Uneven Growth

Automation's Impact on Income and Wealth Inequality

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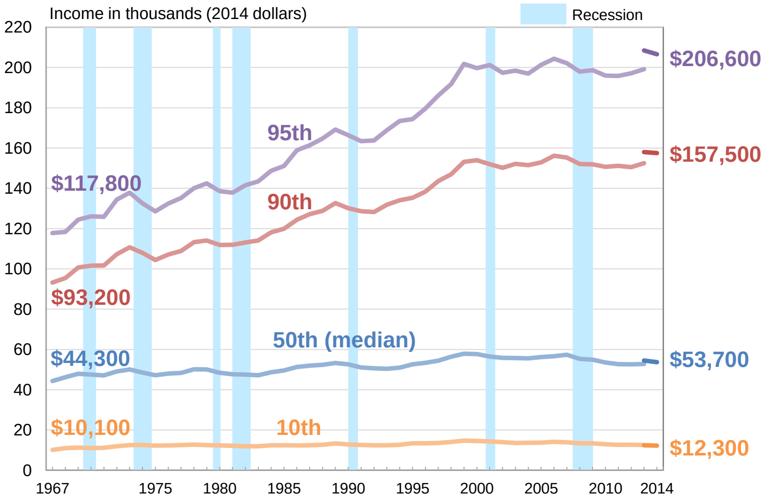
Uneven Growth in the United States: Stagnant incomes at bottom, rising incomes at top



Source: U.S. Census (2015)

Candidate Cause: Technology

- Huge literature: technology affects wage inequality
- Examples: SBTC and polarization of wages
- But what about capital income and wealth? ▸ inequality & capital inc ▸ SYZZ

What We Do

- Theory that links tech to income & wealth distribn, not just wages
- Use it to examine distributional effects of automation technologies
  = technologies that substitute labor for capital in production
- Tractable framework to study dynamics of
  1. macro aggregates
  2. factor income distribution: capital vs labor
  3. personal income, wealth distribution
- Key modeling difference to growth model: perpetual youth $\Rightarrow$
  - nondegenerate wealth distribution
  - long-run capital supply elasticity $< \infty$

Our Main Point

why now?

Technology $\Rightarrow$ returns $\Rightarrow$ distributional consequences

Analytic version in our theory:

$$\text{return to wealth} = \rho + \sigma g + \text{premium}(\alpha)$$

where α = capital share = average automation

1. New mechanism: technology increases inequality via return to wealth
   - income/wealth distributions have Pareto tail with fatness = α
2. Automation may lead to stagnant wages and lackluster investment
   - productivity gains partly accrue to capital owners
   - $\alpha := R \times \frac{K}{Y}$ and part of $\alpha \uparrow$ shows up in R not K/Y

Paraphrasing these results

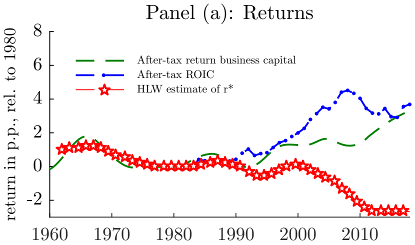
- if "robots" increasingly outperform labor, this benefits people owning lots of robots rather than "workers"

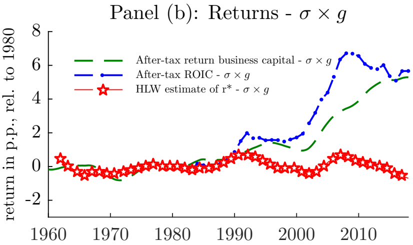
How does this square with trends in returns?

Just told you that

$$\text{return to wealth} = \rho + \sigma g + \text{premium}(\alpha)$$

But haven't treasury rates decreased over time?



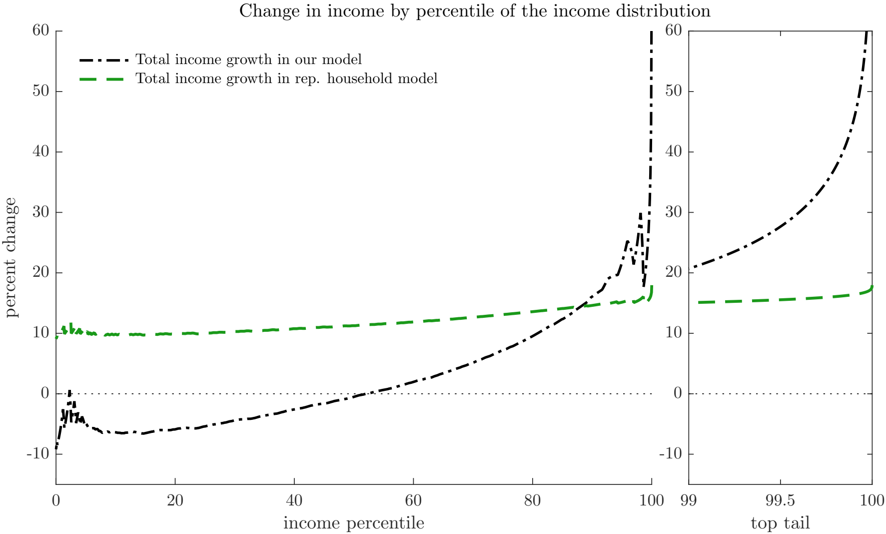


1. Treasury rates = return on specific asset, ave return on US capital $\uparrow$
2. Model w risky & safe assets: relevant $r = \sum_{j=1}^{J} r_j \times \text{portfolio share}_j$
3. Inequality depends $r - \rho - \sigma g$. Even if $r \downarrow$, arguably $r - \rho - \sigma g \uparrow$.

Model Meets Data

- Calibrate incidence of automation using exposure to routine jobs
  - accounts for changes in wage inequality 1980-2014
- Conservative (i.e. high) value for long-run capital supply elasticity
- Examine consequences of automation for
  - aggregates? Small expansions in I, Y
  - income, wealth inequality? Sizable increase, uneven growth
  - wages? Stagnation except for top of distribution
- Small shock (3% inc in TFP) can have large distributional effects

Small productivity gains but large distributional effects



Literature and Contribution

Automation and inequality (Acemoglu-Restrepo, Caselli-Manning, Hémous-Olsen, ...)

- capital income & wealth, not just wages
- capital supply elasticity $< \infty$ very different from $= \infty$

Technology and wealth distribution (Kaymak-Poschke, Hubmer-Krusell-Smith, Straub ,...)

- new mechanism: technology $\Rightarrow$ return $\Rightarrow$ wealth inequality
  (in addition to: technology $\Rightarrow$ wage dispersion $\Rightarrow$ wealth inequality)

Returns as driver of top wealth inequality (Piketty, Benhabib-Bisin, Jones,...)

- tractable form of capital income risk, integrated in macro model
- Piketty: $r - g \uparrow$ due to lower taxes, lower g. This paper: technology.

Tractable theory of macro aggregates, factor and personal income dist

Perpetual youth literature (Blanchard): closed form for wealth distribution

Plan

1. Framework and model of automation

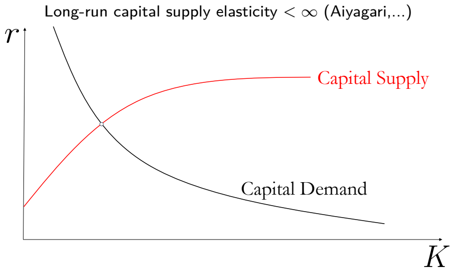
2. Steady state

3. Transition dynamics – skip today

4. Model meets data

1. Framework: Households and Technology

Model has two key building blocks



$+$

returns $\Rightarrow$ wealth inequality

(Benhabib-Bisin, Piketty, Jones, ...)

- Our paper: model this in very stylized fashion – perpetual youth
  - cost: some unrealistic implications
  - payoff: analytic solution for everything incl distributions
- Same mechanisms would be present in richer, less tractable models

Framework: Perpetual Youth Households

Households: age s, skills z, solve

$$\max_{\{c_z(s), a_z(s)\}_{s\geq 0}} \int_0^\infty e^{-(\varrho+p)s} \frac{c_z(s)^{1-\sigma}}{1-\sigma} ds \quad \text{s.t.} \quad \dot{a}_z(s) = ra_z(s) + w_z - c_z(s)$$

- w_z : wage for skill z, ℓ_z households
- r : return to wealth
- ϱ: discount rate
- p: probability of dying ($p = 0 \Rightarrow$ rep agent)
- $\rho = \varrho + p$: effective discount rate

Key assumption: "imperfect dynasties"

- average wealth of newborn $<$ average wealth of living
- stark implementation: eat wealth when die $\Rightarrow$ no bequests, $a_z(0)=0$
- other mechanisms: annuities, pop growth, estate taxation
- perpetual youth $=$ just tractable stand-in for other sources of churn

Framework: Technology (Zeira, Acemoglu-Restrepo)

Task-based model: machines/software substitute for tasks, not jobs

First: "reduced form" production side, next slide: where this comes from

1. Each skill type z works in different sector that produces Y_z

$$Y = A \prod_z Y_z^{\gamma_z} \qquad \text{with} \quad \sum_z \gamma_z = 1$$

2. Y_z produced using Cobb-Douglas tech with skill-specific exponent α_z

$$Y_z = \left(\frac{k_z}{\alpha_z}\right)^{\alpha_z} \left(\frac{\psi_z \ell_z}{1-\alpha_z}\right)^{1-\alpha_z}$$

$\alpha_z =$ share of tasks technologically automated. Automation: $\alpha_z(t) \uparrow$

3. Capital mobile across sectors, labor immobile

Derivation from Task-based Model (Zeira, Acemoglu-Restrepo)

For simplicity, derivation with only one skill type. Reduced form:

$$Y = \left(\frac{K}{\alpha}\right)^{\alpha} \left(\frac{\psi L}{1-\alpha}\right)^{1-\alpha} \tag{$*$}$$

Comes out of following task-based model:

1. Final good produced combining unit continuum of tasks u

$$\ln Y = \int_0^1 \ln \mathcal{Y}(u) du$$

2. Tasks produced using capital $k(u)$ or labor $\ell(u)$ at prices R and w

$$\mathcal{Y}(u) = \begin{cases} \psi \ell(u) + k(u) & \text{if } u \in [0, \alpha] \\ \psi \ell(u) & \text{if } u \in (\alpha, 1] \end{cases}$$

- α = share of tasks technologically automated. Automation: $\alpha(t) \uparrow$
- Example: HR manager, tasks = screen CVs, interview applicants,...
- Displacement vs productivity effects

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- 1. and 2. with $k(u) = K/\alpha, \ell(u) = L/(1-\alpha)$ imply $(*)$.□

2. Characterizing Steady State

Output, Factor Payments and Capital Demand

- Aggregate output:

$$Y = \mathcal{A} K^{\sum_z \gamma_z \alpha_z} \prod_z (\psi_z \ell_z)^{\gamma_z(1-\alpha_z)}$$

$\alpha = \sum_z \gamma_z \alpha_z$: aggregate capital-intensity, $\mathcal{A} = \text{constant}(\alpha_z, \gamma_z)$

- Factor payments:

$$w_z \ell_z = (1-\alpha_z)\gamma_z Y, \qquad RK = \alpha Y, \qquad \overline{w} = (1-\alpha) Y$$

α_z's $\Rightarrow$ relative wages, factor shares. But effect on levels unclear

- Aggregate capital demand

$$\frac{K}{\bar{w}} = \frac{\alpha}{1-\alpha} \frac{1}{R}$$

- Expositional assumption for presentation: $g = 0, \delta = 0 \Rightarrow R = r$

Steady State Capital Supply

Households' consumption and saving decisions:

$$c_z(s) = \left(\frac{\rho - r}{\sigma} + r\right)\left(a_z(s) + \frac{w_z}{r}\right)$$

$$\dot{a}_z(s) = \frac{1}{\sigma}(r - \rho)\left(a_z(s) + \frac{w_z}{r}\right) \qquad (*)$$

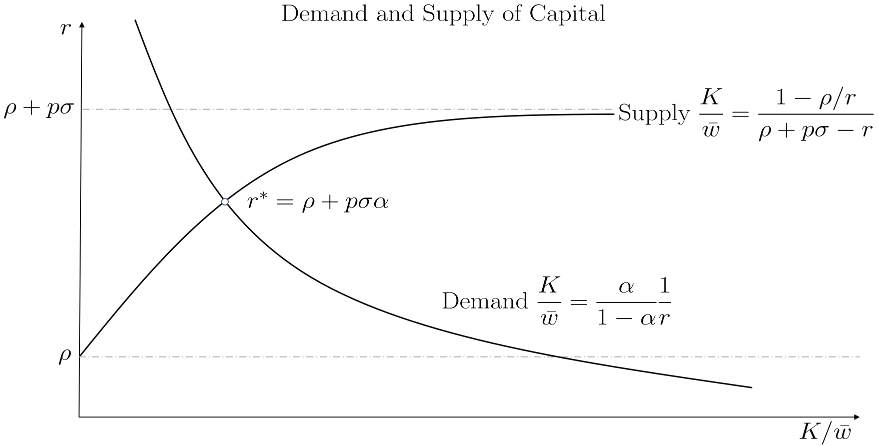
Useful later: relevant state $=$ effective wealth $=$ assets $+$ human capital

$$x_z(s) := a_z(s) + \frac{w_z}{r}$$

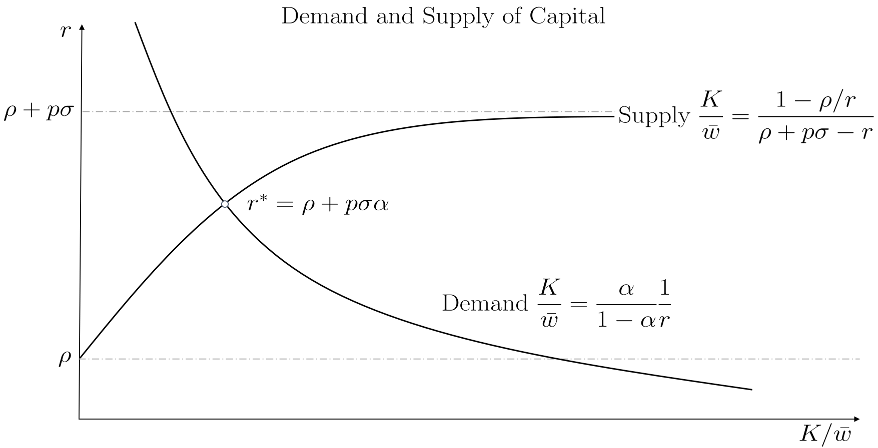
Find aggregate capital supply by integrating $(*)$ with $\overline{w} := \sum_z w_z \ell_z$:

$$0 = \dot{K} = \underbrace{\frac{1}{\sigma}(r - \rho)\left(K + \frac{\overline{w}}{r}\right)}_{\text{Wealth accumulated by surviving households}} - \underbrace{pK}_{\text{Imperfect dynasties}} \quad \Rightarrow \frac{K}{\bar{w}} = \frac{1 - \rho/r}{\rho + p\sigma - r}$$

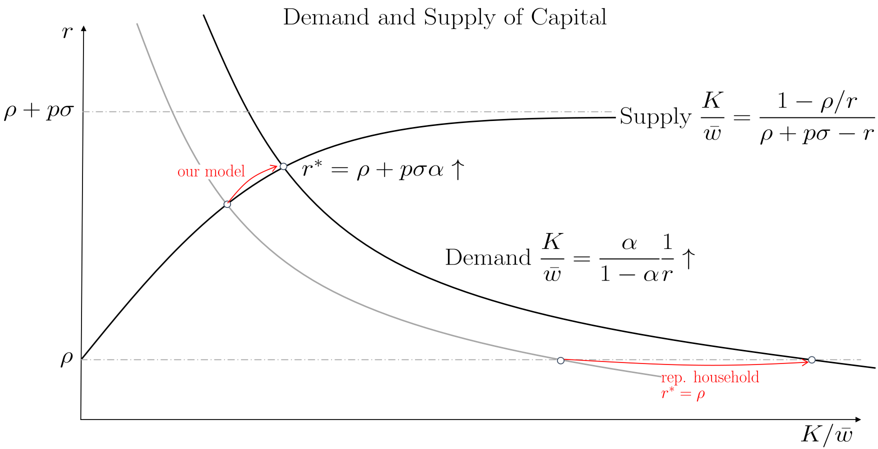
Steady-State Equilibrium: Return to Wealth



Same diagram as in richer theories (Aiyagari, Benhabib-Bisin,...)

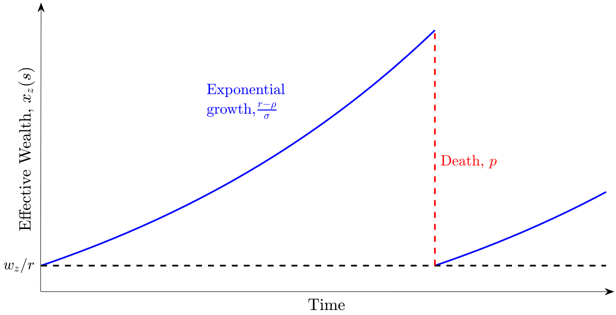


Automation $\Rightarrow$ higher r and modest expansion in K



Steady State Income and Wealth Distributions

Recall wealth dynamics: $\dot{a}_z(s) = \frac{1}{\sigma}(r-\rho)\left(a_z(s) + \frac{w_z}{r}\right)$



Proposition: stationary distribution of effective wealth by skill type is

$$g_z(x) = \left(\frac{w_z}{r}\right)^{\zeta} \zeta x^{-\zeta-1}, \qquad \frac{1}{\zeta} = \frac{1}{p}\frac{r-\rho}{\sigma}$$

Pareto distribution with scale w_z/r and inverse tail parameter

Steady State Income and Wealth Distributions

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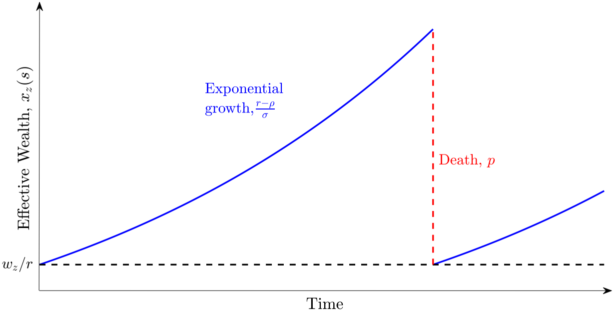

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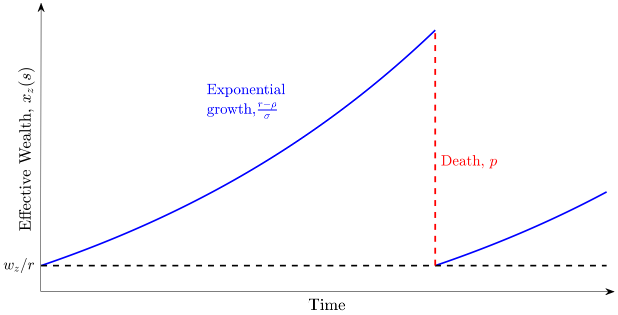

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Pareto distribution with scale w_z/r and inverse tail parameter $\frac{1}{p}\frac{r-\rho}{\sigma}$

Steady State Income and Wealth Distributions

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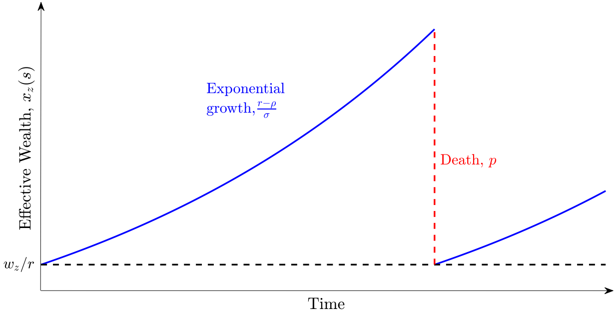


Proposition: stationary distribution of effective wealth by skill type is

$$g_z(x) = \left(\frac{w_z}{r}\right)^{\zeta} \zeta x^{-\zeta-1}, \qquad \frac{1}{\zeta} = \frac{1}{p}\frac{r-\rho}{\sigma} = \alpha \quad (\text{recall } r = \rho + p\sigma\alpha)$$

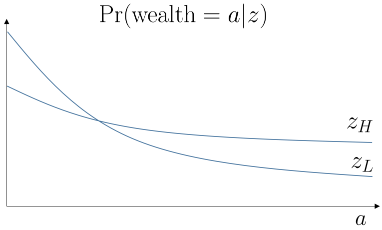
Pareto distribution with scale w_z/r and inverse tail parameter α

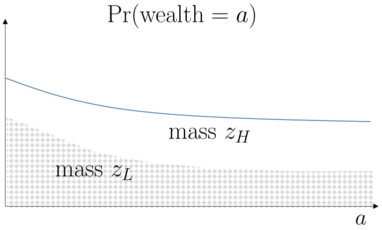
Distribution of Wealth

- Closed form for entire distributions:

$$\Pr(\text{wealth} \geq a|z) = \left(\frac{a + w_z/r}{w_z/r}\right)^{-\zeta}, \quad \frac{1}{\zeta} = \text{fatness}(r) = \alpha$$

$$\Pr(\text{wealth} \geq a) = \sum_z \ell_z \left(\frac{a + w_z/r}{w_z/r}\right)^{-\zeta}.$$





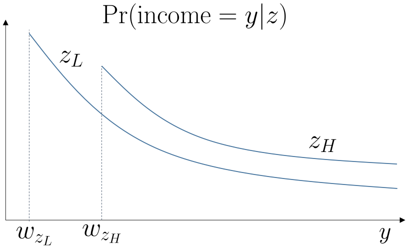
- Automation has two effects on wealth distribution
  1. via wages: determine scale of wealth distribution by type
  2. via return: determines fatness of tail

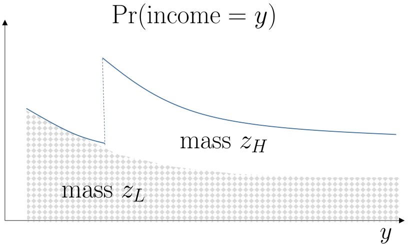
Distribution of Income

- Again, two sources of inequality: wages and return to wealth
- Again, closed form for entire distributions:

$$\Pr(\text{income} \geq y|z) = \left(\frac{\max\{y, w_z\}}{w_z}\right)^{-1/\alpha}$$

$$\Pr(\text{income} \geq y) = \sum_z \ell_z \left(\frac{\max\{y, w_z\}}{w_z}\right)^{-1/\alpha}.$$





Wage Stagnation with Upward-sloping Capital Supply

- CRS aggregate production function with technology indexed by θ

$$F(K, \{\ell_z\}_{z\in\mathcal{Z}}; \theta), \qquad F_\theta > 0$$

- Question: effect of technological change $d\theta > 0$ on factor prices?

$$\underbrace{d\ln \mathrm{TFP}}_{\text{TFP gains } >0} = \alpha d\ln R \quad + \quad \underbrace{(1-\alpha) d\ln \overline{w}}_{\text{change in average wage} \lesseqgtr 0} \quad , \quad \overline{w} := \sum_z w_z \ell_z$$

(Derivation: see e.g. Jaffe-Minton-Mulligan-Murphy (2019), uses $F = RK + \sum_z w_z \ell_z$)

- Bulk of literature: $d\ln R = 0$ because perfectly elastic capital supply
  - rep agent or small open economy (Acemoglu-Restrepo, Caselli-Manning, ...)

    $\Rightarrow$ all productivity gains accrue to labor, wages track TFP

- Our paper: $d\ln R > 0 \Rightarrow$ wages may stagnate or even decrease

  $\Rightarrow$ lackluster investment response

3. Transition Dynamics

Skip this today

4. Model meets Data

Aggregate and Distributional Effects of Automation

Consequences of automation for income inequality and aggregates?

- interpret each z as percentile of wage dist; focus on 1980-2014
- use variation in routine jobs across wage percentiles z

  (Autor-Levy-Murnane, Autor-Dorn, Acemoglu-Autor, ...)

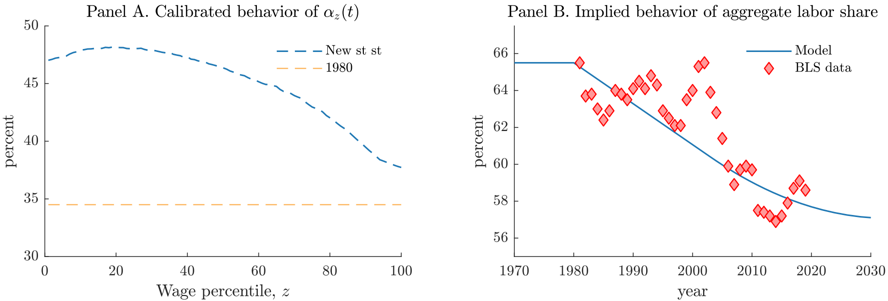
$$\Delta \alpha_z(t) \approx -\text{exposure}_z \times \Delta \text{Labor share}(t)$$

  exposure_z : share of wages paid to routine jobs in z (2000 Census)

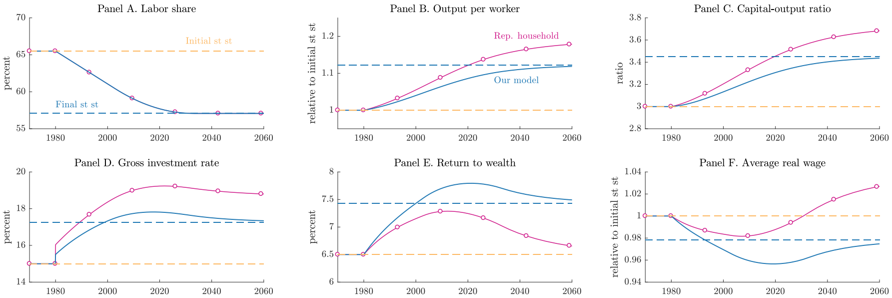
  scale: automation drives decline in $\text{Labor share}(t) = 1 - \alpha(t)$

- calibrate ψ_z so automation yields cost-saving gains $\ln \frac{w_z}{\psi_z R} = 30\%$
- calibrate $p = 3.85\%$ to target capital-supply elasticity $\frac{d \log K}{dr} = 50$

Automation of Routine Jobs: The Shock



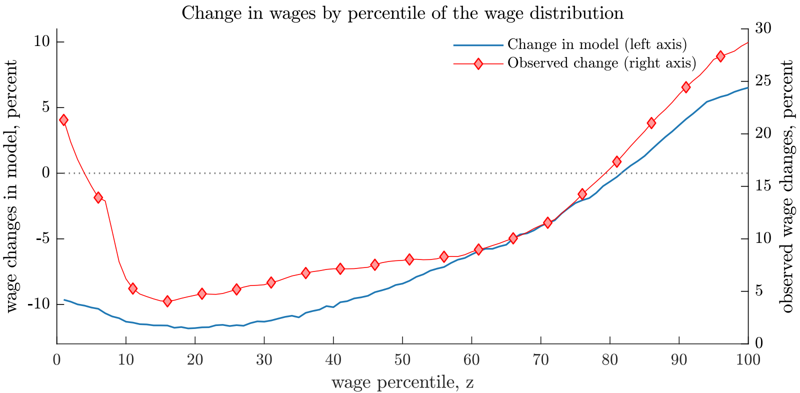
Macroeconomic Aggregates and Factor Prices



- 1 pp increase in return to wealth ▸ Data; 15% increase in K/Y ▸ Data.

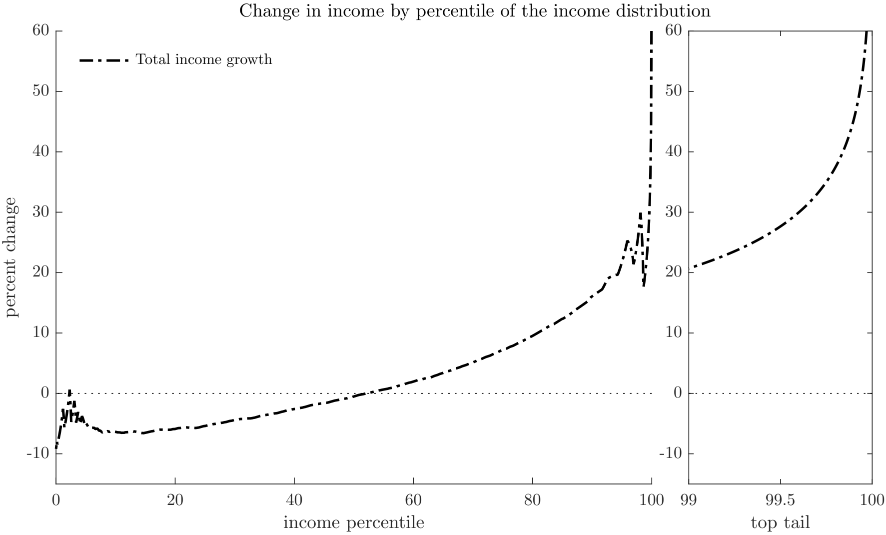
$$\underbrace{d\ln \mathrm{TFP}}_{3\%} = \underbrace{\alpha}_{0.4}\ \underbrace{d\ln R}_{10\%} + \underbrace{(1-\alpha)}_{0.6}\ \underbrace{d\ln \overline{w}}_{-2\%}, \qquad \overline{w} := \sum_z w_z \ell_z$$

Declining wages except at top



$$\text{Recall} \quad w_z(t) = (1 - \alpha_z(t))\gamma_z \frac{Y(t)}{\ell_z}$$

... and substantial uneven growth



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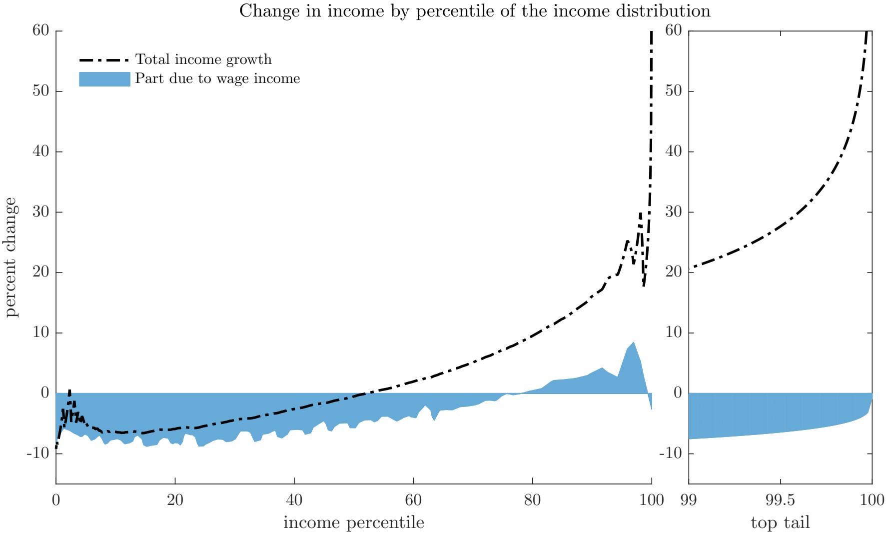

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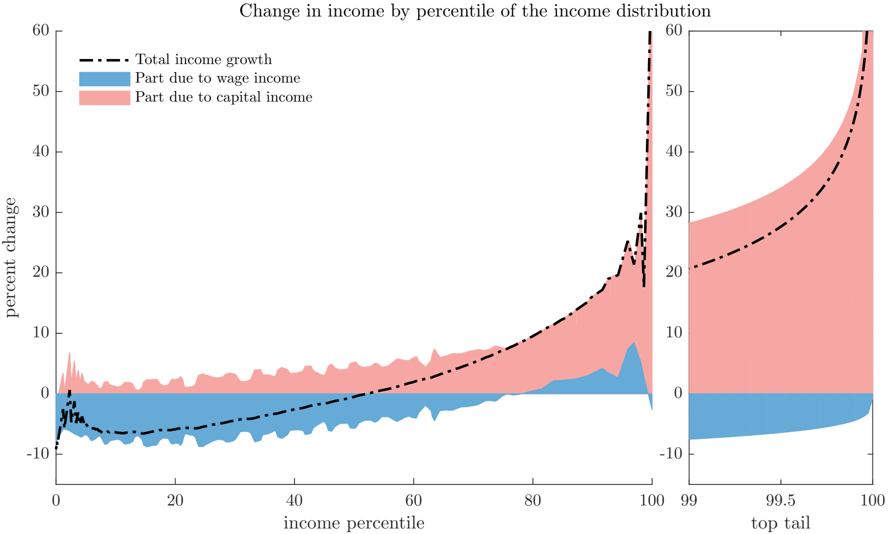

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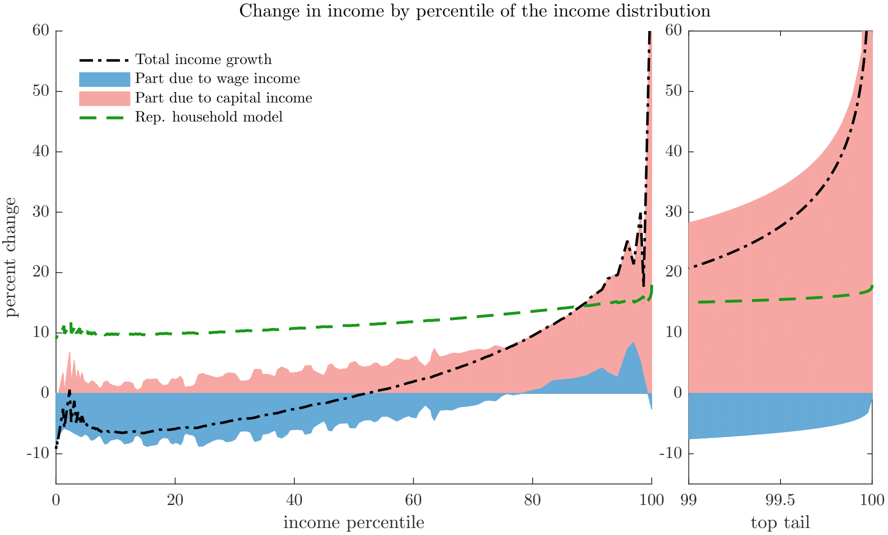
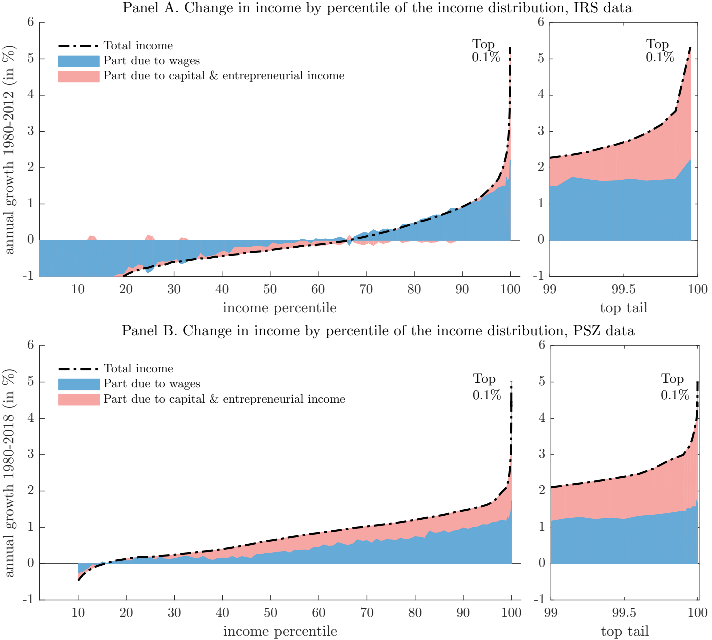
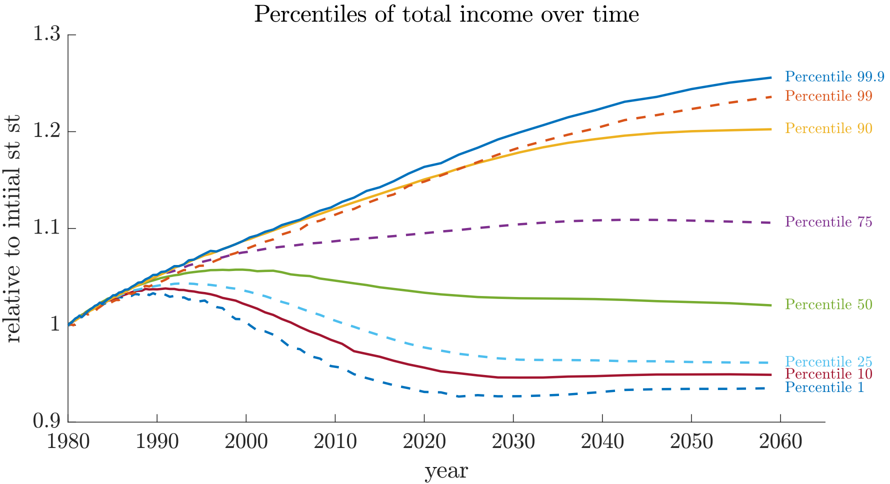


Empirical counterpart: uneven growth in IRS, Piketty-Saez-Zucman data



Caveat: model transition too slow



Good news: know how to fix this (Gabaix-Lasry-Lions-Moll)

- heterogeneous returns or saving rates

Conclusion

- Tractable framework to think about uneven growth
  - have used it to study distributional effects of automation
  - not just on wages but also on income and wealth distributions
- Technology $\Rightarrow$ returns $\Rightarrow$ distributional effects
  - rising concentration of capital income at top
  - stagnant or declining wages at the bottom
- Framework has lots of other potential applications
  - trade: globalization's impact on income and wealth inequality?
  - PF: optimal capital income and wealth taxation?
  - ...
- Needed: better evidence on asset returns (x-section & time-series)

Thanks for listening!