Uneven Growth: Automation's Impact on Income and Wealth Inequality

Moll, Rachel, and Restrepo (Econometrica, 2022)

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Motivation

Key observation: Rising income inequality, especially at the top

Traditional explanations focus on labor income:

- Skill-biased technological change (SBTC)
- Automation replacing routine tasks
- Rising college premium

But capital income matters too!

- Capital income is highly concentrated at the top
- Top 1% receive ∼60% of their income from capital
- Automation affects both labor *and* capital returns

This Paper's Contribution

Two key innovations:

1. **Household heterogeneity in skills**
   - Different skill types face different automation exposure
   - Wages affected differentially across the distribution
2. **Dissipation shocks to wealth**
   - Wealth resets to zero with some probability $p > 0$
   - Creates a non-degenerate wealth distribution
   - Key insight: Automation increases equilibrium returns to capital

Uneven growth: Benefits of automation concentrated at the top through *capital income*

Main Results

1. **Automation raises equilibrium returns to wealth**
   - Standard representative-agent models: $r = \rho$
   - In this model: $r^* = \rho + p\sigma\alpha^*_{net}$ where α^*_{net} is the net capital share (automation rate) and p is the probability of receiving dissipation shocks.
2. **Uneven income growth**
   - Bottom/middle: wage losses dominate
   - Top: capital income gains dominate
   - The very top benefits most from automation
3. **Model matches key empirical patterns**
   - Rising capital share
   - Wage polarization
   - Top income share growth

Environment

Time: Continuous time, we focus on the steady state

Households:

- Unit continuum indexed by skill type z
- Population share ℓ_z for type z
- Each type earns wage w_z (constant in steady state)

Assets:

- Single asset (capital) with return r
- Households can borrow: $a_{zt} \geq -w_z/r$

Key feature: Dissipation shocks

- With Poisson intensity $p > 0$, wealth resets to $a = 0$
- Assume $p = 0$ reverts the model back to a representative agent setting.

The rationale for dissipation shock

- Related to Blanchard (1985)'s model of perpetual youth. Individuals die with probability p and leave no bequests. A newborn starts life with zero assets and only labor income.
- Finite lives and stochastic altruism: At the rate p, the current member of the dynasty stops being altruistic and consumes all of her wealth.
- Population growth: p is the net increase in population as newborn starts with zero assets.
- Related to Krusell & Smith (1998) where households become infinitely impatient and consume all of their wealth with under a probability p

Household Problem

Household of type z solves:

$$\max_{\{c_{zt}, a_{zt}\}} \mathbb{E}_0 \left[\int_0^\infty e^{-\rho t} \frac{c_{zt}^{1-\sigma}}{1-\sigma} dt \right]$$

subject to:

- Flow budget constraint: $\dot{a}_{zt} = w_z + r a_{zt} - c_{zt}$
- Borrowing limit: $a_{zt} \geq -w_z / r$
- Dissipation shocks: wealth resets to $a_{zt} = 0$ at rate p

Where:

- $\rho = \varrho + p =$ effective discount rate
- $\sigma =$ inverse of IES

Solution: Effective Wealth

Define effective wealth:

$$x_{zt} := a_{zt} + \frac{w_z}{r}$$

Sum of financial wealth and wage

Budget constraint becomes:

$$\dot{x}_{zt} = r x_{zt} - c_{zt}$$

The HJB equation:

$$\rho V(x_z) = \max_{c_z} \left\{ \frac{c_z^{1-\sigma}}{1-\sigma} + V'(x_z)(r x_z - c_z) + p \underbrace{[V(w_z/r) - V(x_z)]}_{dissipation\ shocks} \right\}$$

Euler equation:

$$\frac{\dot{c}_z}{c_z} = \frac{r-\rho}{\sigma}$$

Household Policy Functions

The problem can be solved by guessing a linear consumption function $c_z = \mu x_z$ and solve for policy functions

Policy functions:

$$\boxed{c_{zt} = \left[r - \frac{r - \rho}{\sigma} \right] x_{zt}}$$

$$\boxed{\dot{x}_{zt} = \frac{r - \rho}{\sigma} x_{zt}}$$

with resets to $x_{z0} = w_z / r$ at rate p

Production: Task-Based Framework

Each skill z works in a sector producing Y_z:

$$\ln Y_z = \int_0^1 \ln Y_z(u)\, du$$

Tasks can be produced by:

- Capital $k_z(u)$ if $u \in [0, \alpha_z]$ (automated tasks)
- Labor $\ell_z(u)$ with productivity ψ_z if $u \in (\alpha_z, 1]$ (non-automated)

Aggregate production function:

$$Y(K) = AK^\alpha \prod_z (\psi_z \ell_z)^{\eta_z(1-\alpha_z)}$$

where $\alpha := \sum_z \alpha_z \eta_z$ is the aggregate capital share

Factor Prices

Capital rental rate:

$$R = \frac{\partial Y}{\partial K} = \alpha \frac{Y}{K}$$

Wage for skill z:

$$w_z = \frac{\partial Y}{\partial \ell_z} = (1 - \alpha_z)\eta_z \frac{Y}{\ell_z}$$

Return to wealth:

$$r = R - \delta = \alpha \frac{Y}{K} - \delta$$

where δ is the depreciation rate

Steady-State Equilibrium

Definition: A steady-state equilibrium consists of:

- Return to wealth r^*
- Aggregate capital K^*, output Y^*
- Factor prices $\{w_z^*, R^*\}$
- Consumption/saving policies $\{c_{zt}, a_{zt}\}$

such that:

1. Households optimize given prices
2. Firms maximize profits (factor prices = marginal products)
3. Capital market clears

Capital Market Clearing

In steady state: $\dot{K} = 0$

Capital accumulation condition:

$$\frac{r-\rho}{\sigma}\left(K + \frac{\bar{w}}{r}\right) = pK$$

where $\bar{w} := \sum_z w_z \ell_z$ is the total labor compensation.

- LHS: Aggregate savings = growth rate of wealth × total effective wealth
- RHS: Capital "dissipated" at rate p

Capital Supply Curve

Rearranging the capital market clearing condition:

$$\boxed{k^s := \frac{K}{\bar{w}} = \frac{1 - \rho/r}{p\sigma + \rho - r}}$$

Properties:

- Upward sloping in r for $r \in (\rho, \rho + p\sigma)$ because as the return to wealth rises, households accumulate and supply more capital
- Higher $r \Rightarrow$ higher savings $\Rightarrow$ more capital supplied
- Bounded above: $r < \rho + p\sigma$

Key difference from representative agent:

- Representative agent: there is no dissipation shock. The supply of capital is perfectly elastic, and the return to wealth is fixed at $r = \rho$.

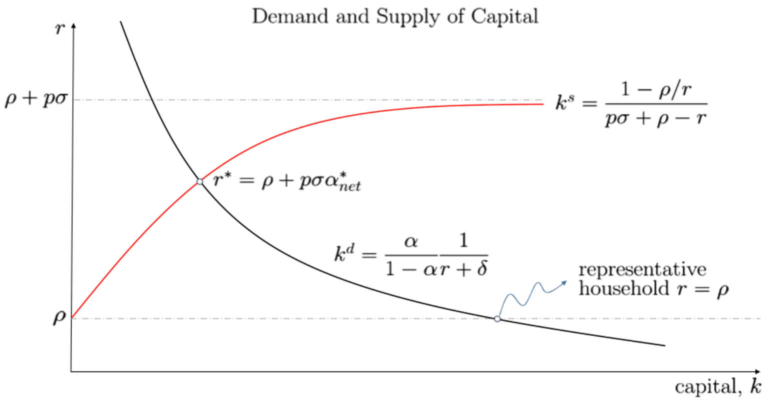


FIGURE 1.—The supply and demand for capital and the determination of the return to wealth.

Capital Demand Curve

From profit maximization:

$$R = \alpha \frac{Y}{K} = r + \delta$$

and $\bar{w} = (1 - \alpha) Y$

Capital demand:

$$\boxed{k^d := \frac{K}{\bar{w}} = \frac{\alpha}{1 - \alpha} \cdot \frac{1}{r + \delta}}$$

Properties:

- Downward sloping in r
- Standard neoclassical demand
- Shifts out when α increases (more automation)

Equilibrium Determination

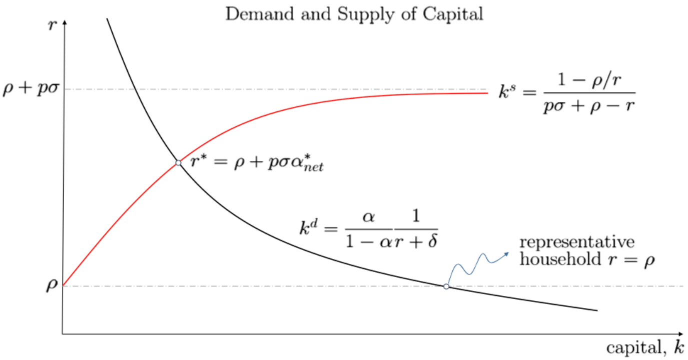


FIGURE 1.—The supply and demand for capital and the determination of the return to wealth.

Key Result: Equilibrium Return

Equilibrium condition: $k^s = k^d$ yields:

$$\frac{1 - \rho/r}{p\sigma + \rho - r} = \frac{\alpha}{1-\alpha} \cdot \frac{1}{r+\delta}$$

Equivalent characterization: Define net capital share

$$\alpha^*_{net} := \frac{r^* K^*}{r^* K^* + \bar{w}^*}$$

Then:

$$\boxed{r^* = \rho + p\sigma\alpha^*_{net}}$$

Return to wealth *increases* with capital share. Intuition

- Since wealth dissipates, higher returns are needed to incentivize savings from households

Why Does Automation Raise Returns?

$$r^* = \rho + p\sigma\alpha^*_{net}$$

Mechanism:

1. Dissipation shocks create a "wedge" from the capital market. Some households accumulate wealth for a long time, some are "newborns" (or receive wealth resets)
2. Higher $\alpha \Rightarrow$ capital income is larger share of total
3. To sustain more capital, r must rise to induce more savings

Contrast with representative agent:

- No dissipation ($p = 0$) $\Rightarrow r^* = \rho$ always
- Returns are *pinned down* by preferences
- Automation has no effect on r

Effect of Automation on Equilibrium

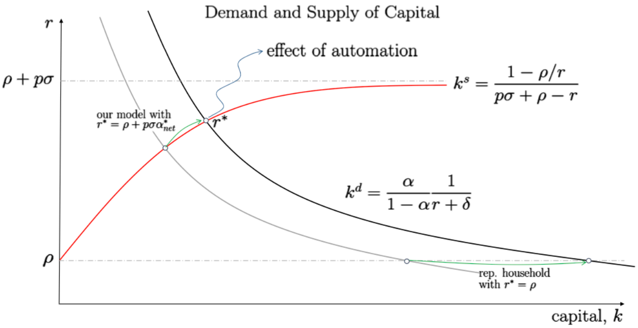
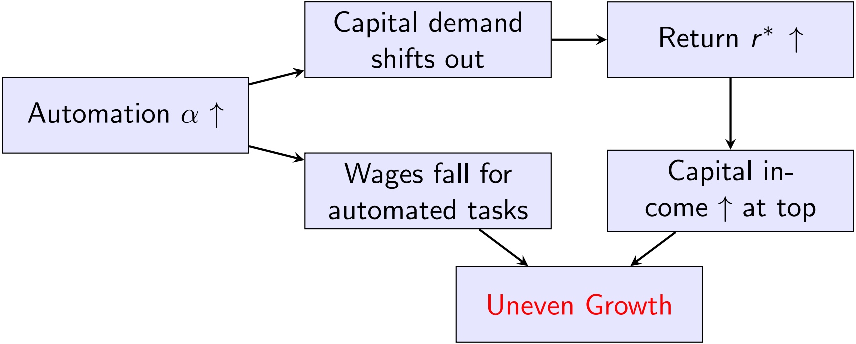


FIGURE 2.—Effect of automation—an increase in α—on the equilibrium return to wealth, r^*. The green arrows illustrate how the equilibrium changes in our model and in the representative-household benchmark.

Mechanism

Automation increases ($\alpha \uparrow$):



Effects on real wage (Proposition 2)

A more novel implication of the proposition is the possibility that automation may lead to stagnant wages for the average worker, which necessarily implies a more pronounced real decline in the wages of workers displaced by automation

First-order approximation for output:

$$d\ln Y^* = \underbrace{\frac{1}{1-\alpha}\sum_z \eta_z \ln\left(\frac{w_z^*}{\psi_z R^*}\right) d\alpha_z}_{:=d\ln \mathrm{TFP}_\alpha} + \frac{\alpha}{1-\alpha} d\ln(K/Y)^* > 0.$$

Two channels

1. labor is substituted $\rightarrow$ automation increases TFP
2. endogenous capital accumulation raises output

When p is large, the second effect is smaller.

Stagnant wage

Consider an improvement in automation that raises TFP by $d \ln TFP_\alpha > 0$

$$d \ln \mathrm{TFP}_\alpha = (1-\alpha)\, d \ln \bar{w} + \alpha\, d \ln R, \quad R = r + \delta.$$

1. When there is no shock ($p = 0$), supply perfectly elastic, $d \ln R = 0$ so all productivity gains go to labor.
2. When p increases, capital supply is more inelastic, and a larger share of these productivity gains accrues to capital in the form of a higher return. In other words, the displacement effect tends to dominate output expansion as p increases.

Wealth Distribution

Effective wealth dynamics:

$$\dot{x}_{zt} = \frac{r - \rho}{\sigma} x_{zt}$$

with resets to $x_{z0} = w_z / r$ at rate p

Stationary distribution: Pareto with tail index ζ

$$\Pr(x > \bar{x}) \propto \bar{x}^{-\zeta}$$

Tail index:

$$\zeta = \frac{p\sigma}{r - \rho}$$

When $r \uparrow$: $\zeta \downarrow \Rightarrow$ fatter tail $\Rightarrow$ more inequality (?)

Extensions to the Baseline

The extended model adds:

1. **Multiple assets**
   - Risky capital (return r_K)
   - Safe bonds (return r_B)
2. **Investor heterogeneity**
   - Fraction χ: can invest in both assets
   - Fraction $1-\chi$: only bonds ("non-investors")
3. **Capital income risk:** Idiosyncratic returns with volatility ν
4. **Markups:** Firms charge markup $\varphi \geq 1$
5. **Taxation:** Capital income taxed at rate τ
6. **Growth:** Factor-neutral productivity grows at rate g

Extended Model: Capital Share

With markups and taxes, the after-tax capital share is:

$$\tilde{\alpha} = (1-\tau)\left[\frac{\alpha}{\varphi} + \frac{\varphi-1}{\varphi}(1-\alpha)\right]$$

Net capital share increases with:

- α (automation)
- φ (markups / market power)
- $1-\tau$ (lower taxation)

$\Rightarrow$ Multiple drivers of rising capital share

Calibration Strategy

Two steady states:

- Initial: 1980 (before automation wave)
- Final: 2014 (after automation)

Key parameters calibrated:

Parameter	Symbol	Value
Discount rate	ρ	1% to target $r = 6.5\%$
IES	$1/\sigma$	0.5
Risk aversion	γ	2
Dissipation rate	p	4.5%
Depreciation	δ	0.05
Growth rate	g	0.02

Calibration: Technology

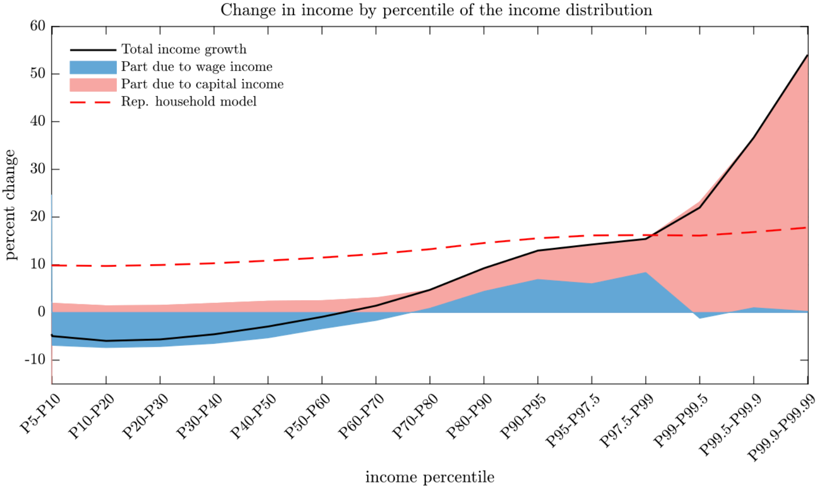
Automation shares α_z by skill type:

- Estimated from task content of occupations
- Use O*NET data on routine task intensity
- Middle-skill workers: highest automation exposure

Change in aggregate capital share:

- 1980: $\alpha \approx 0.345$
- 2014: $\alpha \approx 0.428$

Main Result: Uneven Growth



Wage Changes by Percentile

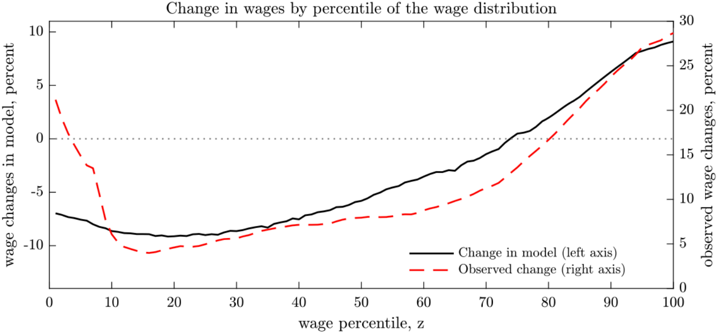


FIGURE 9.—Predicted change in wages by wage percentile (left axis) and observed change in wages by wage percentile (right axis). *Notes*: Observed wage changes computed using the 1980 Census and 2012–2016 ACS. See Appendix G for details.

Model vs Data: Wage Distribution

Figure 9 shows wage polarization:

- **Bottom:** Small wage losses (automation of low-skill tasks)
- **Middle:** Largest wage losses (routine tasks most automated)
- **Top:** Wage gains (complementarity with capital)

Model captures U-shaped pattern:

- Solid black line: model predictions
- Dashed red line: data
- Qualitatively similar patterns

Who Benefits from Automation?

Winners:

- High-skill workers (complementarity with capital)
- Wealthy households (higher returns to capital)
- Capital owners at the top

Losers:

- Middle-skill workers (replaced by machines)
- Low-skill workers (indirect wage effects)
- Households with little wealth

Policy implication: Redistribution should target capital income, not just wages

Summary

Key contributions:

1. **Theory:** Dissipation shocks break representative-agent result

$$r^* = \rho + p\sigma\alpha^*_{net}$$

   Returns increase with capital share

2. **Mechanism:** Automation causes uneven growth
   - Bottom/middle: wage losses
   - Top: capital income gains
3. **Quantitative:** Model matches key patterns
   - Wage polarization
   - Rising top income shares
   - Composition of top incomes

Broader Implications

For understanding inequality:

- Capital income crucial at the top
- Labor market focus is incomplete
- General equilibrium effects matter

For policy:

- Taxing capital income may be more effective
- Skills training helps wage distribution
- But doesn't address capital income concentration

For future research:

- Wealth taxation and redistribution
- Optimal response to automation
- Interaction with other secular trends