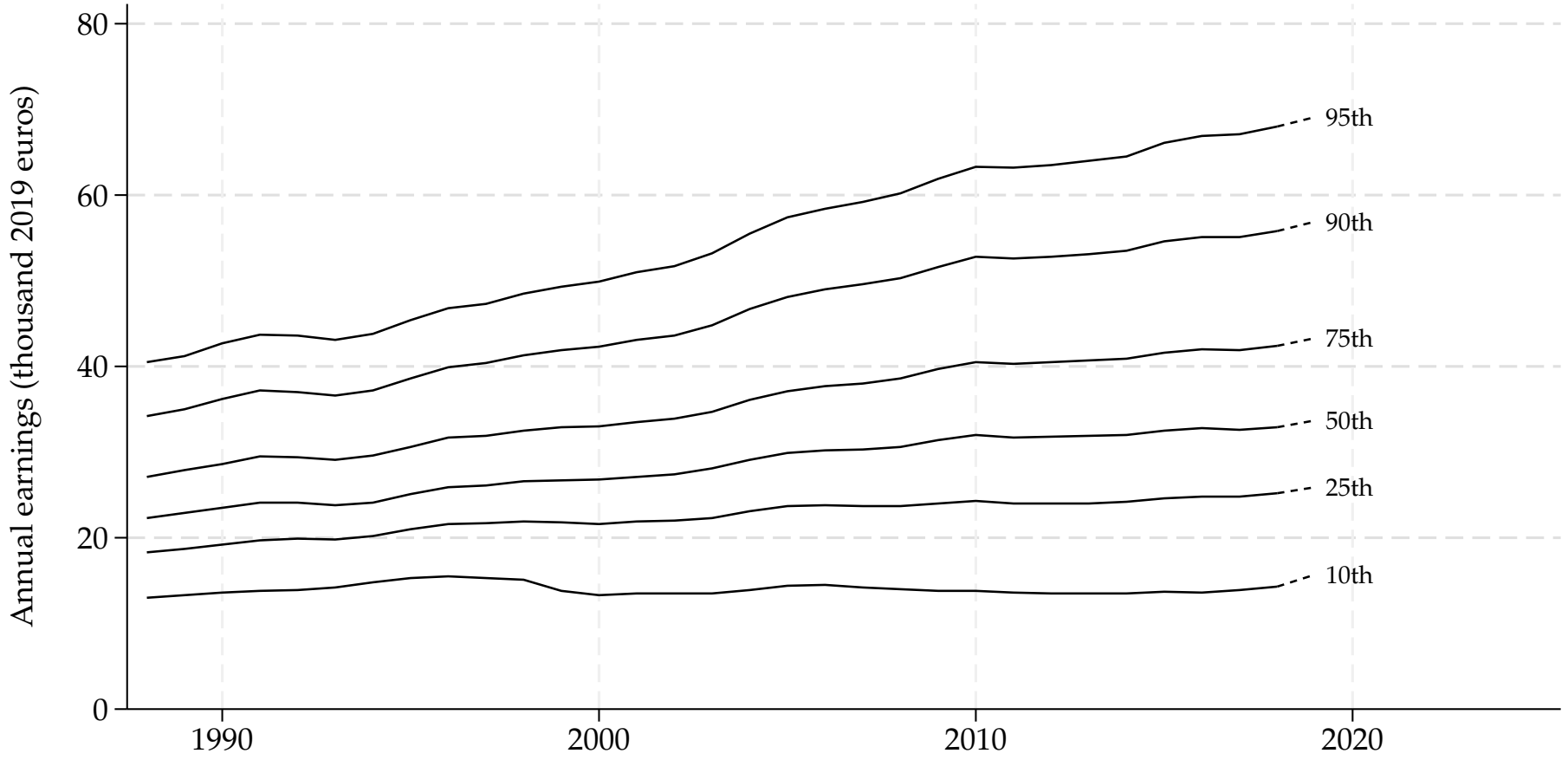
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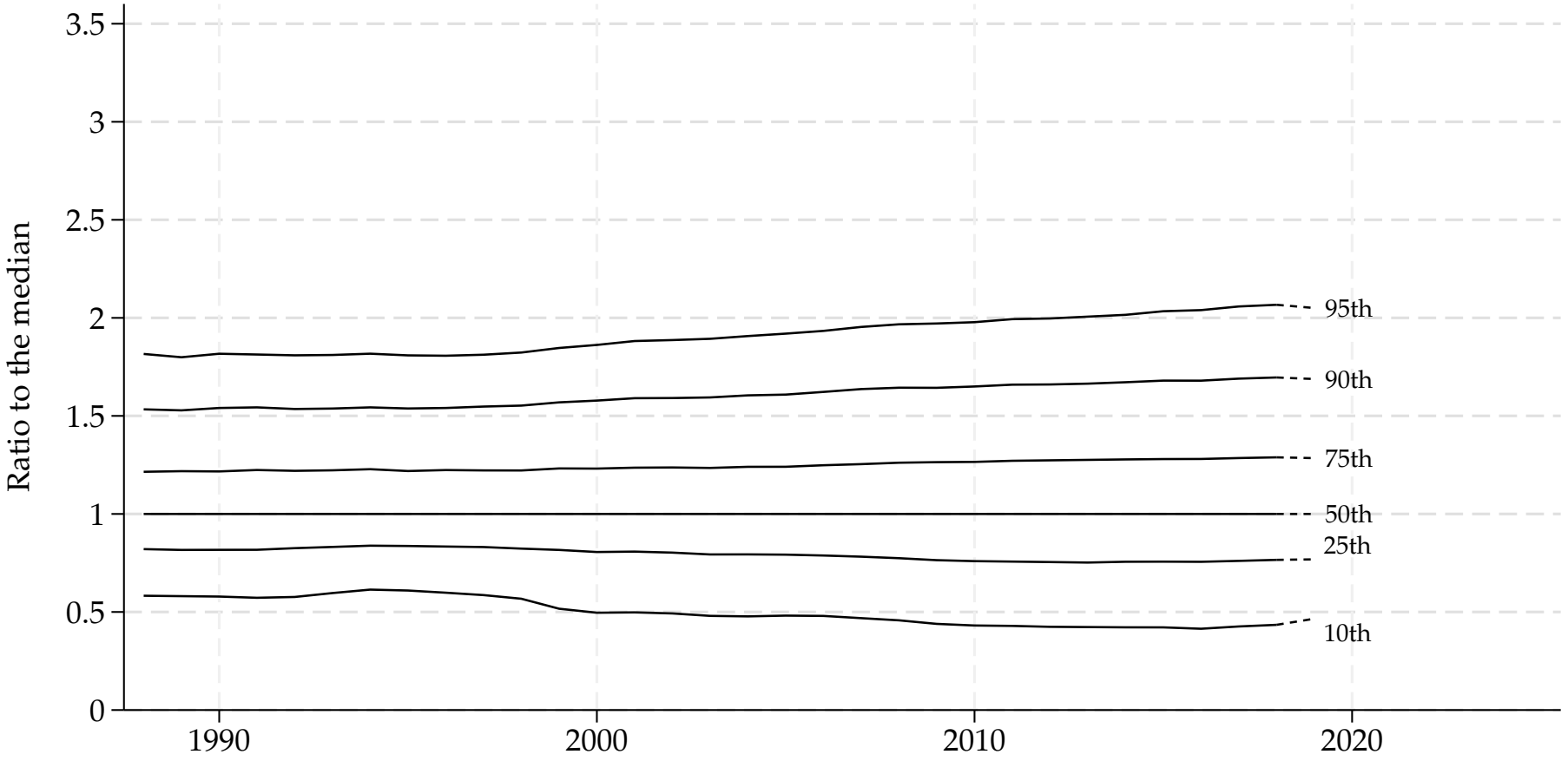
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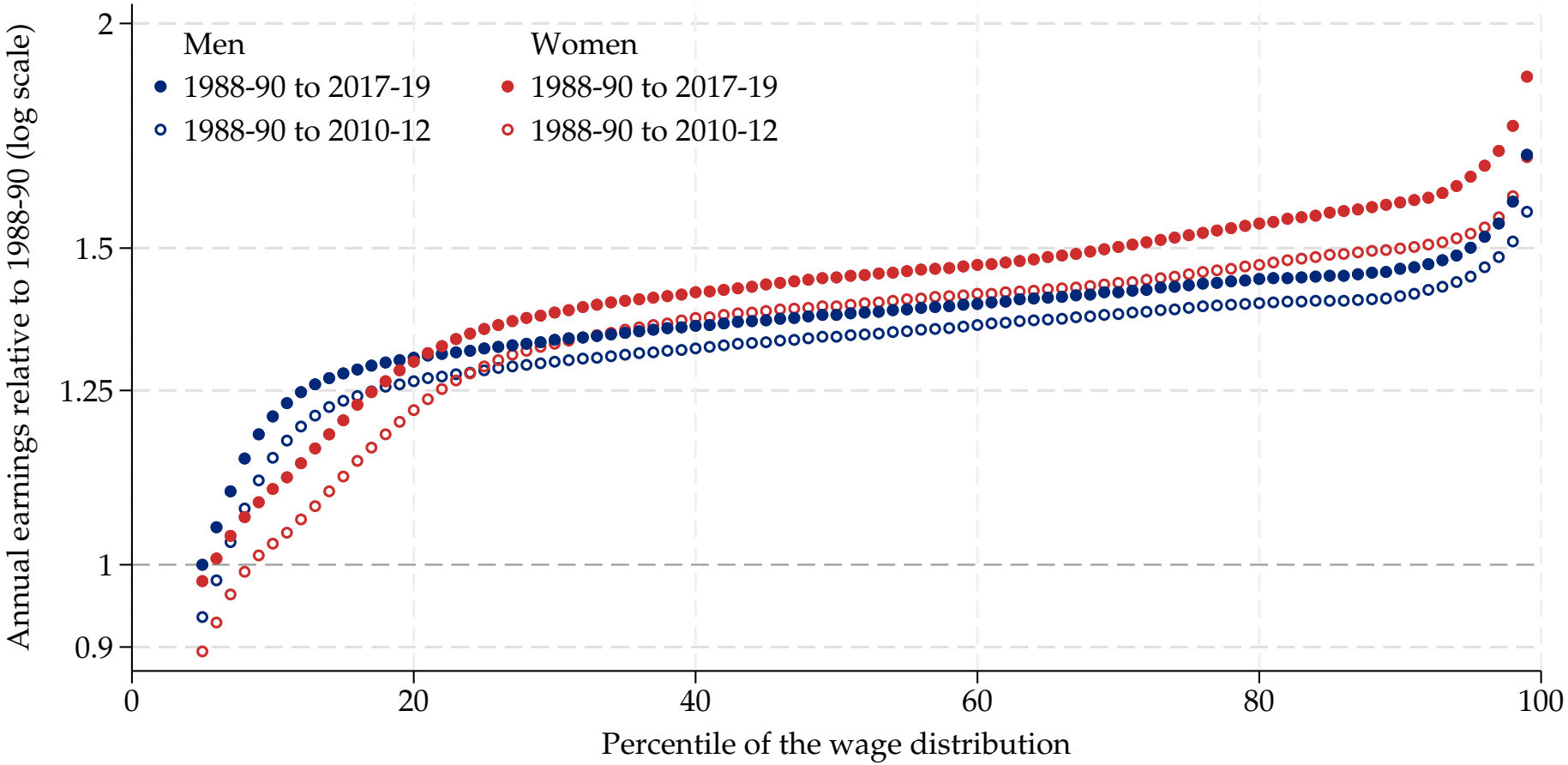
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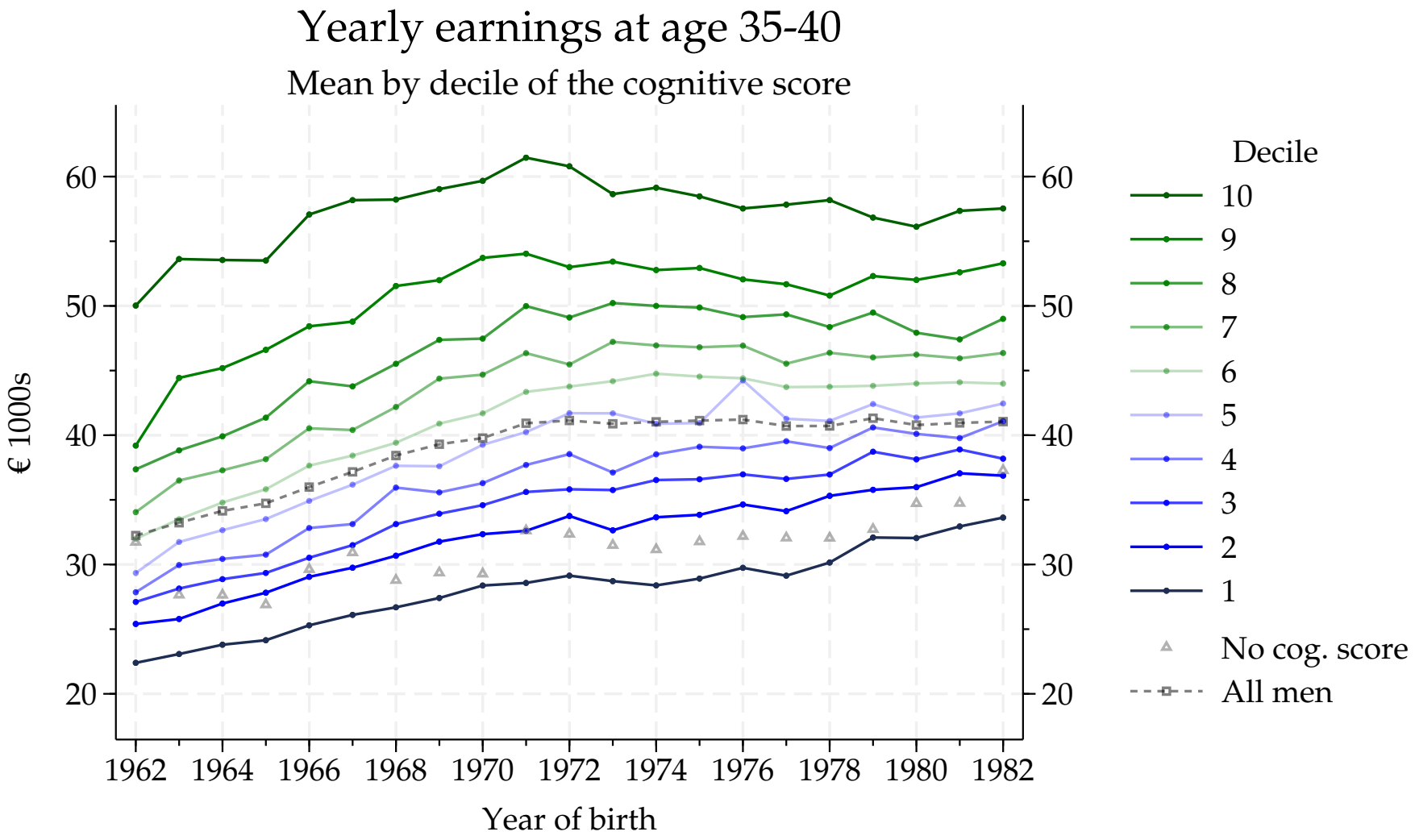
Change in Wage by Percentile (Finland)

Annual earnings of full-year wage and salary earners, change since 1988–90



Finland, men and women 18-64, wage and salary earners at the end of the year and the previous one, no unemployment in the year. Annual wage income deflated by the CPI; 3 years pooled; 2019 a break in the register. Source: Statistics Finland, FOLK.

Labor earnings by cognitive score (Finland, Men)



Modeling labor markets

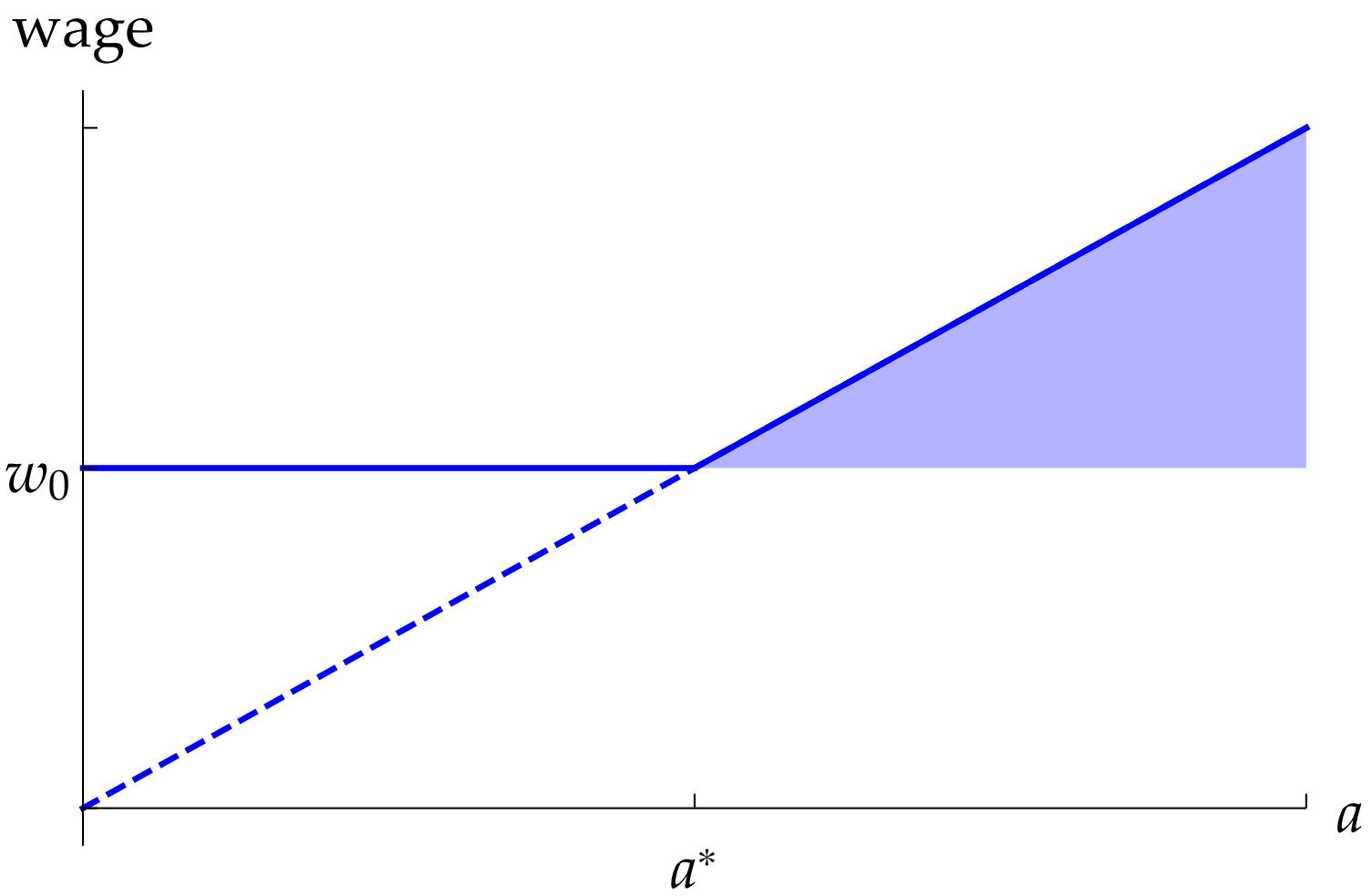
How differences in individual productivity translate to differences in wages? Indivisibilities or not...

- Step 1. Which allocation of resources would maximize total surplus?
- Step 2. Which distribution of wages would make this allocation an equilibrium?
- Variant: Under this structure of information, which allocation would maximize expected surplus?
- Consider: which resources are indivisible, in which time frame? Types of capital, ability, education, effort...

The world's simplest model of wage differences: Ricardian rents in partial equilibrium

- Adapted from the analysis of land rents by Ricardo (1817)
  That is where the definition of "rents" in economics comes from!
- Population of potential workers, with heterogeneous ability a and outside value w_0
- Ability a is measured as the revenue worker generates for the firm, gross of the wage $\rightarrow$ Profit $\pi(a) = a - w(a)$
- Industry with competitive firms, wages get bid up to $w(a) = a$
  Key assumption: MPL same at every firm
- Workers with $a < w_0$ will take the outside opportunity,
  marginal worker $a^* = w_0$ earns w_0,
  inframarginal workers $a > w_0$ earn ability rents $a - a^*$

Ricardian model: Ability rents in partial equilibrium



Equilibrium wage $w(a) = a$ if $a \geq w_0$.

Ricardian ability rents: Market equilibrium

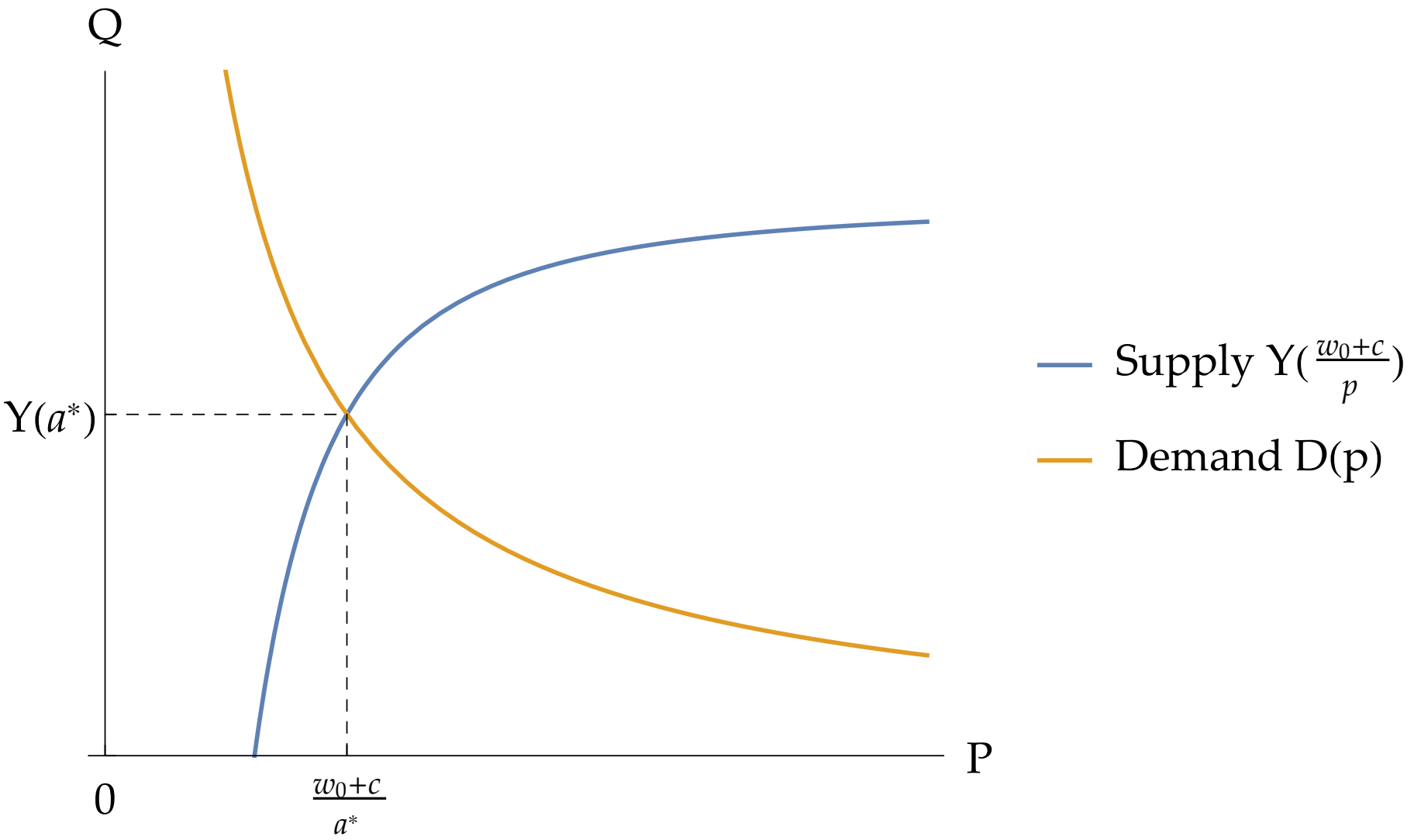
- Worker ability a measured as the level of output
  Worker outside option w_0
- Population of N workers with ability distributed $F(a)$, $a \in [0, \bar{a}]$
- Fixed production cost c (constant per worker)
  Firms make zero profits $\rightarrow$ wages $w(a) = pa - c$
- Surplus generated by a worker is $y(a) = pa - c - w_0$
- Demand for output: $D(p)$
- Market price of output, p, determined in equilibrium $\rightarrow a^*, w$

Ricardian ability rents: Market equilibrium

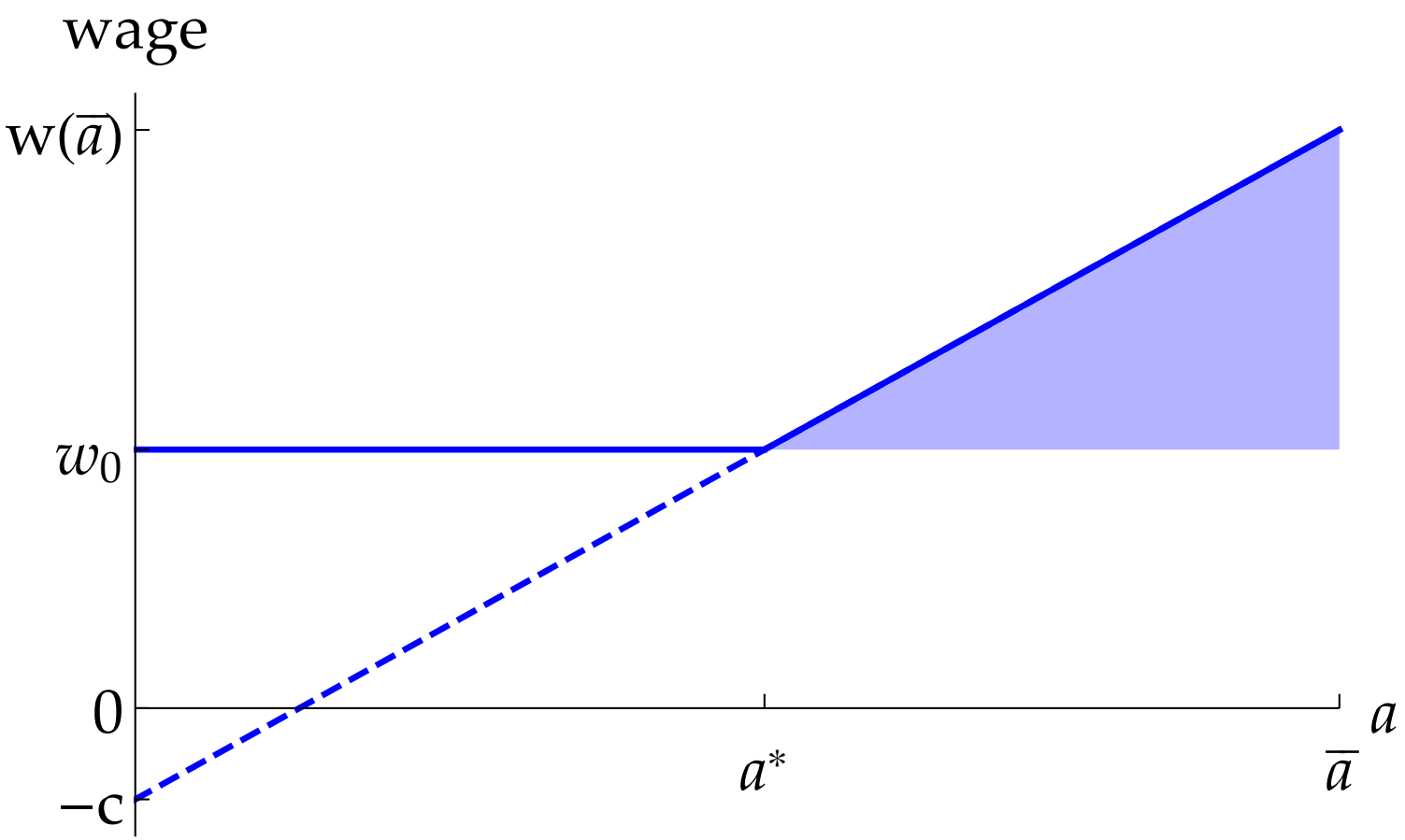
- Marginal worker type a^* earns w_0
- Wages $w(a) = p(a - a^*) + w_0$,
  where $p(a - a^*)$ is the ability rent.
- Marginal worker produces zero surplus:
  $pa^* - w_0 - c = 0 \rightarrow p^* = \frac{w_0 + c}{a^*}$
- Workers with $a \geq a^*$ produce,
  total output $Y(a^*) = N \int_{a^*}^{\bar{a}} af(a)\,\mathrm{d}a$,
  supply $S(p) = Y(\frac{w_0 + c}{p})$
- Market clears when
  p such that $S(p) = D(p) \iff$
  a^* such that $Y(a^*) = D(\frac{w_0 + c}{a^*})$

Ricardian model: Market equilibrium

(Under the hood)

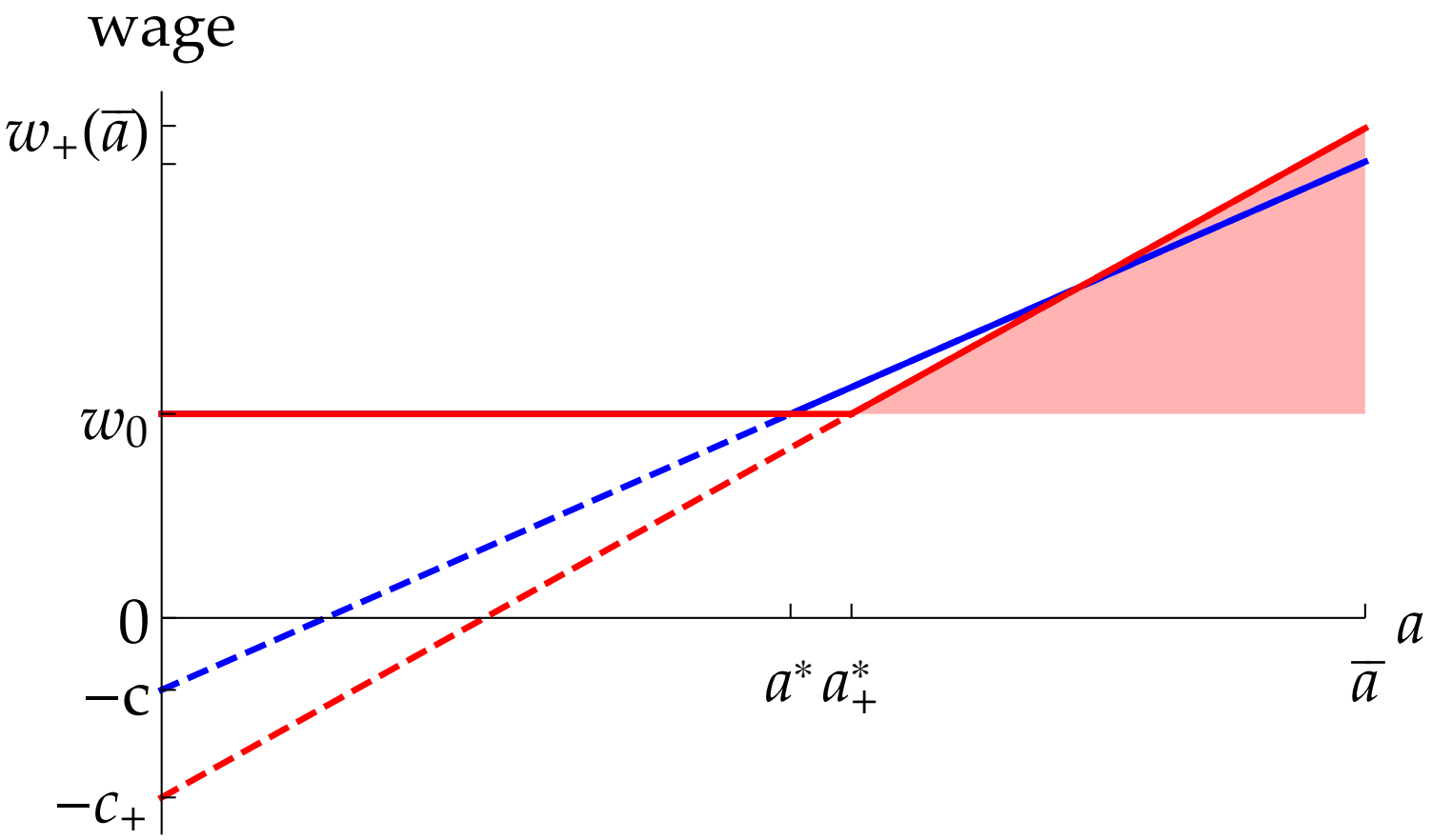


Ricardian model: Ability rents



Equilibrium wage $w(a) = w_0 + p^*(a - a^*) = w_0 + (w_0 + c)\frac{a-a^*}{a^*}$

Ricardian model: Ability rents



Increase in non-labor cost $c \implies \uparrow p^*, \uparrow a^*$

Ability rent $p^*(a - a^*)$ can be affected only linearly, via p^* or a^*, direction of top wage change depends on elasticity of demand

Ricardian ability rents, aka talent rents

In a market for a skill with individual productivity differences

- With a given output price p, ability rents $p(a - a^*)$ proportional to ability difference wrt marginal worker
- In equilibrium, higher non-labor cost of production per worker
  1. scales up the value of any ability difference.
  2. raises the ability threshold a^*
  3. w reduced for lower abilities,

     w may be increased for highest abilities (depends on F, D)

Good to be talented in a resource-intensive occupation – but you need to be higher up the tail to benefit

Efficient to economize on worker fixed costs w_0 when jobs costly

–> fewer but better workers

Scale of operations effect

How to allocate scarce productive resources between individuals?

Mayer (1960), Lucas (1978), Rosen (1982), “folk theorem”

Individual ability a, resources k.

Complementarity between factors: $y_{ak} > 0$.

$$y(a, k) = a\, g(k)$$

a is indivisible, k is adjustable, $g' > 0$, $g'' < 0$.

Workers & capital,

Managers & personnel (span of control),

Talent & education/training/effort. . .

Scale of operations effect

Allocate resources k to maximize surplus at every job.

$$\frac{\partial}{\partial k}\left(ag(k) - rk - w_0\right) = 0 \Longrightarrow k^*(a) = g'^{-1}\left(\frac{r}{a}\right)$$

Example: $g(k) = k^{\beta}, \quad \beta \in (0,1)$ captures scale economies

$$k^*(a) = \left(\frac{a\beta}{r}\right)^{\frac{1}{1-\beta}}$$

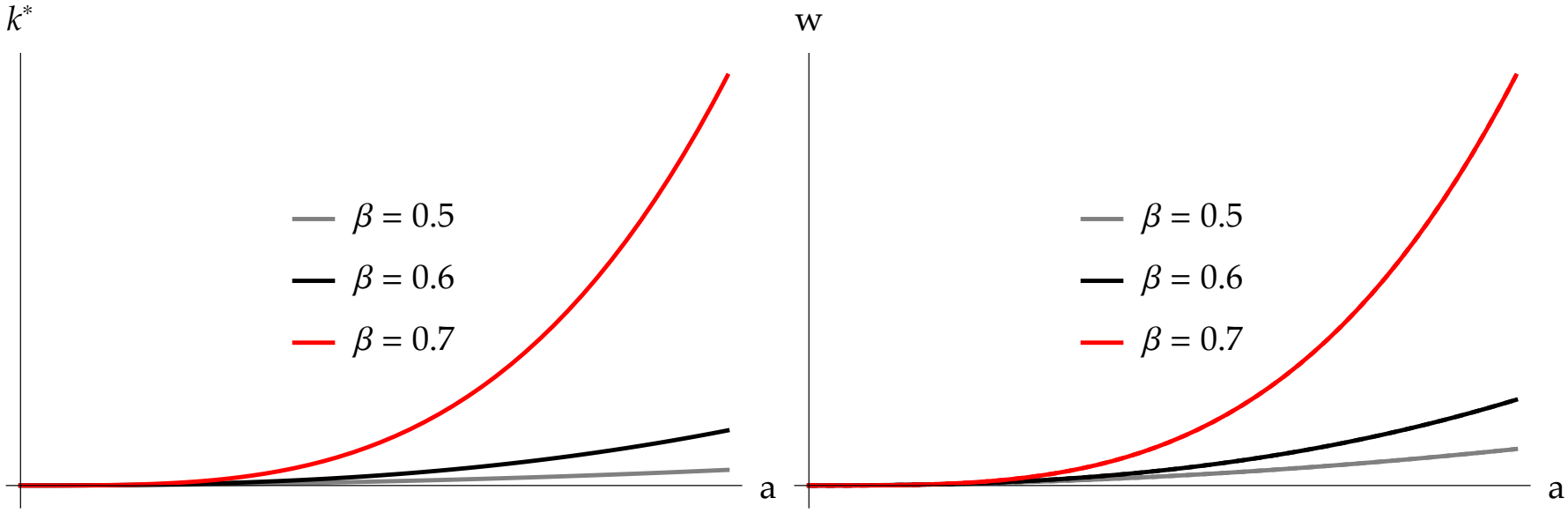
$$w(a) = ag(k^*(a)) - rk^*(a)$$

$$= b(\beta)a^{\frac{1}{1-\beta}} r^{\frac{-\beta}{1-\beta}}$$, where $b(\beta) > 0$ is an ugly-ish constant

For those who have more a, more k shall be given to work with.

Q. How do $\log(k)$ and $\log(w)$ vary with $\log(a)$, $\log(r)$?

Scale of operations effect: technological change



Scale economies for complementary factor $\rightarrow$

Higher and more skewed wages.

With $\beta = 0$, $w(a) \propto a$. What if $\beta \geq 1$?

In Rosen (1982), subordinate labor is complementary

Implication: improvements in communication tech $\rightarrow$

higher, more skewed wages for managers in fewer, larger firms

PSA: On the measurement units of indivisible factors

Ability is an indivisible factor of production. This means that it cannot be transferred between individuals.

Hence any positive monotone transformation of units a is meaningless in terms of observables.

Suppose $\tilde{y}(\tilde{a}, k) = \tilde{a}^{\alpha} k^{\beta}$, where $\alpha > 0$
Redefine units $a = \tilde{a}^{\alpha}$ and use $y(a, k) = ak^{\beta}$
Any positive monotone transformation of a is wlog (and woag)

Ability rents and scale of operations: examples

- Smith et al. (QJE 2019): US pass-through businesses
  Profit falls by 3/4 when the owner dies early or retires
  $\rightarrow$ top "capital income" was largely an ability rent
- Garicano et al. (AER 2016): Lucas (1978) model, French firms
  Labor rules bind from 50 employees: firms bunch at 49
  Like a 2.3% tax on labor, costing 1.3–3.4% of GDP
- Rajan & Wulf (REStat 2006): 300 large US firms, 1986–98
  Managers reporting to the CEO up by half, fewer layers below
  Removal of a layer above $\rightarrow$ 6–7% higher pay
- Fenizia (Ecma 2022): Italian social security offices
  1 SD better manager $\rightarrow$ +10% office productivity
  Best managers to largest offices $\rightarrow$ +7% output

Matching aka assignment: historical notes

More than one indivisible heterogeneous factor of production $\longrightarrow$ the units of production must be *matched*

Workers and jobs. Tinbergen (1951)

Generalized (unrestricted) assignment problem
Koopmans and Beckmann (1957)

Becker's marriage model (1973)

Sattinger's assignment model (1975, 1979) and JEL survey (1993)
The dog and bone economy, the impact of rank

The world's simplest matching problem

Surplus function

$$Y(a,b) = ab$$

Two workers, types $a_2 > a_1$. Two jobs, types $b_2 > b_1$.

Total output maximized with Positive Assortative Matching (PAM)

$$\begin{aligned} a_2 b_2 + a_1 b_1 &> a_2 b_1 + a_1 b_2 \iff \\ a_2(b_2 - b_1) &> a_1(b_2 - b_1) \iff \\ (a_2 - a_1)(b_2 - b_1) &> 0 \end{aligned}$$

Consider e.g., $a_1 = 1, a_2 = 2, b_1 = 1, b_2 = 2$

$Y(2,2) + Y(1,1) = 5 > Y(2,1) + Y(1,2) = 4.$

When is there PAM?

Supermodular Y is sufficient for PAM

Y is supermodular Y if, for all $a_2 > a_1$, $b_2 > b_1$,

$$Y(a_2, b_2) + Y(a_1, b_1) > Y(a_2, b_1) + Y(a_1, b_2)$$

When Y is differentiable, this is equivalent with

$$\frac{\partial^2 Y(a, b)}{\partial a \partial b} > 0 \text{ for all } (a, b)$$

An arbitrary increasing function Y unlikely to result in PAM or NAM

Example of NAM: $Y(a, b) = \bar{Y}(1 - \frac{1}{ab})$, where $(a, b) \in [1, \infty)^2$

General version of the assignment problem is analytically intractable $\rightarrow$ numerical black box

Matching workers with workers (team production)

Kremer (QJE 1993) O-Ring production function

Worker quantity not substitutable with worker quality

$$y(a_1, \ldots, a_n, k) = \bar{y} k^{\beta} \Pi_{i=1}^{n} a_i \qquad \text{(production)}$$

$$\pi(a_1, \ldots, a_n, k) = y(a_1, \ldots, a_n, k) - \sum_{i=1}^{n} w(a_i) - rk \qquad \text{(profit)}$$

a_i probability that worker i succeeds

k^{β} contribution of capital (DRS)

$\bar{y}$ output if $k = 1$ and all n workers succeed

Workers (team members) are complements $\Longrightarrow$ PAM

Teams are complements with capital $\Longrightarrow$ Scale effect

Kremer (1993) O-Ring Theory of Ec. Development

Workers (team members) are complements $\Longrightarrow$ PAM.

Continuous distribution of a $\Longrightarrow$ homogeneous teams.

The teams have a scale-of-operations effect wrt k,

capital is adjustable $\Longrightarrow$ $k^*(a)$ increasing but earns just $rk^*(a)$

$\Longrightarrow$

1. Skill-segregation between firms
2. Right-skewed wage distribution

Extension: Choice of n from a schedule $\bar{y} = B(n)$ of complexity by product.

Kremer lists 10 conclusions. Dev econ: in developed countries, firms are larger and specialize in more complex products

Håkanson et al. (JHR 2021): Sorting by skill

Are firms becoming more segregated by skill?

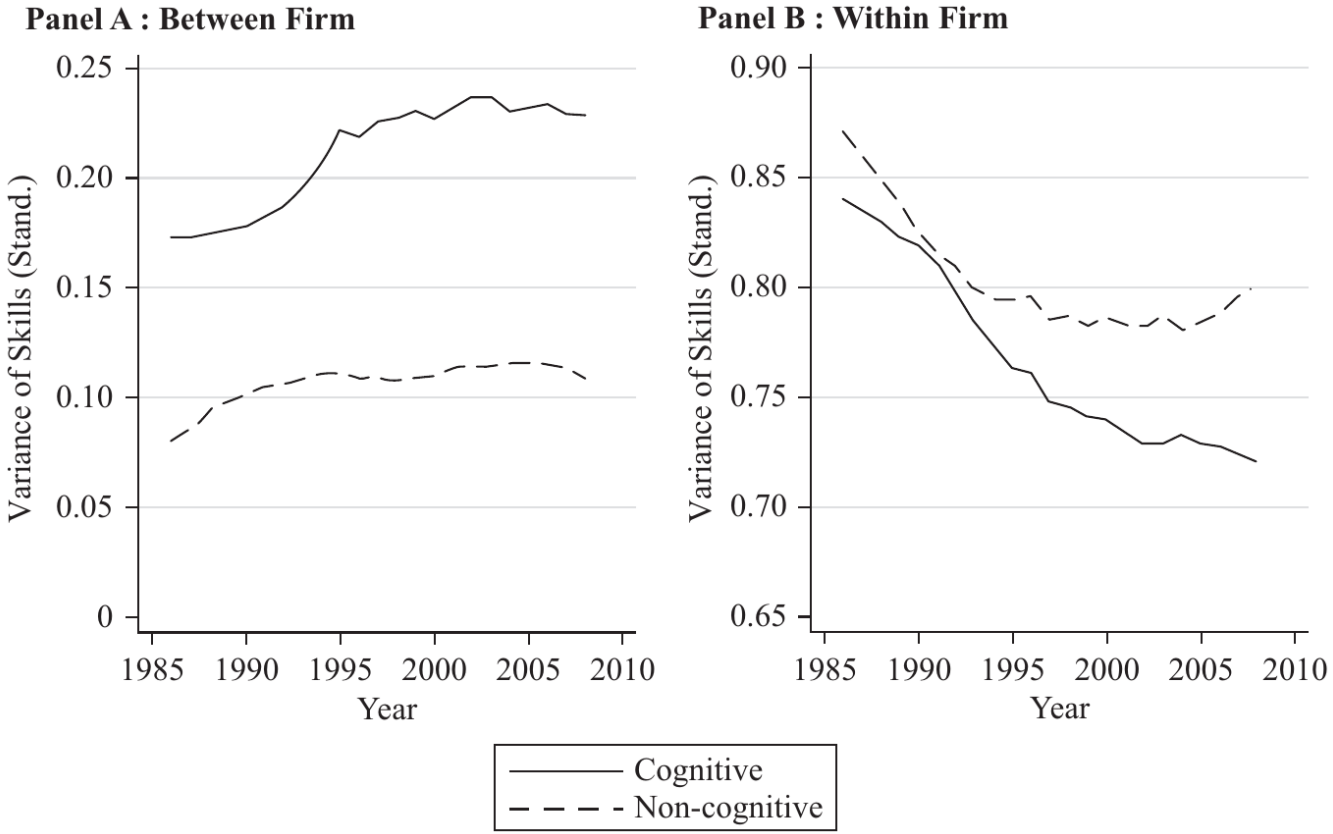
Data: Swedish men aged 30–35 in private firms (10+ employees)
1986–2008, linked to military conscript tests at age 18-19
Cognitive and non-cognitive skill standardized by cohort

Skill variance = between-firm + within-firm component
Between-firm share of cognitive skill variance: 17% $\rightarrow$ 24%
Firms with mean skill $\geq$ 1 SD: 2.3% $\rightarrow$ 4.8% of workers
Removing ICT industries takes out over half of the rise
Within-firm variance fell in all industries, most in manufacturing

Sorting and steeper skill gradients account for 45% of the
rise in between-firm wage variance; sorting the larger part

Håkanson et al. (2021): Sorting by skill

Figure 1: Variance of skills between and within firms



Main rise during the 1991–93 crisis, but not reversed after

Sorting by AKM worker effects rose only a decade later

Assignment Model

Matching without frictions: full info, market clears at once

1. Technology: Net and gross surplus functions

$$Y(a,b) = \max_{\mathbf{x}} \left\{ y(a,b,\mathbf{x}) - \left(w_0 + \pi_0 + c(\mathbf{x}) \right) \right\}$$

$$\tilde{Y}(a,b) = Y(a,b) + \left(w_0 + \pi_0 \right)$$

Adjustable factors $\mathbf{x}$ chosen optimally for the given match.

2. Factor supply: Distributions of indivisible factors
3. Outside prices: w_0, π_0

Scale of operations effect is a limiting case where distribution of b degenerate

Distributions of factor quality

Definition: quantile function (aka inverse CDF)

$$x(i) = x \text{ s.t. } \{F(x) = i\} \quad \Longrightarrow \quad x'(i) = \frac{1}{f(x(i))}$$

Quantiles $i \in [0, 1]$ are convenient and have empirical content

Example: Pareto distribution (x_0,γ)

$$F(x) = 1 - \left(\frac{x}{x_0}\right)^{-\gamma} \qquad \text{for } x \geq x_0$$

$$f(x) = \frac{\gamma}{x_0}\left(\frac{x}{x_0}\right)^{-(1+\gamma)} \qquad \text{for } x \geq x_0$$

$$x(i) = x_0(1-i)^{-\frac{1}{\gamma}} \qquad i \in [0, 1)$$

$$x'(i) = \frac{x_0}{\gamma}(1-i)^{-(1+\frac{1}{\gamma})} \qquad i \in [0, 1)$$

Assignment Model: Equilibrium

An assignment model determines the equilibrium division of surplus between indivisible factors

Assume $Y_{ab} > 0 \implies$ PAM: $a(i)$ matched with $b(i)$, for some $[i_0, 1]$

Marginal unit is the lowest to i_0 cover the outside opportunities:
$\tilde{Y}(a(i_0), b(i_0)) = w_0 + \pi_0$

Let's discard the inactive quantiles and normalize $i_0 := 0$.
Inframarginal units of indivisible factors always earn rents.

Equilibrium factor rents must add up:
$Y(a(i), b(i)) = w(i) + \pi(i)$ for $i \in [0, 1]$

We can solve for either factor rent, say $w(i)$; the other gets the rest.

Assignment Model: Equilibrium rents

Continuum of factor owners, so price-taking decision makers and no bargaining rent.

1. All participants get at least zero rents

2. Every factor-owner chooses best match by maximizing own surplus.

3. $Y_{ab} > 0$, so total surplus is maximized by PAM

2. & 3. imply that every firm $b(i)$ is maximizing profits by hiring $a(i)$, taking as given the entire a, w

Observable incomes = Factor rents mixed up with compensation to adjustable inputs (return to capital, to education, effort. . .)

Assignment Model: Equilibrium rents

Firm i factor rent if hire worker $j \in [0,1]$ is

$$\pi(j|i) = Y\big(a(j), b(i)\big) - w(j)$$

Firm i first order condition

$$\frac{\partial \pi(j|i)}{\partial j} = Y_a\big(a(j), b(i)\big)a'(j) - w'(j)$$

FOC must hold at $i = j$ by PAM:

$$Y_a(a(i), b(i))a'(i) - w'(i) = 0$$

Added surplus from matching with $a(i)$ instead of $a(i-\varepsilon)$ is worth paying $w(i) - w(i-\varepsilon)$ for $b(i)$ but, by $Y_{ab} > 0$, not for $b(i-\varepsilon)$. $\Longrightarrow$ SOC

Assignment Model: Equilibrium rents

Equilibrium wage distribution by integrating FOC(i) over i

$$w(i) = w_0 + \int_0^i Y_a\big(a(j), b(j)\big)\, a'(j)\mathrm{d}j \tag{1}$$

Firm profits analogously, or as the residual $Y(a(i), b(i)) - w(i)$

$$\pi(i) = \pi_0 + \int_0^i Y_b\big(a(j), b(j)\big)\, b'(j)\mathrm{d}j$$

Division of surplus at quantile i depends on the production function and the distributions of both factors below i.

Inherent symmetry. Both matching factors earn rents, benefit from high quality matches below, no impact from above.

Marginal Product of Indivisible Factors

With more than one indivisible factor of production, indivisible units must be *matched* to produce.

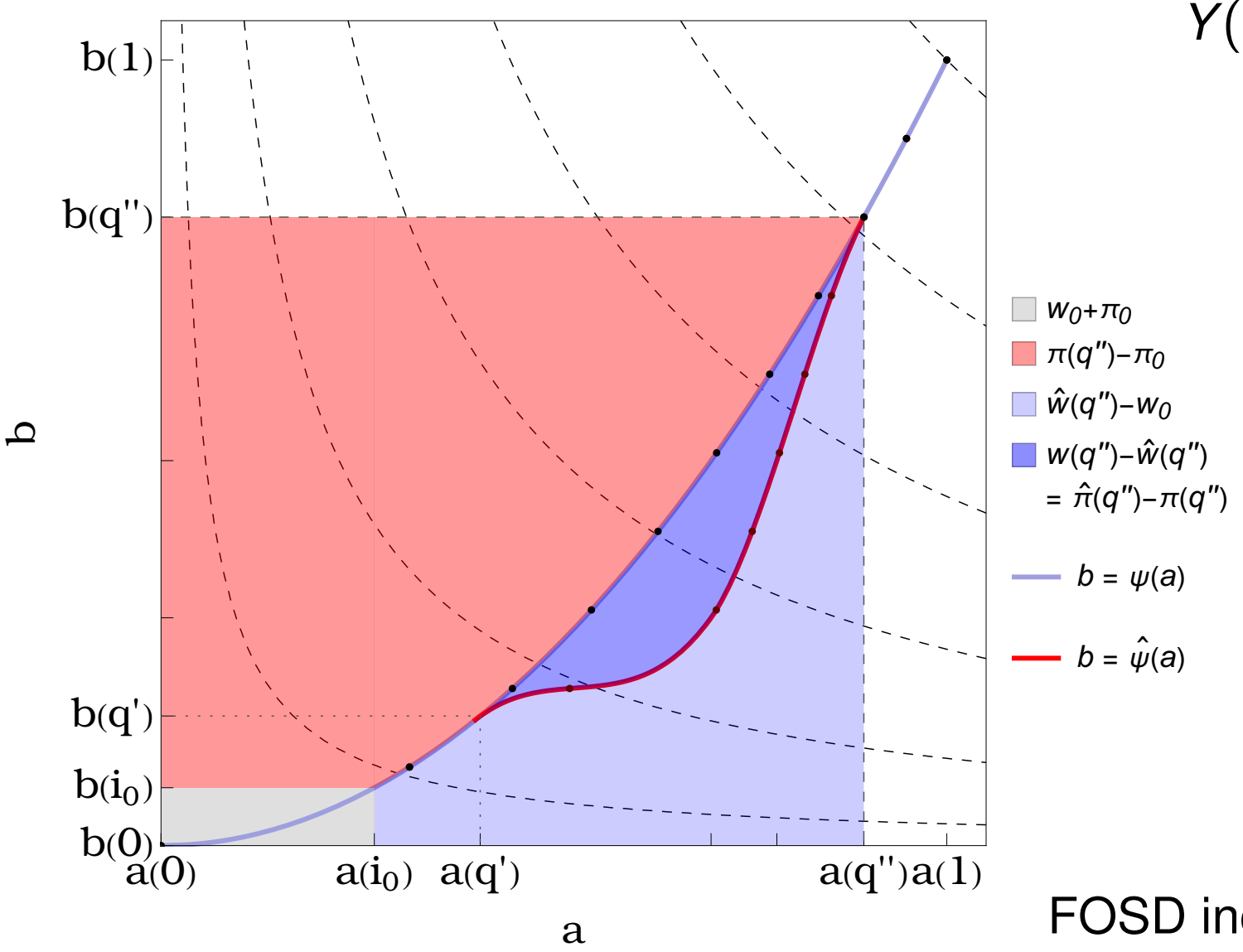
There can be no "marginal product" to a factor where there is no margin at which the amount of that factor could be adjusted. (Compare with MPL in the canonical model).

The correct margin is "How does total surplus change if this unit leaves the market, taking into account the resulting optimal rearrangement of matches in the whole market."

In equation (1), $w(i) - w_0$ is the marginal product of individual i in this proper sense: if worker i is removed, all firms $j \in (0, i]$ will have to match with a slightly lower-ability worker.

Wage Spillovers in a Matching Market

$$Y(a,b) = ab$$



FOSD increase in a

Application to CEO pay in the US

Terviö (2008): The Difference that CEOs Make: An Assignment Model Approach

1. What explains growth in level of top CEO pay?
2. What is the impact of heterogeneous CEO ability vs heterogeneous firm quality?

$w(i), \pi(i)$ observed. But: π must be purged of the value of adjustable capital. Market value –> stock to flow.

Assuming functional form Y, distributions $b(i)$ and $a(i)$ can be inferred via AM equilibrium conditions

Firm size is an unobserved type, market value is an equilibrium outcome

What is the indivisible factor at firms/jobs?

Beyond scale effects

Not adjustable capital or labor, not outcomes

Firm quality is persistent. Bloom and Van Reenen (2011)

Legacy of past decisions and luck.
Sunk capital, organizational capital/corporate culture, brand

The natural scale of the market niche: technology, location

What is ability? Whatever generates surplus – not critical acclaim or technical proficiency!

Terviö (2008): Difference that CEOs make

Model assumptions

(This notation simplified from the paper)

$$\tilde{Y}_t(a,b) = \max_k \left\{ abh_t(k) - rk \right\}$$

$$Y_t(a,b) \propto G_t ab$$

Firm's market value v_t is the present value of $Y_t(a,b) - w_t(a)$, $t = 1, \ldots, \infty$. Assuming 1. distributions of a and b are stable, 2. $h_t(k) = g_t h(k)$, and 3. discount rate, π_t can be calculated from v_t and w_t.

The shape of distributions a and b inferred up to a multiplier. Counterfactuals about firm heterogeneity sensitive to assumed h, so only consider counterfactuals about CEO heterogeneity.

Terviö (2008): The Difference that CEOs make

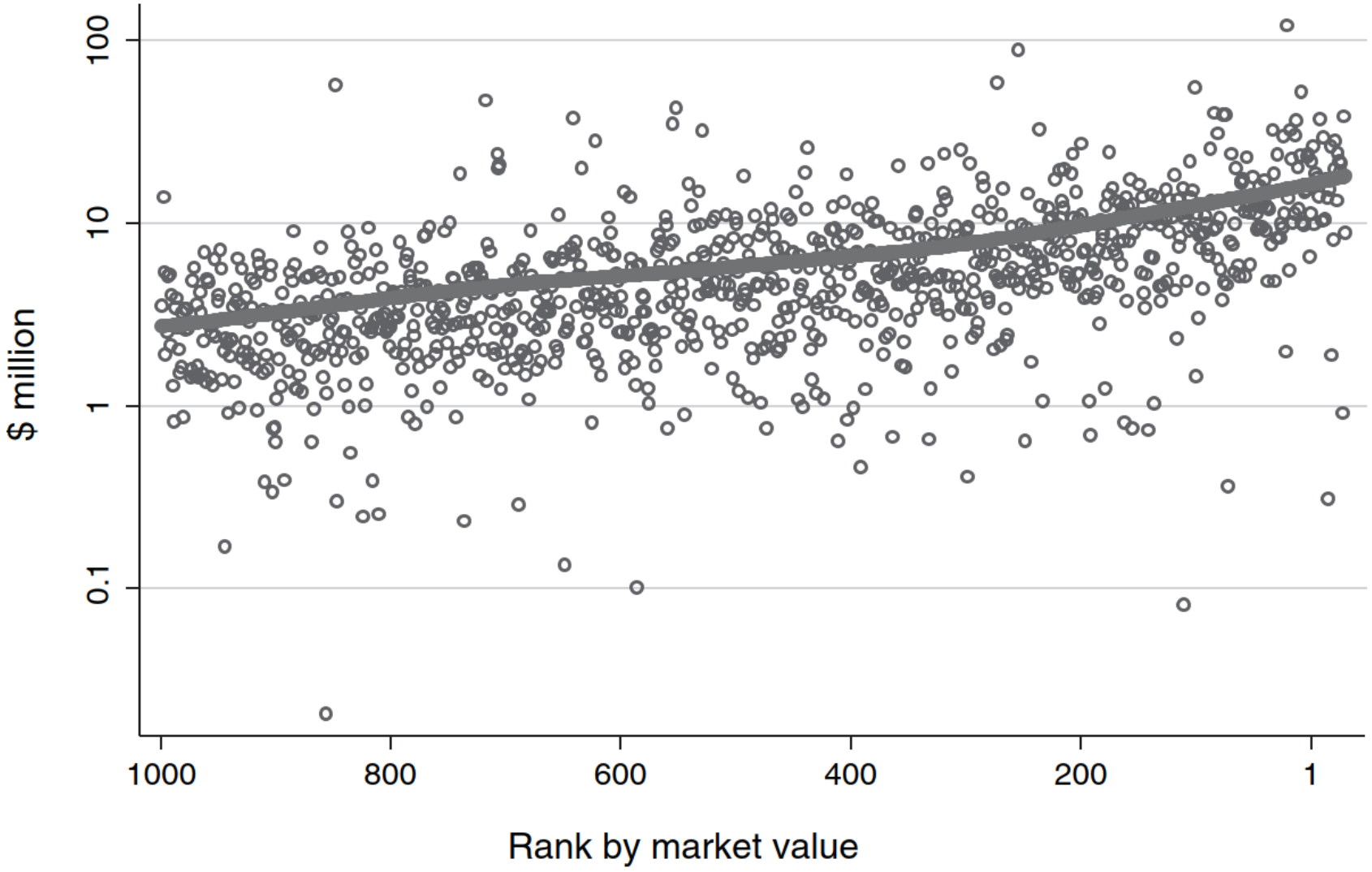


FIGURE 2. RELATION OF CEO PAY AND FIRM RANK BY MARKET VALUE IN 2004

Terviö (2008): The Difference that CEOs make

How consistent is data with model, if G_t the only change?

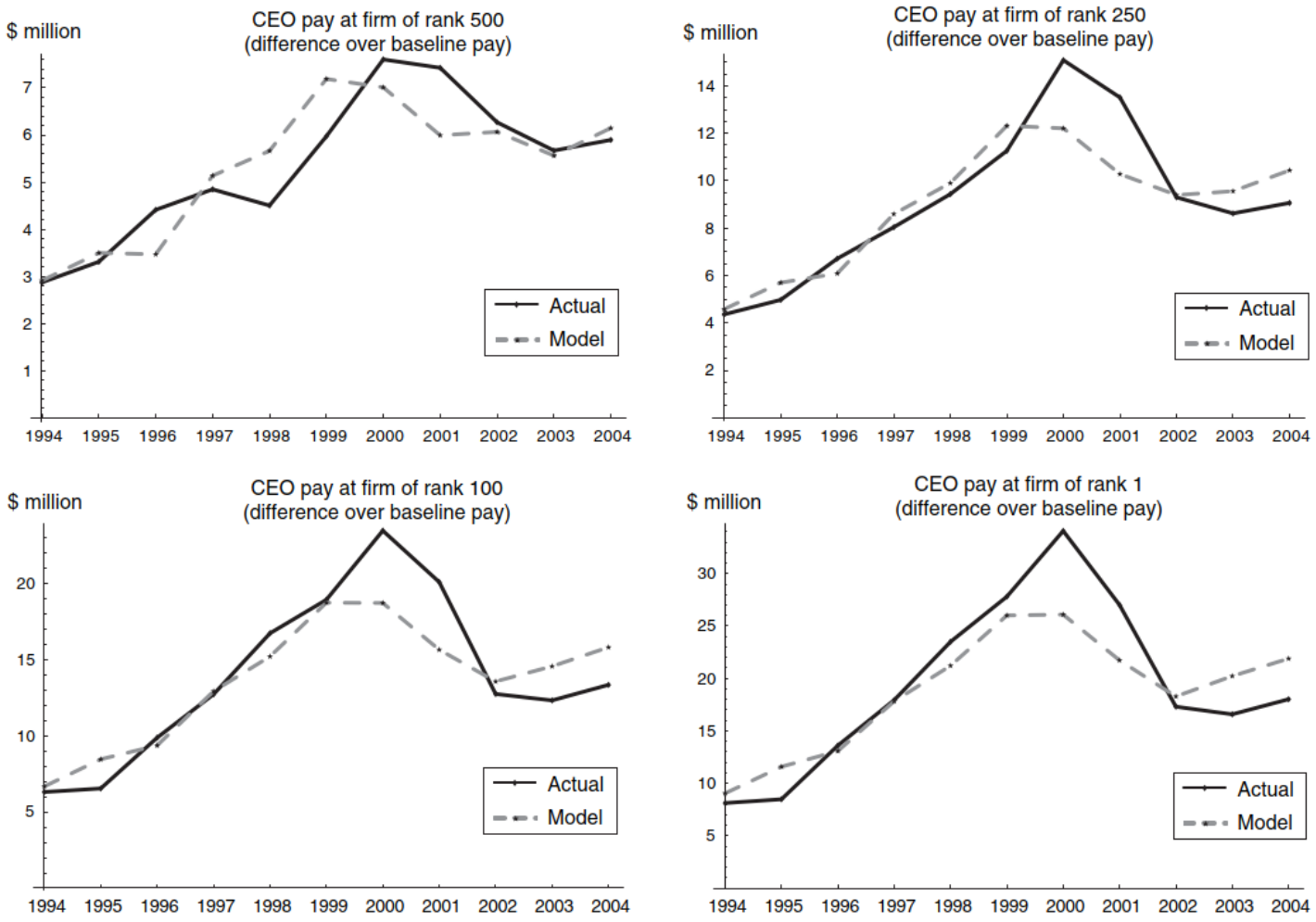


FIGURE 6. THE DIFFERENCE IN PAY BETWEEN THE CEOS OF SELECTED RANKS AND THE BASELINE (1,000TH) CEO

Terviö (2008): The Difference that CEOs make

How consistent is data with model, if G_t the only change?

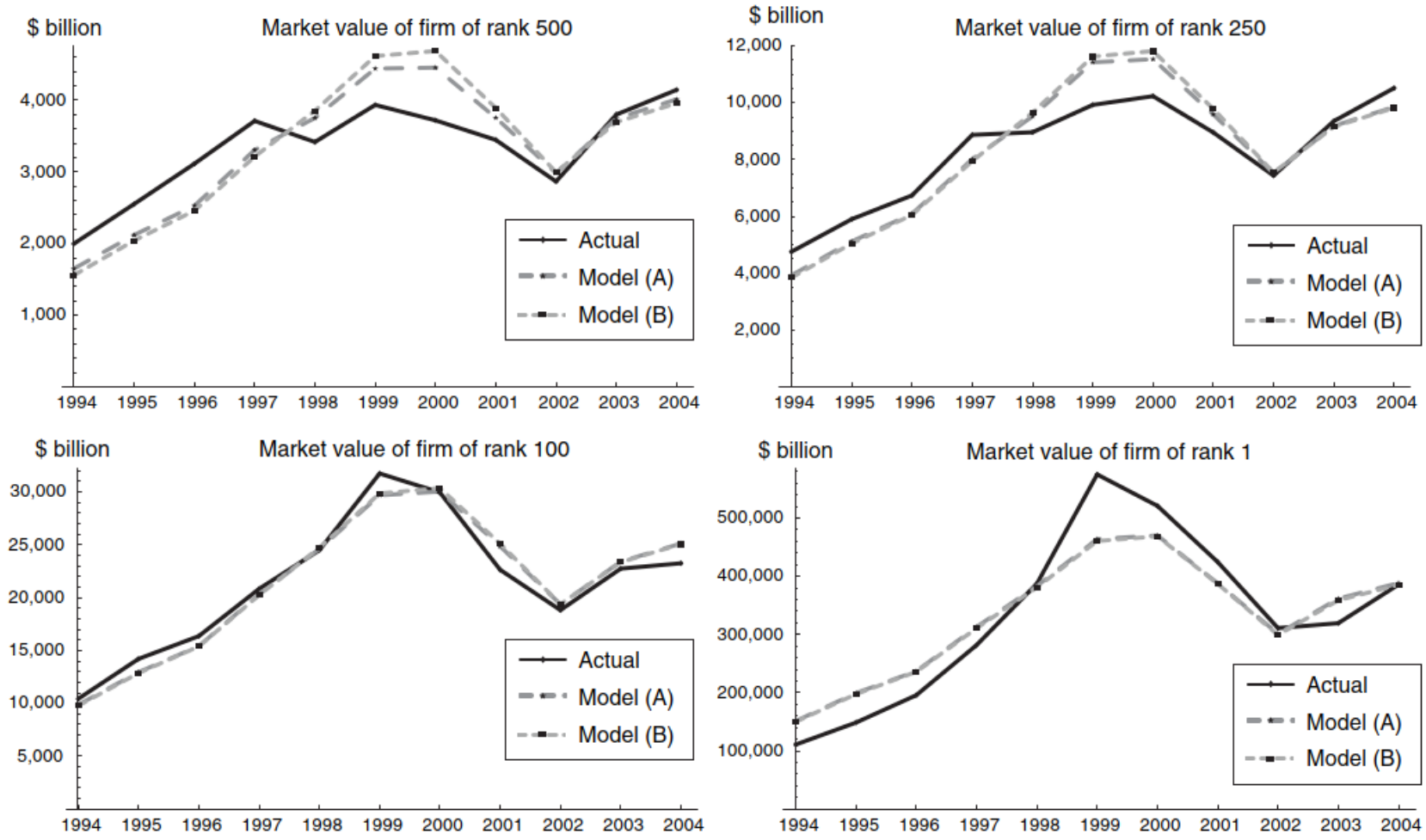


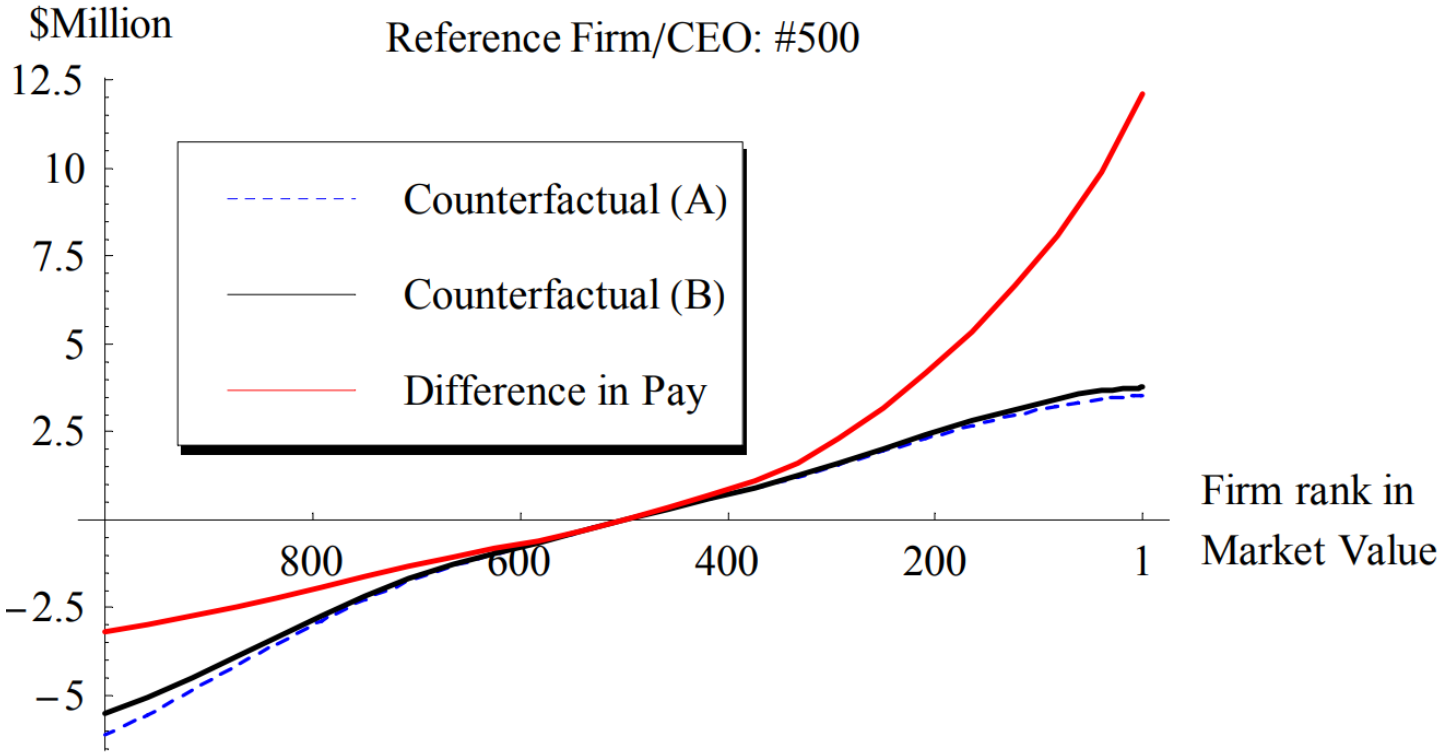
FIGURE 7. PREDICTED MARKET VALUES IN THE TIME-INVARIANT CALIBRATION

NB label typo: “billion” should be “million”

Terviö (2008): The Difference that CEOs make

How much surplus would other CEOs produce at firm 500?

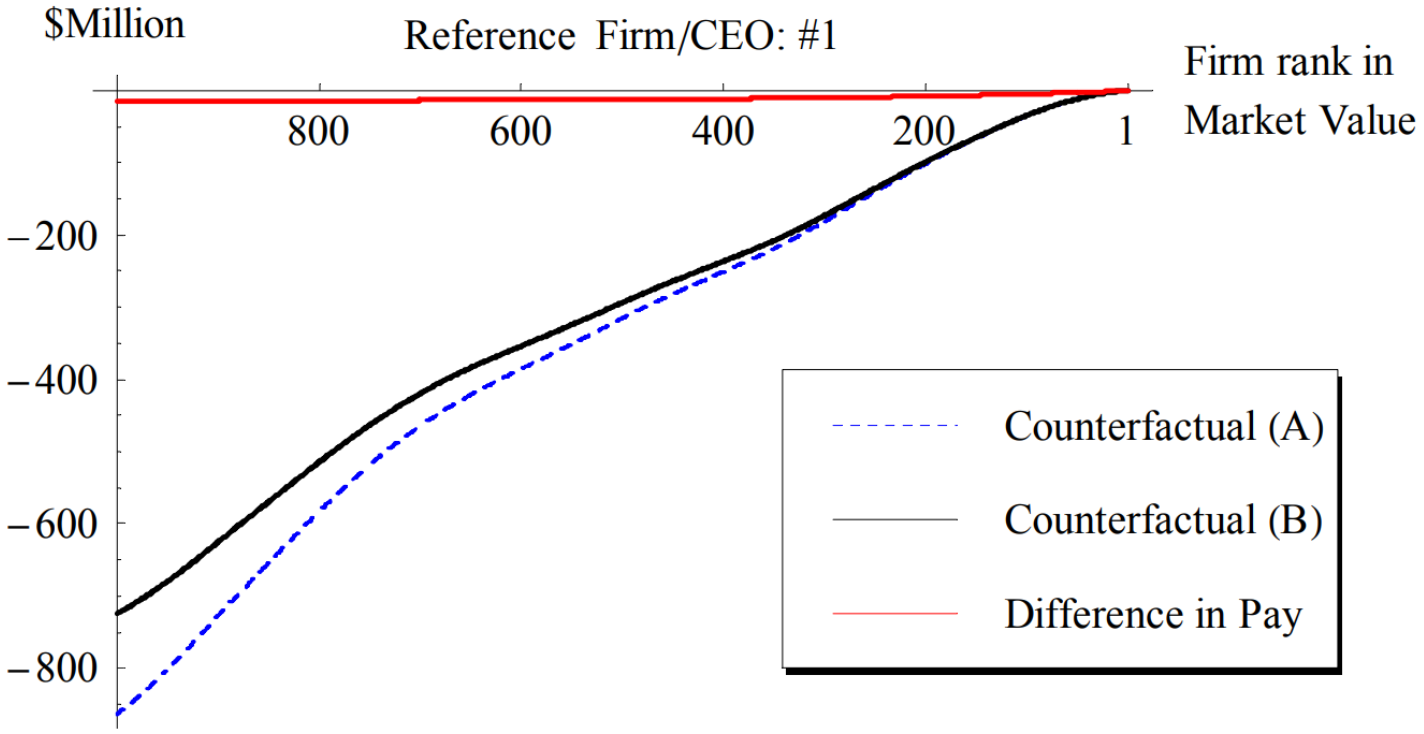
$Y(a(i), b(0.5)) - Y(a(0.5), b(0.5))$ and $w(i) - w(0.5)$



Terviö (2008): The Difference that CEOs make

How much surplus would other CEOs produce at the top firm?

$Y(a(i), b(1)) - Y(a(1), b(1))$ and $w(i) - w(1)$



Matching and Dynamics

In the frictionless matching framework, worker movements between firms reflect changes in (expected) skills and firm types.
No amount of mobility will enable estimation of $\{a, b, Y\}$ from a LEED wage panel.
Be careful interpreting AKM/TWFE results. Bonhomme, Lamadon, and Manresa (2019), Lopes de Melo (2018)

Matching with learning about type. Anderson and Smith (2010)

Matching with frictions and search. Chade, Eeckhout and Smith (2017)

Matching while learning from coworkers. E.g., Herkenhoff, Lise, Menzio, Phillips (2024)

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Recommended Browsing

- Acemoglu, Daron, and David Autor: Lectures in Labor Economics https://bit.ly/3YvJUS4
- Autor, David: Graduate Labor Economics https://economics.mit.edu/people/faculty/david-h-autor/courses
- Handbook of Labor Economics https://www.sciencedirect.com/handbook/handbook-of-labor-economics/volumes

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