Who receives the gains from automation?

Automation, asset ownership and the labour share

Sergio Ocampo
ECON 3399 · AI and Robots at Work

Wages, income shares and ownership

Paper	Question
Moll, Rachel & Restrepo (2022) *Uneven Growth*	Who receives the gains when automation raises capital demand?
Restrepo (2025) *We Won't be Missed*	What if all valuable work can be performed with compute?

Uneven Growth



Econometrica, Vol. 90, No. 6 (November, 2022), 2645–2683

UNEVEN GROWTH: AUTOMATION'S IMPACT ON INCOME AND WEALTH INEQUALITY

BENJAMIN MOLL
Economics Department, London School of Economics and Political Science

LUKASZ RACHEL
Economics Department, University College London

PASCUAL RESTREPO
Economics Department, Boston University

The benefits of new technologies accrue not only to high-skilled labor but also to owners of capital in the form of higher capital incomes. This increases inequality. To make this argument, we develop a tractable theory that links technology to the distribution of income and wealth—and not just that of wages—and use it to study the distributional effects of automation. We isolate a new theoretical mechanism: automation increases inequality by raising returns to wealth. The flip side of such return movements is that automation can lead to stagnant wages and, therefore, stagnant incomes at the bottom of the distribution. We use a multiasset model extension to confront differing empirical trends in returns to productive and safe assets and show that the relevant return measures have increased over time. Automation can account for part of the observed trends in income and wealth inequality.

KEYWORDS: Inequality, wealth, capital, returns, wages, labor share, technology, automation.

1. INTRODUCTION

OVER THE PAST 40 YEARS, economic growth in many advanced economies has been unevenly distributed. In the United States, while the aggregate economy has grown at roughly 2% per year, income percentiles corresponding to the lower half of the distribution have stagnated. At the same time, incomes at the 95th percentile have doubled and top 1% incomes tripled.[1]

One potential driver of these trends that is often cited by pundits and policy makers is technical change, and in particular automation. A large literature in macro and labor economics has studied how technology and automation affect the distribution of labor incomes.[2] But not all income is labor income and capital is an important income source, particularly at the top of the distribution where incomes have increased the most. Existing

Benjamin Moll: b.moll@lse.ac.uk
Lukasz Rachel: l.rachel@ucl.ac.uk
Pascual Restrepo: pascual@bu.edu

We thank Daron Acemoglu, Fabrizio Perri, Matt Rognlie, Richard Rogerson, Stefanie Stantcheva, Ivan Werning, three anonymous referees as well as seminar participants at various institutions for useful comments and Bob Allen, Daniel Waldenstram, and Gabriel Zucman for sharing data with us. We also thank Benny Kleinman, Nils Lehr, and Max Vogler for outstanding research assistance. Moll received funding for this project from the Leverhulme Trust and the European Union's Horizon 2020 research and innovation programme under Grant GA: 865227. Restrepo thanks the National Science Foundation for its support under award 2049427.

[1]See, for example, Census Bureau (2015) and Piketty, Saez, and Zucman (2018).

[2]See, for example, Katz and Murphy (1992), Krusell, Ohanian, Ríos-Rull, and Violante (2000), and Autor, Katz, and Kearney (2006).

© 2022 The Econometric Society https://doi.org/10.3982/ECTA19417

Published article · First page

Automation's impact
on income and wealth inequality

Benjamin Moll, Łukasz Rachel, and Pascual Restrepo

Econometrica · 2022

Open the paper

Can capital accumulation make growth broadly shared?

Approach: A task model with unequal skills and asset holdings.

- Households save and accumulate wealth
- Returns to savings/wealth determined by productivity of capital
- Solve for wages, returns and the distribution of income
- Calibrate an automation experiment to U.S. data

> The new channel: higher capital returns change wealth accumulation.

Two sources of income

Households differ in skill z; labour earnings are w_z.

$$y_j = w_z + ra_j$$

Object	Meaning
y_j	Annual income of household j
w_z	Annual labour earnings for skill group z
a_j	Assets owned: a stock
$r = R - \delta$	Net annual return: gross rental R minus depreciation δ

> Competitive wages and capital rentals equal marginal products.
> Household saving determines the supply of capital.

Tasks, automation and aggregate production

- Each skill group z performs a different set of tasks.
- Capital takes over a fraction α_z of that group's tasks.

Object	**Meaning**
η_z, $\sum_z \eta_z = 1$	Value-added weight of group z's tasks
ℓ_z	Group population share
ψ_z	Labour productivity at the group's tasks
Y, K, A	Output; capital stock; productivity, including automation's cost savings

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

> Cobb–Douglas task aggregation: automation raises capital's share and lowers labour's.

Competitive factor payments and income shares

$$\Pi = \max_{K^d, \{n_z\}} \left\{ Y - RK^d - \sum_z w_z n_z \right\} \quad \text{s.t.} \quad Y = A(K^d)^\alpha \prod_z (\psi_z n_z)^{(1-\alpha_z)\eta_z}$$

Optimality Conditions

$$RK = \alpha Y, \qquad w_z \ell_z = (1 - \alpha_z)\eta_z Y$$

Market clearing: $K^d = K$, $n_z = \ell_z$.

$$\text{Net Return: } r = R - \delta; \qquad \text{Wage Bill: } \bar{w} = \sum_z w_z \ell_z = (1 - \alpha) Y$$

Full adoption: $R < w_z/\psi_z \longrightarrow$ use capital wherever automation is feasible.
Automation changes task shares; equilibrium output determines income levels.

Consumption, saving and wealth resets

$$\max_{\{c_t\}} \int_0^\infty e^{-\rho t} u(c_t)\, dt, \qquad u'(c) = c^{-\sigma}$$

$$\dot{a}_t = r a_t + w_z - c_t, \qquad a_t \geq -\frac{w_z}{r} \qquad \left(\dot{y} = \frac{dy}{dt}\right)$$

Parameter	**Meaning**
$\rho = \varrho + p$	Effective discount rate; ϱ: pure time preference
σ	Inverse intertemporal elasticity of substitution
p	Annual reset hazard: assets return to 0; skill is retained

Discrete Time Equivalent:

$$\max_{\{c_t\}} \sum_{t=0}^{\infty} \beta^t u(c_t), \qquad \beta = e^{-\rho}, \qquad a_{t+1} = (1+r)a_t + w_z - c_t$$

The optimal saving rule

At constant wages and returns, define **effective wealth**:

$$x_t = a_t + \frac{w_z}{r}$$

Financial assets + the present value of future labour income.

$$\dot{a}_t = \frac{r-\rho}{\sigma} x_t, \qquad c_t = \left(r - \frac{r-\rho}{\sigma}\right) x_t, \qquad \frac{\dot{x}_t}{x_t} = \frac{r-\rho}{\sigma}$$

> A higher return raises the rate of accumulation; resets return x_t to w_z/r.

Euler equation and the saving-rule derivation

The equations behind capital supply and demand

Aggregate the saving rule; subtract assets consumed at resets:

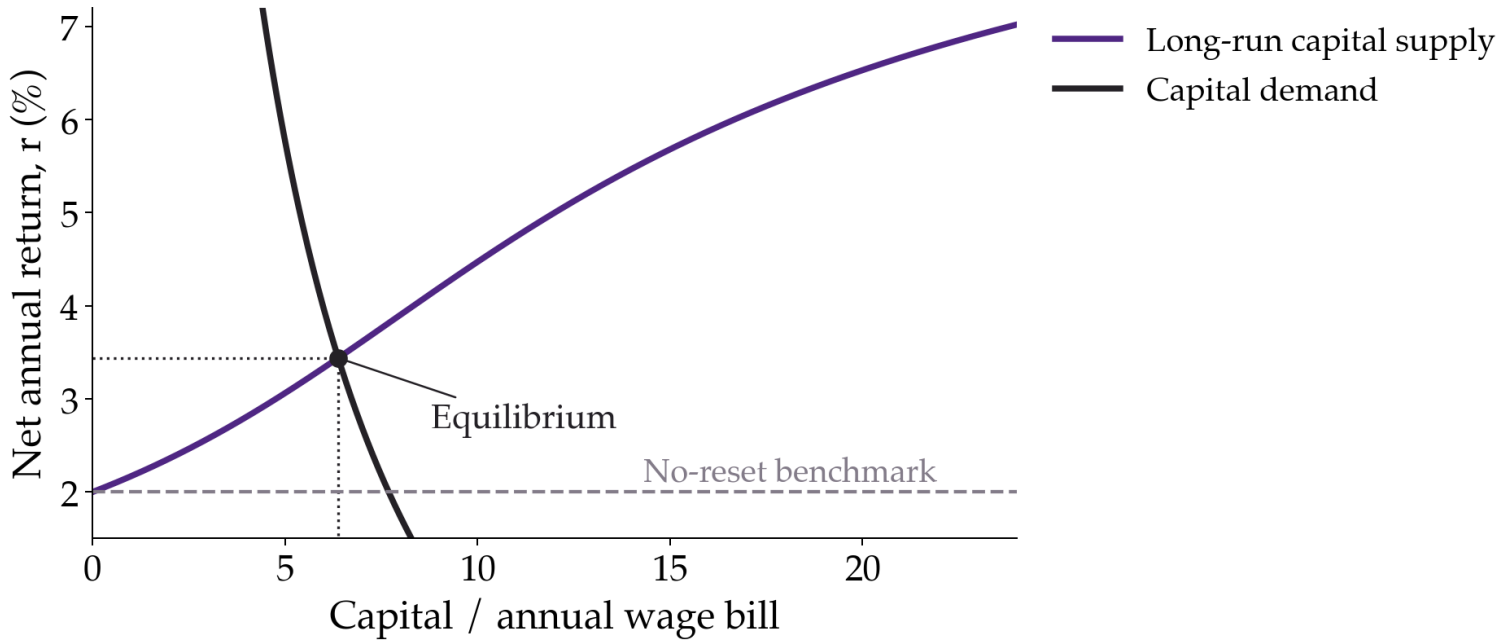
$$\dot{K} = \frac{r-\rho}{\sigma}\left(K + \frac{\bar{w}}{r}\right) - pK \quad \xrightarrow{\text{Steady State } \dot{K}=0} \quad K = \frac{1-\rho/r}{p\sigma+\rho-r}\bar{w}$$

Normalize capital by wage bill: $k = K/\bar{w}$.

$$\underbrace{k^s(r) = \frac{1-\rho/r}{p\sigma+\rho-r}}_{\text{household saving}}, \qquad \underbrace{k^d(r) = \frac{\alpha}{(1-\alpha)(r+\delta)}}_{\text{firm factor demand}}$$

The market clears where $k^s(r^*) = k^d(r^*)$.
Higher α shifts demand; the supply parameters stay fixed.

Capital demand meets long-run capital supply



$$r^* = \rho + p\sigma \underbrace{\frac{r^* K^*}{r^* K^* + \bar{w}^*}}_{\text{Capital Share}}, \qquad \frac{K^*}{\bar{w}^*} = \frac{\alpha}{(1-\alpha)(r^* + \delta)}.$$

No-reset benchmark

The equilibrium return and the net capital share

Define the capital share **after replacing depreciated capital**:

$$\alpha_{\text{net}} = \frac{rK}{rK + \bar{w}} = \frac{rK}{Y - \delta K}$$

Capital-market clearing implies:

$$\underbrace{r^* - \rho}_{\text{return gap}} = p\sigma\alpha^*_{\text{net}}, \qquad \rho < r^* < \rho + p\sigma$$

> Automation raises $\alpha^*_{\text{net}} \longrightarrow$ a permanently higher return.
> Without wealth resets, $p = 0 \longrightarrow$ the benchmark return is $r^* = \rho$.

α: gross capital share; α_{net}: net share; *: steady state. Derivation

Automation raises the long-run return to wealth

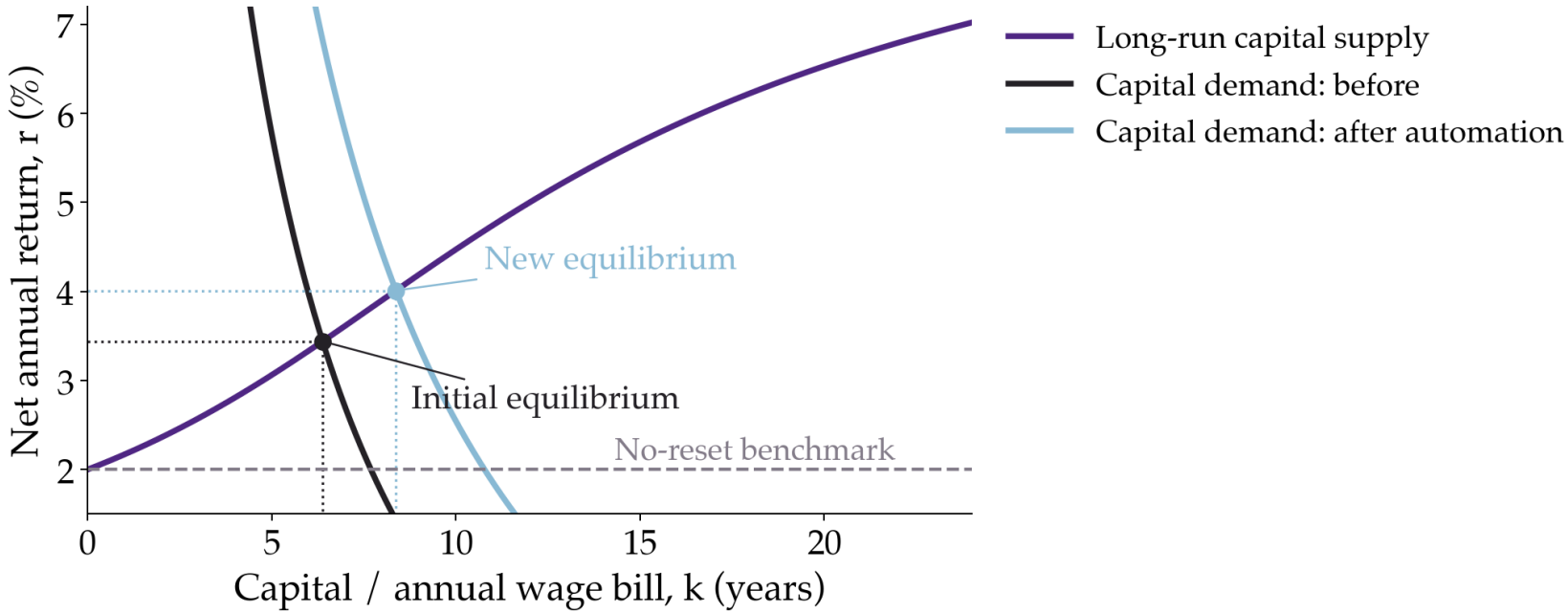


Illustration: α: 35% $\longrightarrow$ 43%; household saving parameters stay fixed.

> Capital demand shifts out $\longrightarrow$ more capital and a higher net return.
> In the no-reset benchmark, capital expands until the return returns to impatience.

Transition paths

Higher returns limit the output expansion

$$\frac{K^*}{Y^*} = \frac{\alpha}{R^*} \quad \longrightarrow \quad d\ln(K/Y)^* = \frac{d\alpha}{\alpha} - d\ln R^*$$

Higher R^* limits *capital deepening*: the expansion of K/Y.

$$d\ln Y^* = \underbrace{d\ln \text{TFP}_\alpha}_{\sum_z \eta_z \ln\left(\frac{w_z^*}{\psi_z R^*}\right) d\alpha_z > 0} + \alpha\, d\ln K^* + \underbrace{\sum_z (1-\alpha_z)\eta_z\, d\ln n_z}_{0\text{: fixed labour supply}}$$

Use $d\ln K^* = d\ln(K/Y)^* + d\ln Y^*$:

$$d\ln Y^* = \underbrace{\frac{d\ln \text{TFP}_\alpha}{1-\alpha}}_{\text{efficiency gain}} + \underbrace{\frac{\alpha}{1-\alpha} d\ln(K/Y)^*}_{\text{capital deepening}} = \frac{d\ln \text{TFP}_\alpha + d\alpha - \alpha\, d\ln R^*}{1-\alpha}$$

Output gains versus displacement in wages

$$\bar{w} = (1-\alpha)Y, \qquad w_z = \frac{(1-\alpha_z)\eta_z}{\ell_z}Y$$

With skill supplies and task weights fixed:

$$d\ln w_z = \underbrace{d\ln Y}_{\text{output gain}} - \underbrace{\frac{d\alpha_z}{1-\alpha_z}}_{\text{task displacement}}$$

> Higher returns limit the expansion of capital and output.
> The output gain may then be too small to offset displacement.

Productivity, returns and the wage equation

Automation increases inequality

Direct effects on labor income

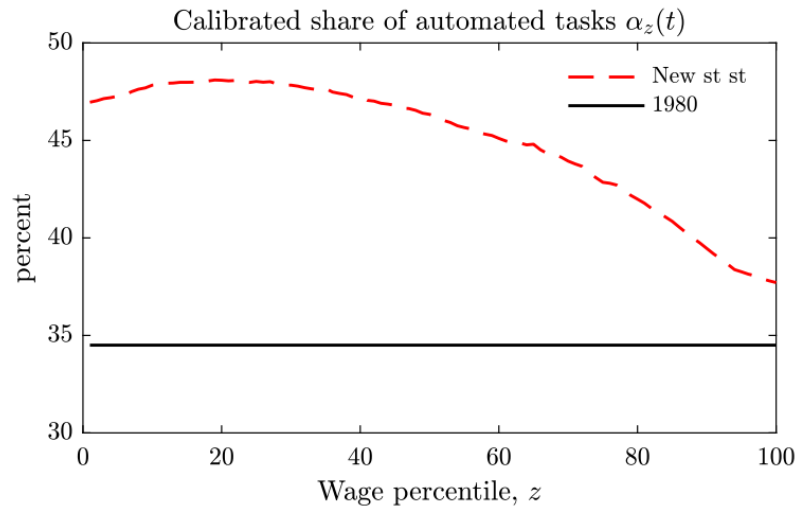
- Skill groups differ in their exposure to task automation.
- More-exposed groups suffer larger relative wage losses; wage levels can also fall.

Indirect effect through asset returns

- More assets ⟶ larger income gains when returns rise.
- Higher returns increase wealth inequality through faster accumulation.
- With capital returns r_K and safe-bond returns r_B, automation widens $r_K - r_B$.
- Capital investors gain more than bond holders ⟶ asset composition also matters.

Next: Simulate the full model with risky capital, bonds and portfolio returns.

The experiment targets routine tasks and the capital share



GURE 7.—Calibrated α_z by wage percentile in 1980 and the new steady state

Figure 7. Horizontal: 1980 wage percentile. Vertical: calibrated fraction of tasks automated.

- Gross capital share: $\alpha = \sum_z \eta_z \alpha_z$: 34.5% $\longrightarrow$ 42.8%
- Routine-task exposure allocates automation across skill groups

> The capital-share change is a calibration input.
> Wages, asset returns and income inequality are model outcomes.

Capital returns rise more than bond returns

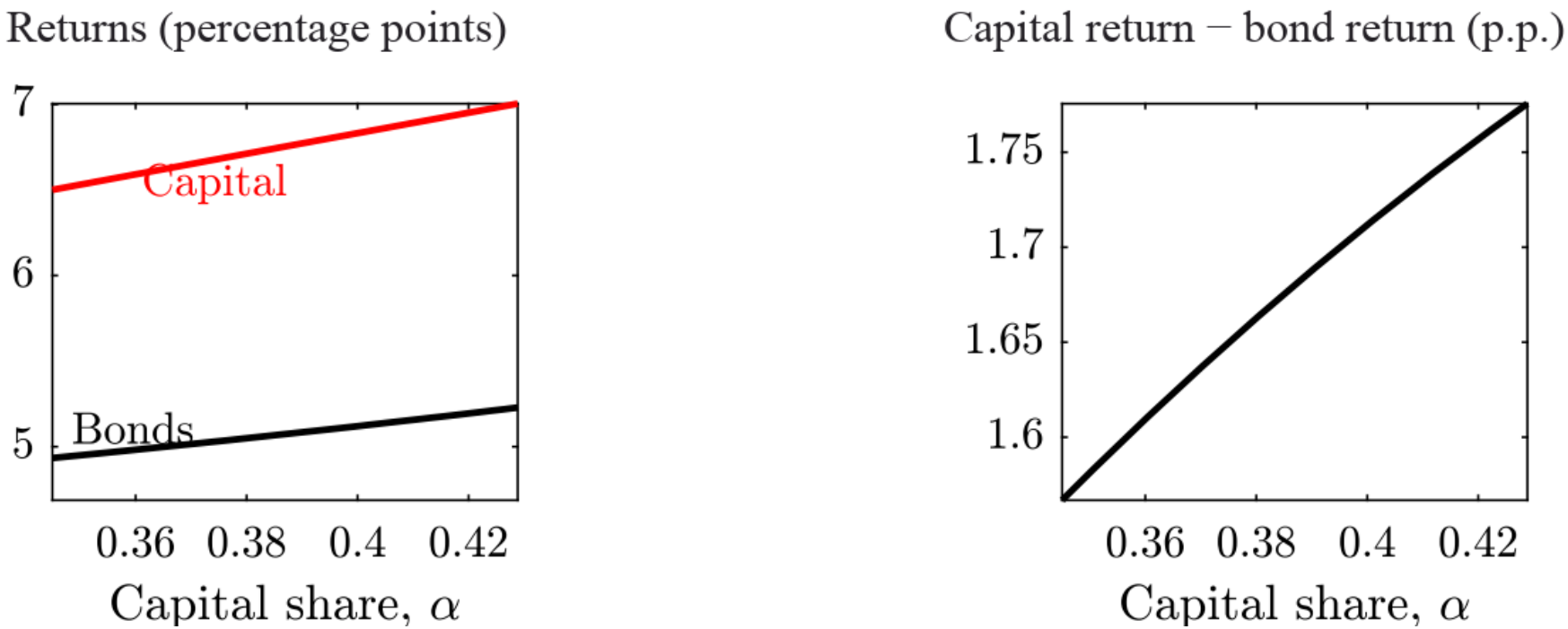


Figure 8: each point is a long-run model economy, indexed by the gross capital share.

Returns to productive capital rise much more than safe-bond returns.
The capital–bond return gap widens as automation increases.

Higher output per hour does not lift the median wage

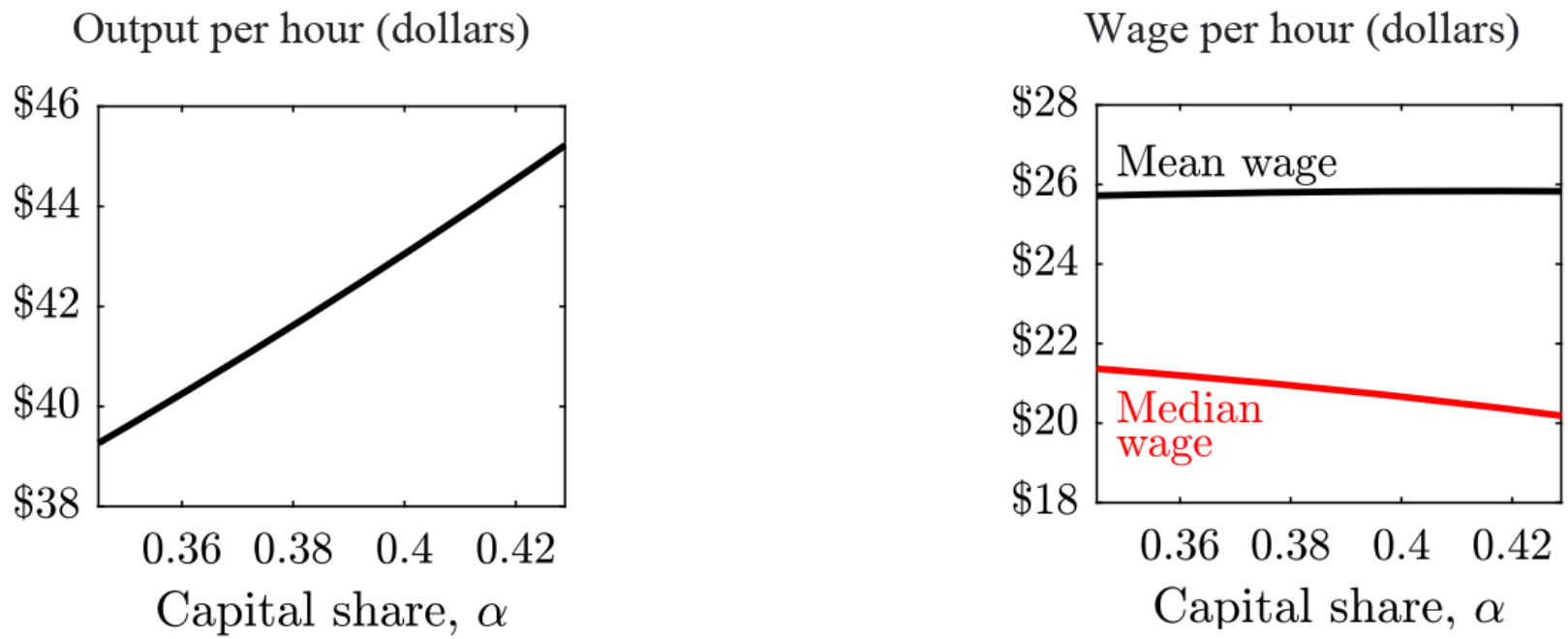


Figure 8 · model steady states; dollars per hour. Mean wage: $(1-\alpha)Y/\varphi$, with fixed markup φ.

> Output per hour rises, the mean wage is roughly flat, and the median wage falls.
> Aggregate productivity growth does not describe the typical worker's gain.

Capital intensity and efficiency gains

The wage effects differ across the distribution

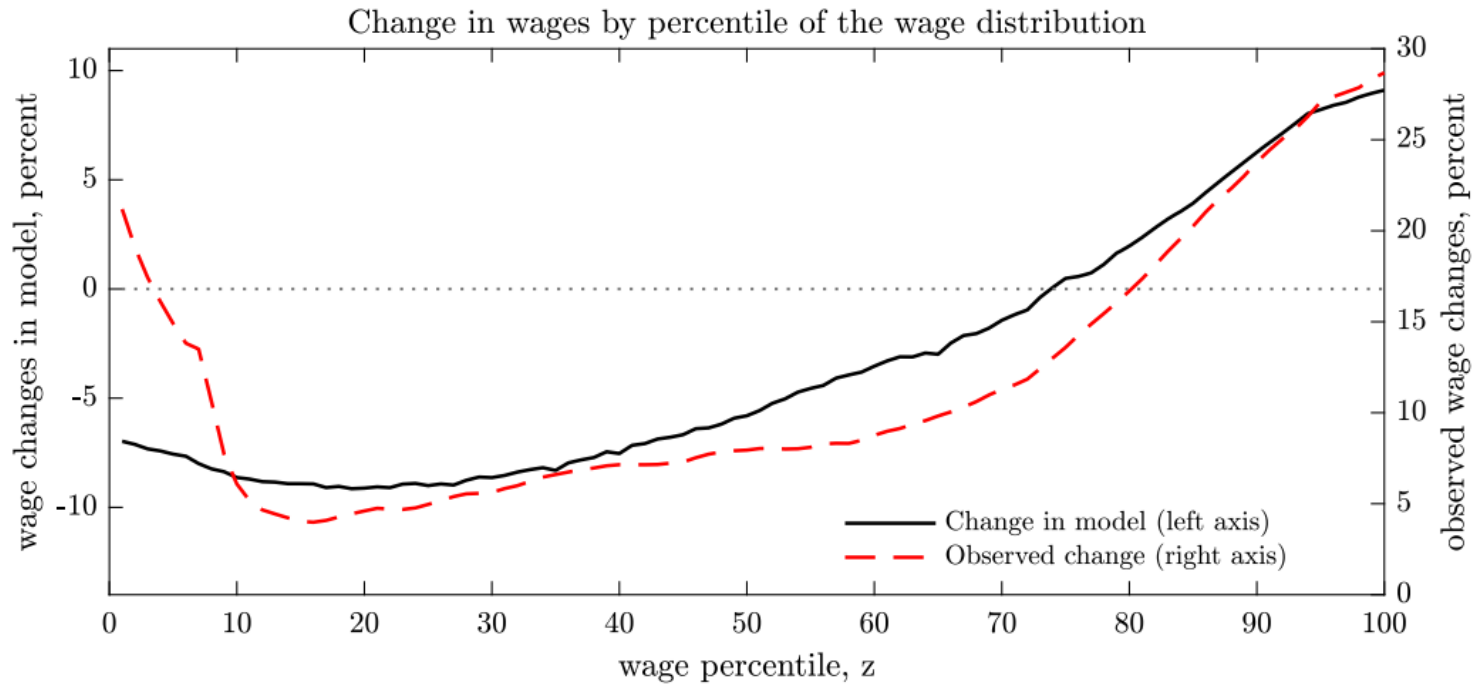


Figure 9 · predicted change (left); data, 1980–2012/16 (right). With fixed markup: $w_z \propto (1 - \alpha_z)Y$.

Model wages fall below roughly the 80th percentile.
About -10% near the 25th percentile; +7% near the 95th.

Unequal income growth: Comparing steady states

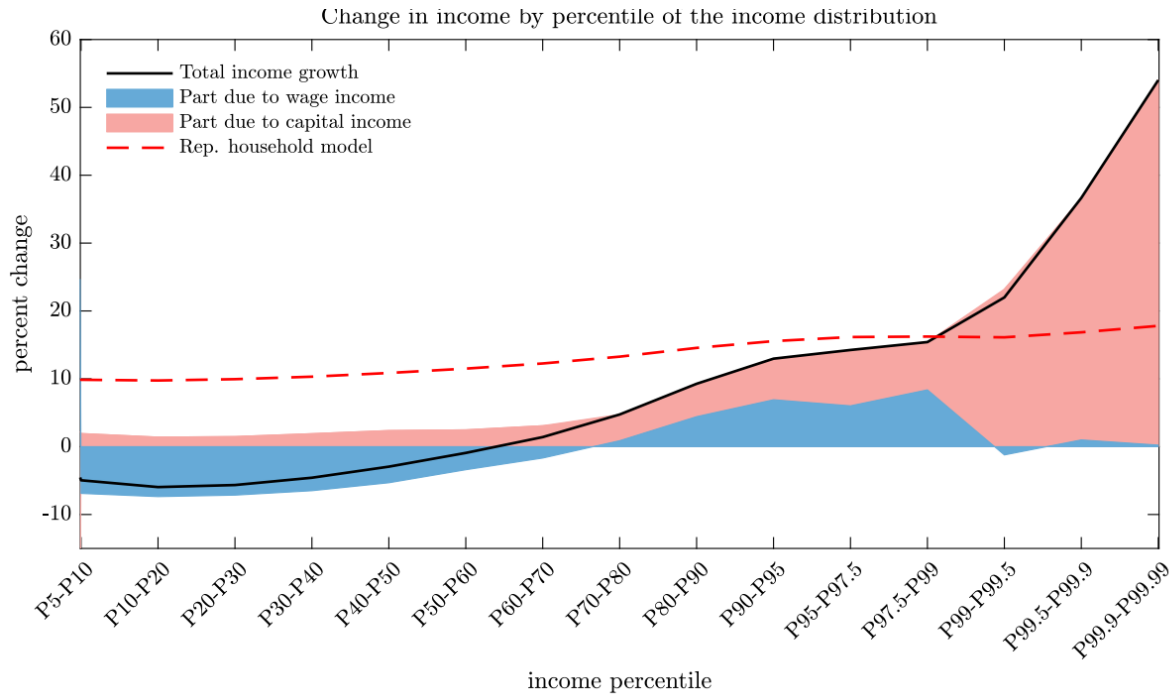


Figure 10: model income changes by total-income percentile; shaded contributions from labour and capital.

> Bottom-half incomes fall about 5–10%; incomes around the 50th–80th percentiles stagnate; the top 0.1% gains about 55%.

Higher returns and upper-tail inequality

The data also show sharply uneven income growth

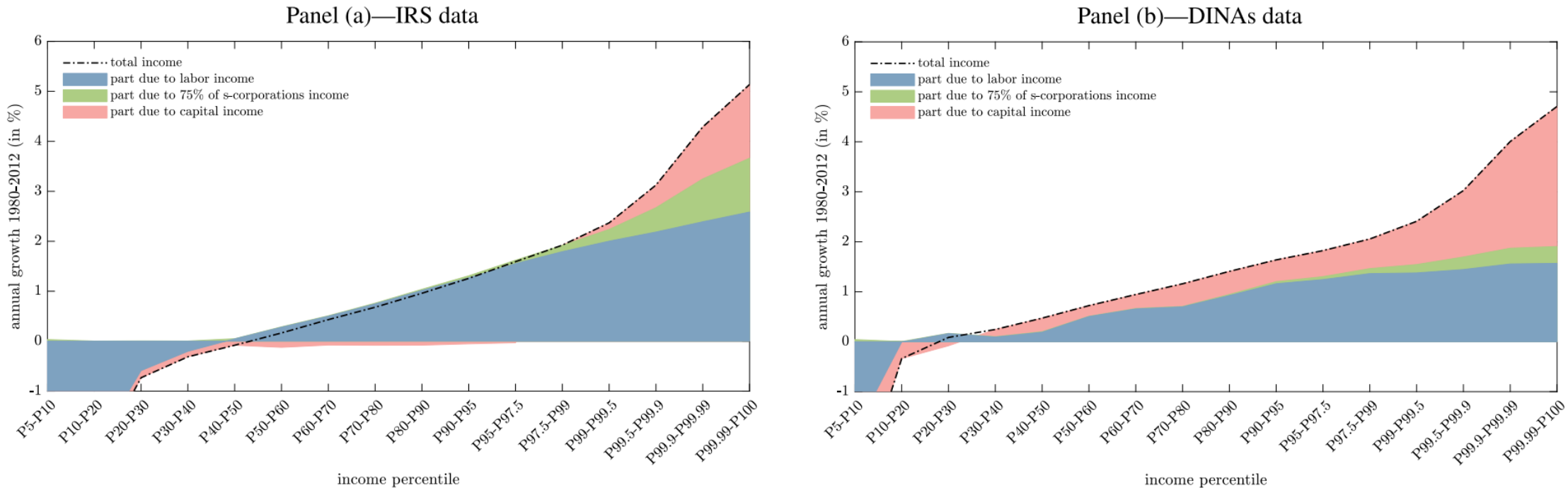
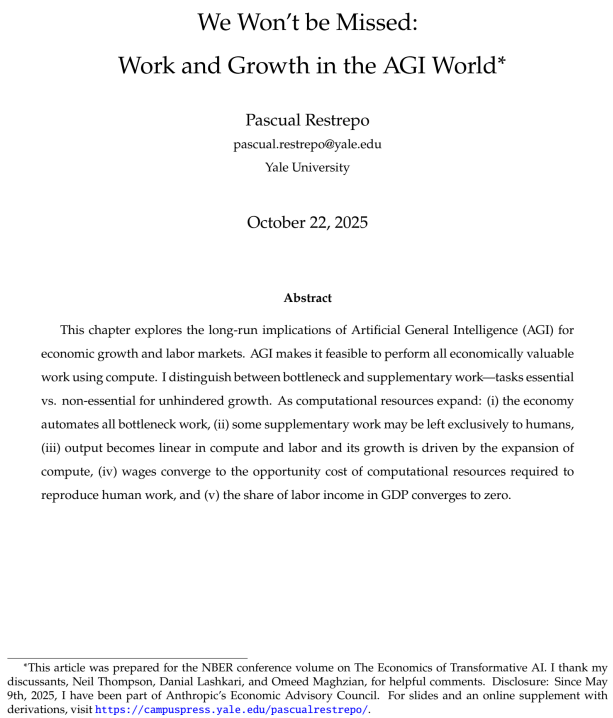


Figure 12: U.S. income growth by percentile, 1980–2012; IRS fiscal income and DINA national-income concepts.

> Both sources show much slower growth below the median than at the top.
> The top 0.1% grows around 5% per year.

We Won't be Missed



We Won't be Missed:

Work and Growth in the AGI World*

Pascual Restrepo
pascual.restrepo@yale.edu
Yale University

October 22, 2025

Abstract

This chapter explores the long-run implications of Artificial General Intelligence (AGI) for economic growth and labor markets. AGI makes it feasible to perform all economically valuable work using compute. I distinguish between bottleneck and supplementary work—tasks essential vs. non-essential for unhindered growth. As computational resources expand: (i) the economy automates all bottleneck work, (ii) some supplementary work may be left exclusively to humans, (iii) output becomes linear in compute and labor and its growth is driven by the expansion of compute, (iv) wages converge to the opportunity cost of computational resources required to reproduce human work, and (v) the share of labor income in GDP converges to zero.

*This article was prepared for the NBER conference volume on The Economics of Transformative AI. I thank my discussants, Neil Thompson, Danial Lashkari, and Omeed Maghzian, for helpful comments. Disclosure: Since May 9th, 2025, I have been part of Anthropic's Economic Advisory Council. For slides and an online supplement with derivations, visit https://campuspress.yale.edu/pascualrestrepo/.

Work and Growth
in the AGI World

Pascual Restrepo

NBER conference volume chapter
October 22, 2025

Open the paper

Chapter · First page

AGI is a recipe; compute is a scarce resource

Object	Premise
AGI	Every task becomes feasible with compute; its compute requirement converges to a finite, positive value
Compute capacity, K_t	Computations available per unit of time; finite today, unbounded over time
Human skills	Fixed supplies and accessible task sets for each skill
Production & markets	Constant returns to scale; efficient allocation; factors paid marginal products

> Feasible automation need not be economical immediately.
> The model asks how scarce compute should be allocated.

A task can use human time or compute

$$y_t(i) = \ell_t(i) + \frac{k_t(i)}{\gamma_t(i)}$$

Symbol	Meaning
i, $y_t(i)$	Task index; quantity completed in human-work units
$\ell_t(i)$, $k_t(i)$	Human input; compute allocated to that work
$\gamma_t(i)$ $\left(\frac{a_\ell(i)}{a_k(i)}\right)$	Compute needed to replace one unit of human work

Firms allocate labour and compute across tasks. Total compute and each skill's available human time are limited.

> Human productivity is normalized to one in the task equation.

Bottleneck and supplementary work

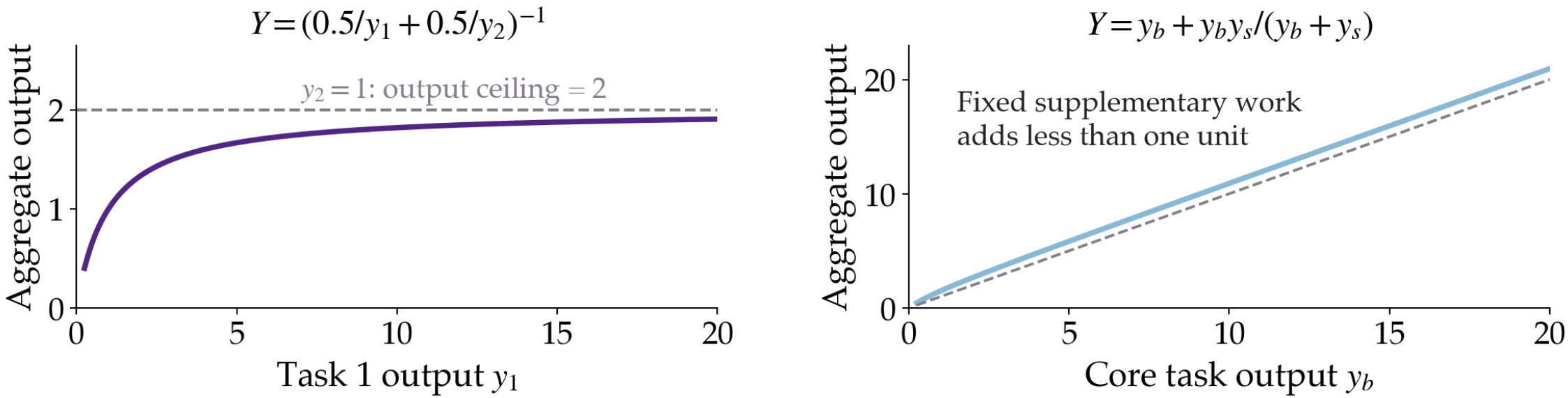
$$Y = \mathcal{F}(y(i))$$

Type of work	**Meaning for sustained growth**
Bottleneck	Must expand—or become arbitrarily valuable—as output expands
	Potential examples: energy, logistics and science
Supplementary	Can stay fixed, with bounded value of an extra unit, while output grows
	Potential examples: arts, hospitality and some customer support

The distinction depends on substitutability across tasks in $\mathcal{F}$:
how easily more output from other tasks can compensate for limited output of one task.

Production determines which tasks are bottlenecks

$$Y_t = \mathcal{F}(\{y_t(i)\}_i)$$



Teaching examples: $y_2 = 1$ (left), $y_s = 1$ (right); y_b: core task output.

A fixed bottleneck can cap output or develop an unbounded scarcity value.
Supplementary work can stay fixed without either outcome.

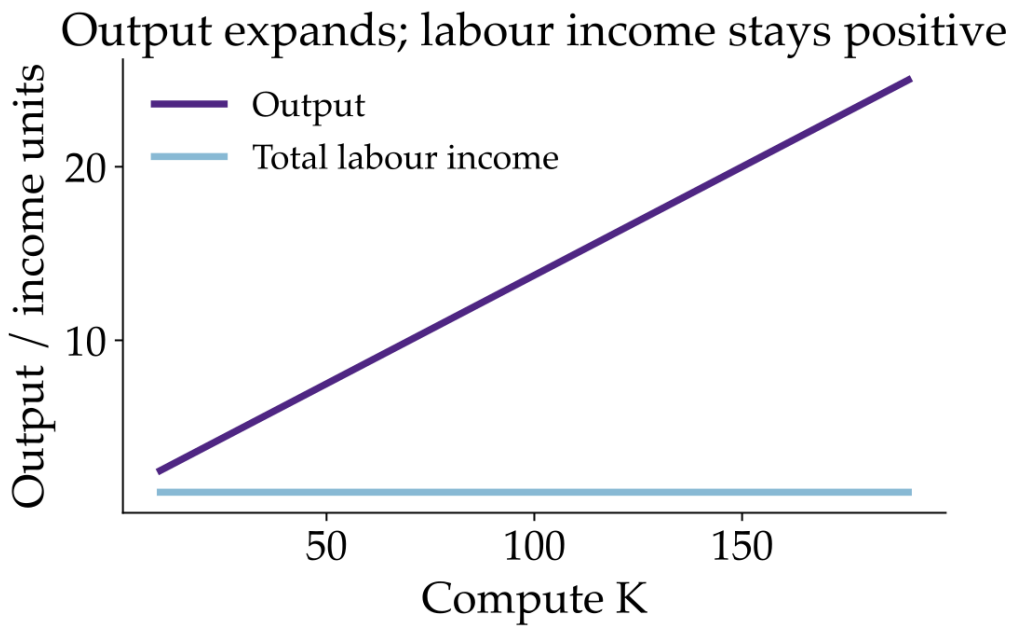
Which tasks eventually use compute?

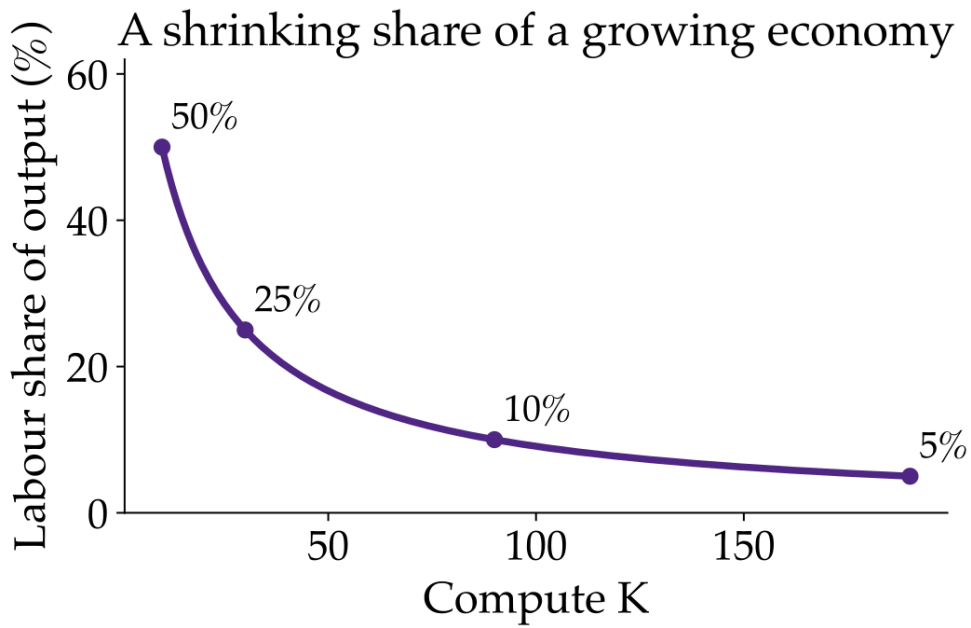
AGI makes every task feasible at finite compute cost; total compute keeps expanding.

Human-only task	**What happens as the economy grows?**	**Why allocate compute?**
Bottleneck	Its fixed supply caps output, or its scarcity value keeps rising	Expanding this task eventually becomes worth the compute
Supplementary	Its quantity and marginal value can both stay bounded	Its value may stay too low to divert compute from other work

> All bottlenecks eventually use compute, possibly alongside people.
> Some supplementary work can remain human-only.

Positive wages can coexist with a vanishing labour share





Labour share = total labour income / output. Illustration: wage bill = 1.25; output = (K + 10) / 8.

> Compute K: 10 ⟶ 190; labour's share: 50% ⟶ 5%.
> The wage bill stays positive while income paid to compute expands.

Two-task example · Aggregate wage-bill comparison

Full automation gives the same limiting factor shares

	Restrepo	**Jones–Tonetti: full automation**
Assumption	Every task has finite compute cost $\gamma(i)$; total compute keeps growing	Machines become cheaper on all tasks; 100% automation in finite time
Consequence	Compute can expand every bottleneck	Capital can expand every essential task

- No essential task must rely only on fixed human input
- Human wages are limited by replication costs; output keeps expanding

$$\frac{\text{Labour income}}{Y} \longrightarrow 0, \qquad \frac{\text{Compute / capital income}}{Y} \longrightarrow 1$$

Jones–Tonetti: when human weak links remain

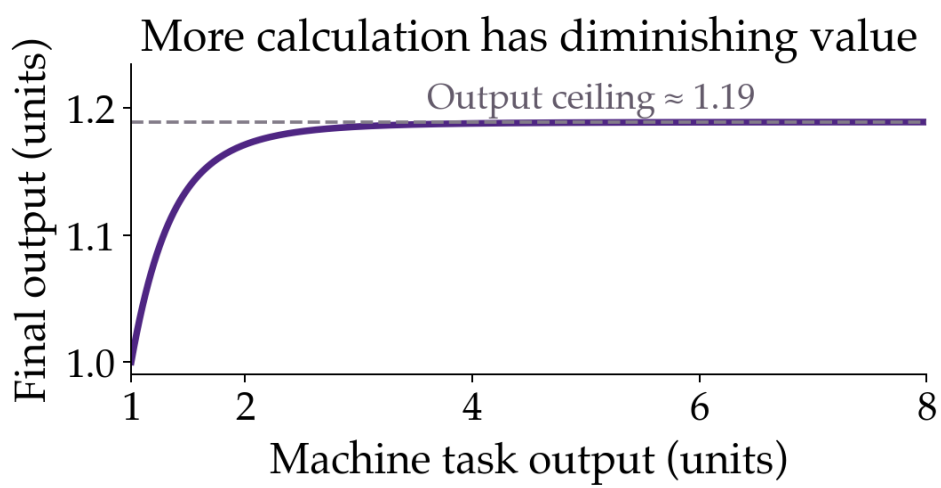
Low substitution across tasks: $\sigma < 1$.
Extra machine-task output cannot fully replace scarce human-task output.

Automation assumption	**Why does human work stay scarce?**	**Capital-share limit**
Permanent human tasks	A set of essential tasks can never use machines; adding machines cannot expand this work	0%
Ever harder last tasks	Replication costs rise without bound near the last task; the human-task set shrinks but never disappears	≈36% in their baseline calibration

> Permanent or increasingly hard human tasks preserve human scarcity.
> These are different automation limits from Restrepo's finite-cost AGI premise.

Weak links can preserve the value of human work

Jones & Tonetti: output needs both calculation and client judgment.
Weak links: tasks whose limited output constrains the whole process.



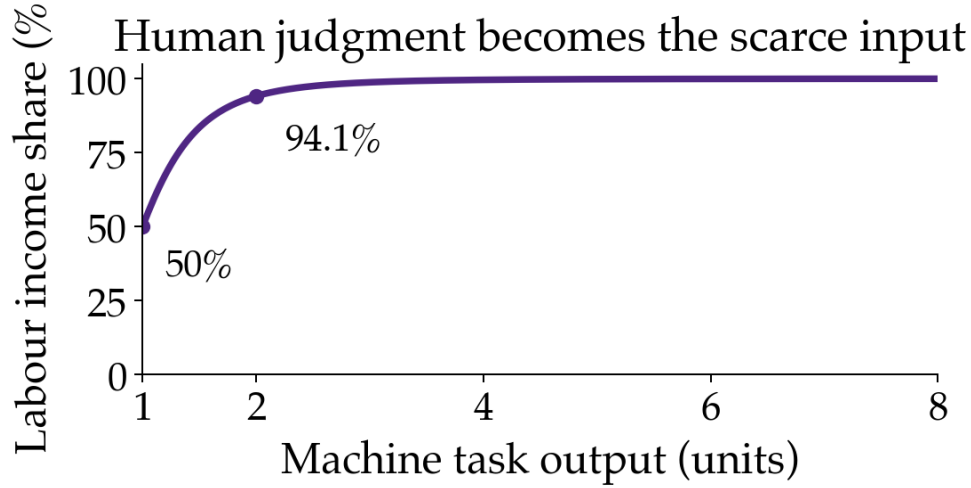
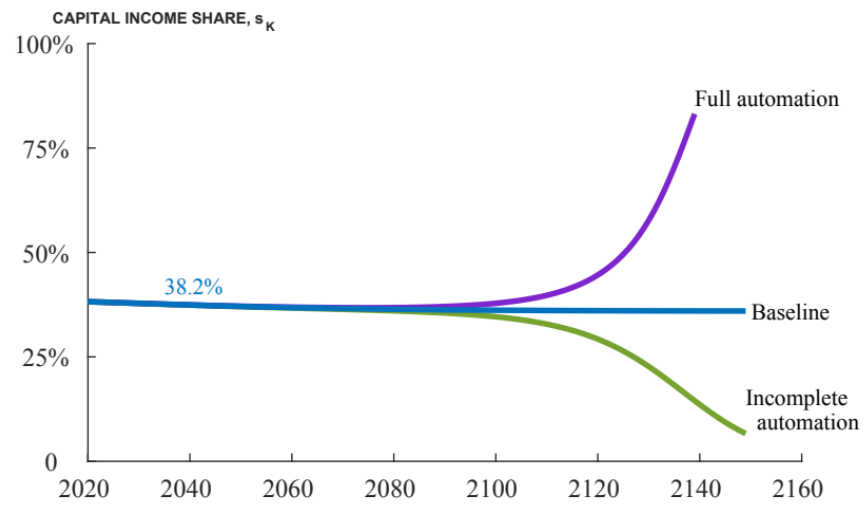


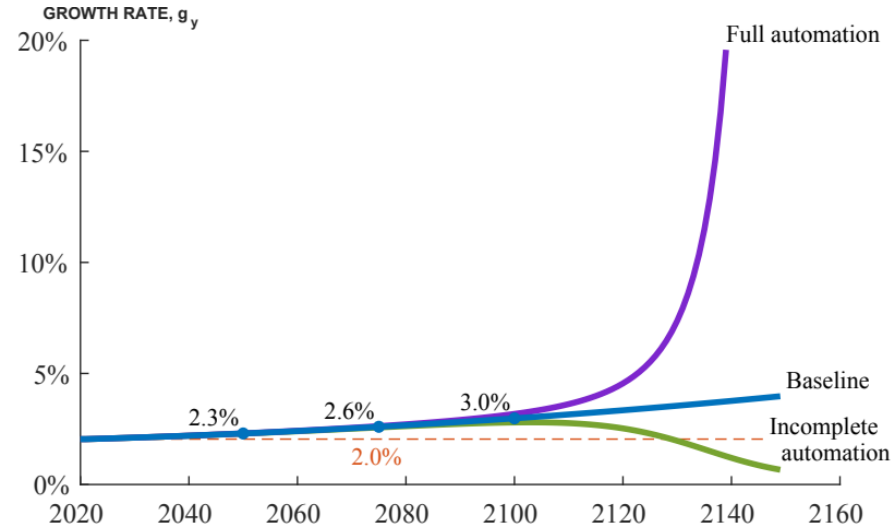
Illustration: human task output stays at 1; labour share = wage bill / output. Paper + setup · Bottleneck comparison

> Better machines on a fixed set of tasks can raise labour's income share.
> Automation sustains growth by bringing rapidly improving machines to more tasks.
> Better machines needed to materialize growth

The last human tasks determine the factor shares



Capital income share (%) · calendar year



Annual output growth (%) · calendar year

More capital ⟶ more AI research ⟶ higher productivity ⟶ more investment.

Conditional model paths; dashed: 2% growth benchmark. Output levels + faster-AI calibration

> Purple: all tasks automated ⟶ capital share 100%; explosive growth.
> Blue: ever harder tasks ⟶ capital share stays around 36%.
> Green: permanent human weak links ⟶ capital share 0%; slow growth.

Quantitative evidence on inequality and factor shares

Paper	Data and comparison
Krusell et al. (2000) *Capital-Skill Complementarity and Inequality*	U.S. CPS skill groups + quality-adjusted equipment; 1963–1992
Acemoglu & Restrepo (2022) *Tasks, Automation, and the Rise in U.S. Wage Inequality*	500 worker groups + industry automation; 1980–2016
Luduvice & Pinheiro (2026) *AI-Augmented Capital-Skill Complementarity*	U.S. macro data, 1963–2024; estimated AI capital model

> Different ways to get at substitutability of labor and capital

Capital, tasks and skills: main results

Paper / exhibits	Main result
Krusell et al. (2000)	Equipment complements skilled labour more than unskilled labour. Its accumulation raises skilled workers' relative wages.
Acemoglu & Restrepo (2022) Wage & labour-share results	Routine-task displacement predicts lower relative wages. The automation model also lowers the labour share.
Luduvice & Pinheiro (2026) AI shocks	AI complements the skilled-labour/equipment bundle **less strongly** than equipment complements skilled labour in Krusell et al. Elasticities: ≈0.89 (AI–bundle) vs ≈0.67 (equipment–skill, Krusell et al.). AI rental income is 1.3% of output in the estimated baseline.

> Who gains depends on which tasks capital replaces and which skills it complements.

What the quantitative results say about inequality

Channel	Reported result	Interpretation
Equipment + skills Krusell et al.	≈ +20% skill premium; ≈ -40% without complementarity	Capital can raise wage inequality through skill demand
Task displacement Acemoglu–Restrepo	Full model explains ≈47% of variation in wage changes across worker groups	Loss of comparative-advantage tasks matters
AI + skills Luduvice–Pinheiro	Greater AI reliance: premium ↓ Cheaper AI: premium ↑	Model outcomes depend on AI's production role versus its price
Returns + ownership Moll et al.	Income becomes more concentrated at the top	Asset accumulation amplifies income inequality

> Technological change and automation have increased wage inequality.
> Higher capital demand amplifies wealth inequality through returns and unequal ownership.

Capital and labour shares across papers

Krusell, Ohanian, Ríos-Rull & Violante (2000); Acemoglu & Restrepo (2022); Moll, Rachel & Restrepo (2022); Luduvice & Pinheiro (2026) · Tables 4–6

Euler equation and the saving rule

At constant prices, the Euler equation gives:

$$\frac{\dot{c}_t}{c_t} = \frac{r-\rho}{\sigma} \equiv b$$

The lifetime budget is effective wealth $x_t = a_t + w_z/r$:

$$x_t = \int_0^\infty e^{-rs} c_t e^{bs}\, ds = \frac{c_t}{r-b}$$

$$c_t = (r-b)x_t, \qquad \dot{a}_t = rx_t - c_t = bx_t$$

Requires $r > b$; b is effective-wealth growth between resets. Back to optimal saving

Deriving the equilibrium return gap

Set aggregate saving net of resets to zero:

$$0 = \frac{r^* - \rho}{\sigma}\left(K^* + \frac{\bar{w}^*}{r^*}\right) - pK^*$$

$$r^* - \rho = p\sigma\frac{K^*}{K^* + \bar{w}^*/r^*} = p\sigma\underbrace{\frac{r^*K^*}{r^*K^* + \bar{w}^*}}_{\alpha^*_{\text{net}}}$$

With $\delta = 0$, gross and net capital shares coincide:

$$r^* = \rho + p\sigma\alpha, \qquad \frac{K^*}{Y^*} = \frac{\alpha}{\rho + p\sigma\alpha}$$

Back to the return result · Capital supply and demand

Waiting for capital accumulation need not restore wages

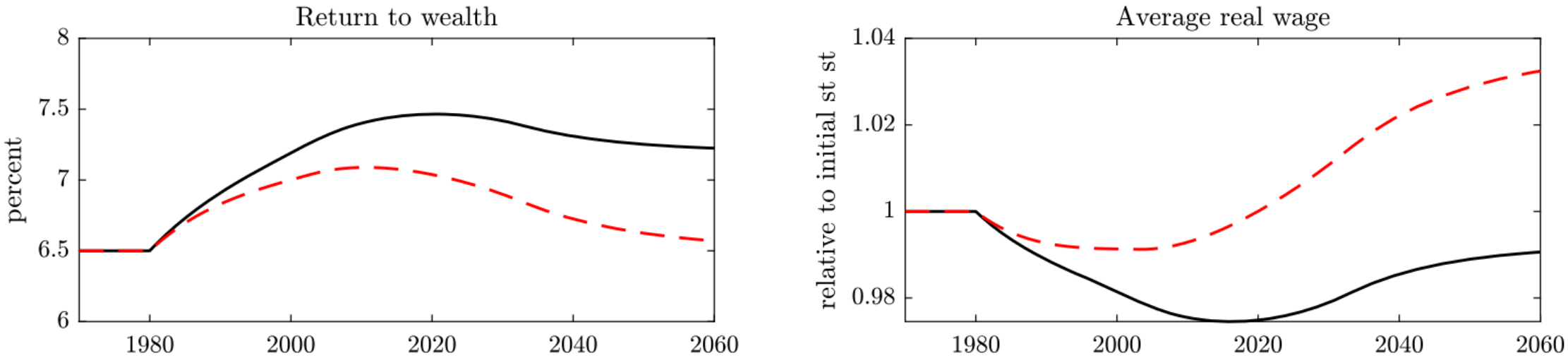


Figure 3, baseline model. Black: wealth dissipation; red dashed: representative-household benchmark.

> In the baseline example, the return rises from 6.5% to about 7.2% in the long run, while the average wage remains about 1% below its initial path.

Back to the main discussion

Returns differ across assets

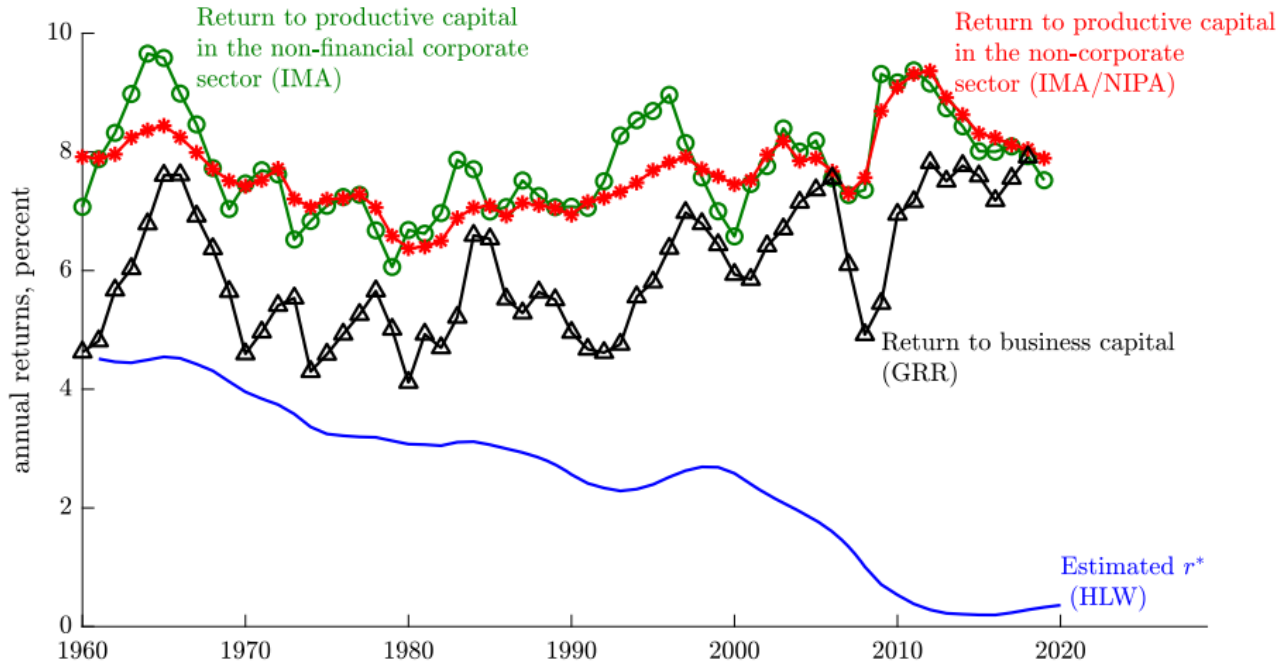


Figure 5: alternative returns to capital and the safe rate over time.

> The safe rate falls while returns associated with productive capital need not fall with it.
> Asset composition matters for the income received by owners.

Back to inequality channels

The full return to investors' wealth

$$r_W = \underbrace{\kappa r_K + (1-\kappa) r_B}_{\text{expected portfolio return}} + \underbrace{\frac{1}{2}(\sigma - 1)\gamma \nu^2 \kappa^2}_{\text{risk-related saving adjustment}}$$

Object	Meaning
γ, ν	Risk aversion; idiosyncratic volatility of capital returns
κ	Optimal risky share of effective wealth: $(r_K - r_B)/(\gamma \nu^2)$
x_t	Net assets + $(w_z + T)/(r_B - g)$; T: common transfer

For $\sigma > 1$, capital-income risk raises saving through the income effect.
The empirical portfolio-return proxy omits this adjustment.

$$\text{return gap} = r_W - \rho - \sigma g$$

Figure 6 reports $r_W - \sigma g$, before subtracting constant ρ. Back to definitions · Capital and bond return evidence

Small efficiency gains can have large distributional effects

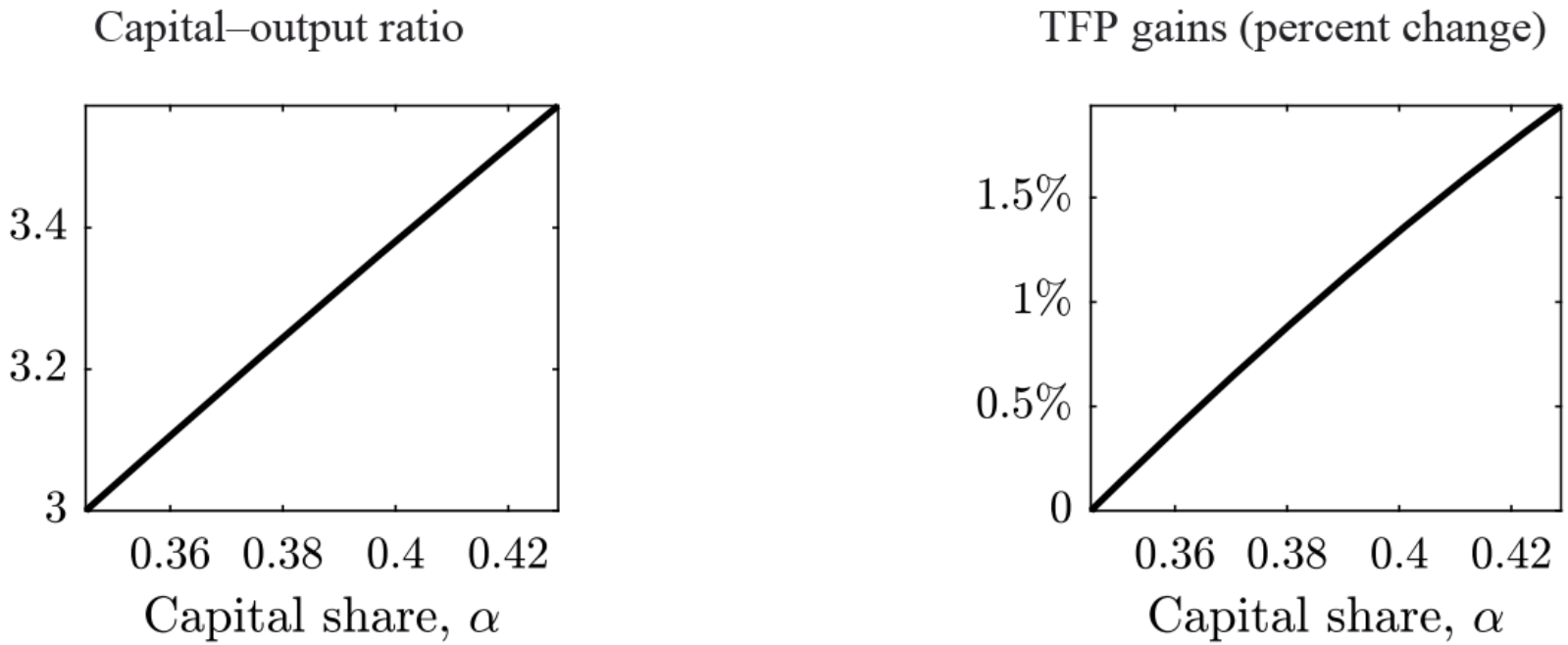


Figure 8, capital/output and TFP panels. Changes between model steady states.

> TFP rises about 2% and capital relative to output about 15%.
> These modest aggregate changes will accompany much larger differences in income growth.

Back to the main discussion

What does a thicker upper tail mean?

The tail describes how slowly the number of very high-income households declines as income rises.

$$\Pr(y > x) \propto x^{-\zeta}; \qquad \text{figure reports } 1/\zeta$$

Illustrative exponent	**Share above 2x relative to share above x**
$\zeta = 2 \longrightarrow 1/\zeta = 0.5$	$2^{-2} = 25\%$
$\zeta = 1.5 \longrightarrow 1/\zeta \approx 0.67$	$2^{-1.5} \approx 35\%$

> A larger $1/\zeta$ means more mass at very high incomes.
> It is a measure of tail inequality, not the top group's share of national income.

Back to the mechanism · Back to Figure 11

The model captures an important pattern, with two clear gaps

Comparison	Implication
Uneven growth across percentiles	Consistent with unequal exposure and concentrated capital ownership.
Labour income at the top	More important in the data than in the model; other skill-biased forces matter.
Speed of rising top inequality	The baseline wealth dynamics are too slow to match the historical transition.

> The model establishes a long-run mechanism.
> Similar distributional patterns do not identify automation as the sole historical cause.

Back to income data

The no-reset benchmark

Set $p = 0$: households no longer lose their financial wealth in dissipation shocks.

$$\frac{\dot{c}}{c} = \frac{r - \rho}{\sigma} \qquad \xrightarrow{\text{Stationary consumption } \dot{c}=0} \qquad r^* = \rho$$

> Long-run capital supply is perfectly elastic at $r = \rho$.
> Automation changes the capital quantity; returns can rise temporarily during adjustment.

Infinite life alone is insufficient: the key change here is removing wealth resets.

Growth-adjusted return gap · Back to the capital-market graph

A two-task example with positive wages and a falling share

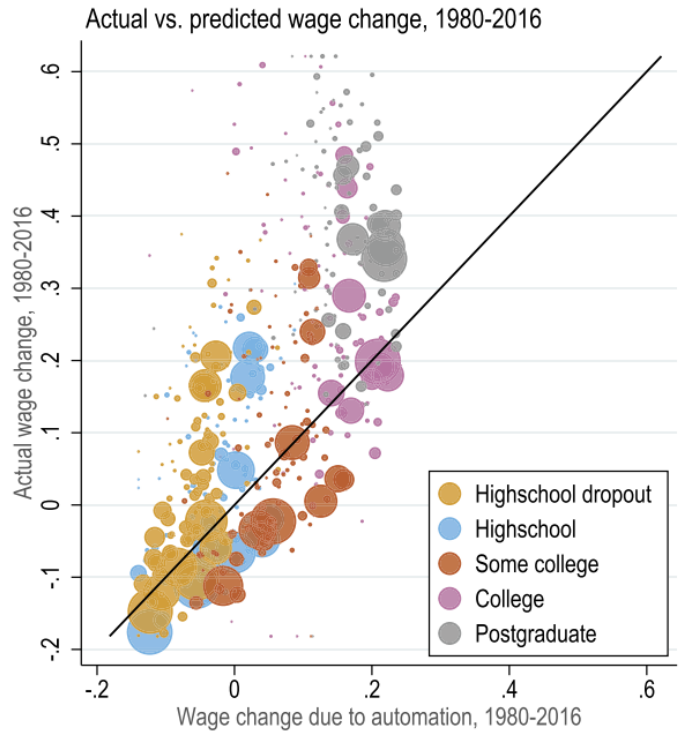
$$Y = \sqrt{y_1 y_2}, \quad y_1 = 1 + k_1/2, \quad y_2 = 1 + k_2/8$$

Two fixed workers: one per skill. Compute costs: $\gamma_1 = 2, \gamma_2 = 8$.
When $K \geq 6$, both tasks use compute; $A = 1/8$.

K	Output Y	Total labour income	Labour share
10	2.50	1.25	50%
30	5.00	1.25	25%
90	12.50	1.25	10%
190	25.00	1.25	5%

Back to the graph

Observed versus automation-predicted wage changes



Published Figure 8. Horizontal: model-predicted wage changes. Vertical: observed wage changes. Marker size: group population.

Back to task-displacement measurement · Back to results

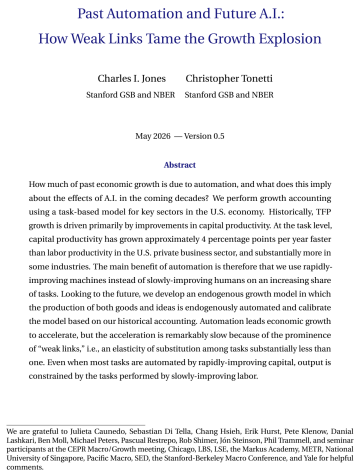
AI complementarity and three different shares

Object	Baseline value
CES production weight on AI	$\approx 2.4\%$
AI share of capital value	2.6%
AI rental income / output	1.3%
AI / skilled-equipment substitution elasticity	≈ 0.89

> A production weight is not an income share.
> Gross rental income is not a return net of depreciation.

Back to baseline shares

Jones–Tonetti: source and teaching example



Past Automation and Future A.I.:
How Weak Links Tame the Growth Explosion

Charles I. Jones Christopher Tonetti
Stanford GSB and NBER Stanford GSB and NBER

May 2026 — Version 0.5

Abstract

How much of past economic growth is due to automation, and what does this imply about the effects of A.I. in the coming decades? We perform growth accounting using a task-based model for key sectors in the U.S. economy. Historically, TFP growth is driven primarily by improvements in capital productivity. At the task level, capital productivity has grown approximately 4 percentage points per year faster than labor productivity in the U.S. private business sector, and substantially more in some industries. The main benefit of automation is therefore that we use rapidly-improving machines instead of slowly-improving humans on an increasing share of tasks. Looking to the future, we develop an endogenous growth model in which the production of both goods and ideas is endogenously automated and calibrate the model based on our historical accounting. Automation leads economic growth to accelerate, but the acceleration is remarkably slow because of the prominence of "weak links," i.e., an elasticity of substitution among tasks substantially less than one. Even when most tasks are automated by rapidly-improving capital, output is constrained by the tasks performed by slowly-improving labor.

We are grateful to Julieta Caunedo, Sebastian Di Tella, Chang Hsieh, Erik Hurst, Pete Klenow, Danial Lashkari, Ben Moll, Michael Peters, Pascual Restrepo, Rob Shimer, Jón Steinsson, Phil Trammell, and seminar participants at the CEPR Macro/Growth meeting, Chicago, LBS, LSE, the Markus Academy, METR, National University of Singapore, Pacific Macro, SED, the Stanford-Berkeley Macro Conference, and Yale for helpful comments.

- Two equally weighted, essential tasks
- x: machine task output; $h = 1$: human task output
- One unit each of capital and labour; only machine productivity rises
- Low substitution across tasks: $\sigma = 0.2$

Charles I. Jones & Christopher Tonetti
May 2026 · version 0.5

$$Y = \left(\tfrac{1}{2}x^{-4} + \tfrac{1}{2}h^{-4}\right)^{-1/4}, \qquad s_L = \frac{h^{-4}}{x^{-4} + h^{-4}}$$

Illustrative special case; factor income = marginal product × input. Back to weak links

Faster AI changes the timing; weak links still matter

Left: output levels versus continued initial growth.
Right: growth rates; dashed 2% = historical private-business benchmark.

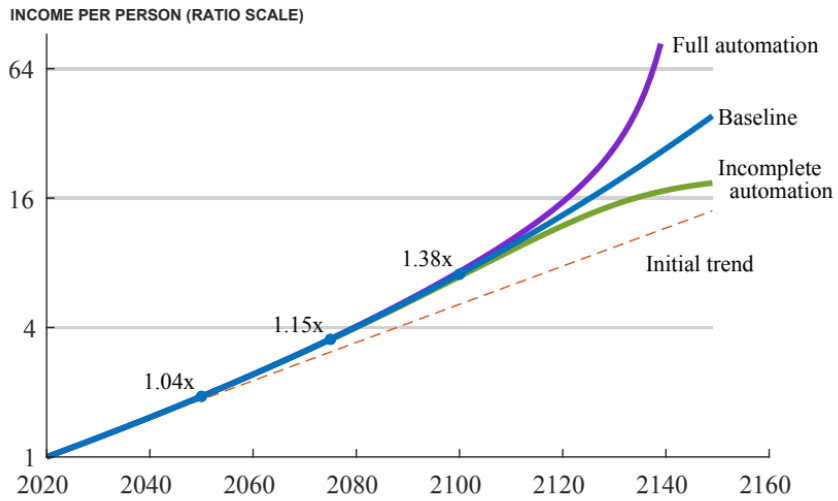


Figure 5c · private business
GDP per person (ratio scale; 1 = 2020)

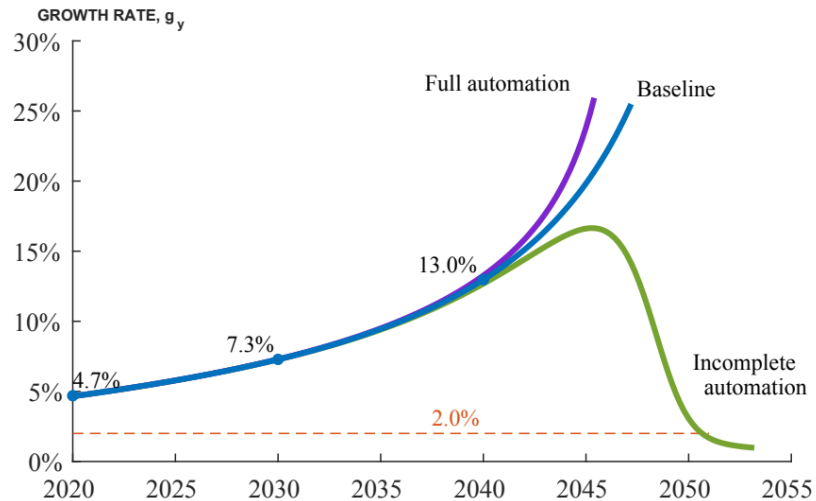


Figure 6b · computer-sector calibration
Annual output growth (%)

> "Moore's Law everywhere" is a conditional high-productivity scenario.
> Its explosive paths require no permanent human weak links. Back

Productivity gains can accrue to capital returns

The dual productivity identity, at competitive factor prices:

$$d \ln \text{TFP} = (1 - \alpha)\, d \ln \bar{w} + \alpha\, d \ln R$$

$$d \ln \bar{w} = \frac{d \ln \text{TFP} - \alpha\, d \ln R}{1 - \alpha}$$

$R = r + \delta$: use the **gross rental** in this expression.
If $p = 0$, long-run $d \ln R = 0$; productivity gains raise mean wages.

> With upward-sloping capital supply, R can rise permanently.
> Workers receive less of the productivity gain; mean wages can fall.

Local changes; fixed skill supplies. Back to wage levels

The income-tail equation with growth and return risk

Scale effective wealth by trend growth. Define:

$$b = \frac{r_W - \rho}{\sigma} - g, \qquad v = \kappa\nu$$

b: relative accumulation drift; v: portfolio-return volatility.
The stationary Pareto exponent ζ satisfies:

$$p = \zeta b + \tfrac{1}{2}\zeta(\zeta - 1)v^2$$

$$\frac{1}{\zeta} = \frac{b - \frac{1}{2}v^2 + \sqrt{(b - \frac{1}{2}v^2)^2 + 2pv^2}}{2p}$$

No-risk case, $b > 0$: $1/\zeta = b/p$. Equation (15), written compactly. Back to Figure 11

From faster accumulation to a thicker income tail

Baseline: one asset, no trend growth; time T since the last reset.

$$x(T) = x_0 e^{(r^* - \rho)T/\sigma}, \qquad \Pr(T > t) = e^{-pt}$$

Some households accumulate uninterruptedly for much longer than others.

$$\underbrace{\frac{1}{\zeta}}_{\text{tail index}} = \frac{\text{accumulation rate}}{\text{reset rate}} = \frac{r^* - \rho}{\sigma p} = \alpha^*_{\text{net}}$$

> Illustration: accumulation 2% / reset rate 4% ⟶ tail index 0.5.
> Faster accumulation at 2.4% ⟶ index 0.6; more mass at high incomes.

ζ: Pareto exponent; $x_0 = w_z/r^*$. Tail probabilities · Risky-model extension

Back to inequality channels

Portfolio returns and the growth-adjusted return gap

Object	Meaning in the extended model
r_K, r_B	After-tax real return: productive capital / safe bonds
κ	Risky capital / effective wealth; $\kappa > 1$ means borrowing

$$r_W = \underbrace{\kappa r_K + (1-\kappa) r_B}_{\text{portfolio return}} + \text{risk adjustment}$$

$$\underbrace{r_W - \rho - \sigma g}_{\text{return gap}} = \sigma \left(\frac{r_W - \rho}{\sigma} - g \right)$$

g: trend growth. Full risky-return formula · Capital and bond evidence · Back to inequality channels

> A higher return gap means faster accumulation relative to the growing economy.

Higher returns thicken the upper income tail

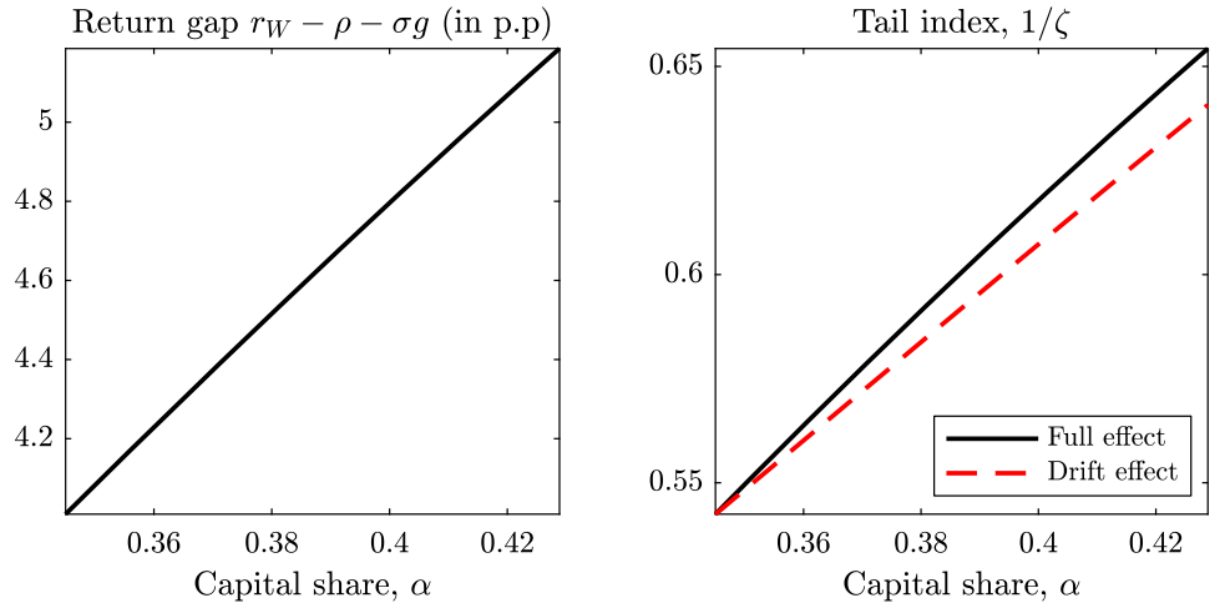


Figure 11 · extended model: return gap + portfolio risk. Index definition · Tail equation

> Income-tail index: 0.54 ⟶ 0.65.
> Higher returns alone account for the increase to about 0.63.

Back to model income growth · Back to inequality channels

A falling labour share need not mean lower total wages

- In the core model, the aggregate wage bill stays at least as high as in the no-AGI economy
- Human skills can still produce; the old production method remains available
- Some workers can nevertheless suffer wage losses during the transition

> This result needs efficient markets, constant returns and only two scarce factors: human skills and compute. Other fixed resources can change the comparison.

Back to the main AGI result

Freezing automation would remove much of past TFP growth

Data: BEA/BLS accounts + LLM reconstruction of automated-task labour costs.
Counterfactual: freeze automation; keep task-productivity growth unchanged.

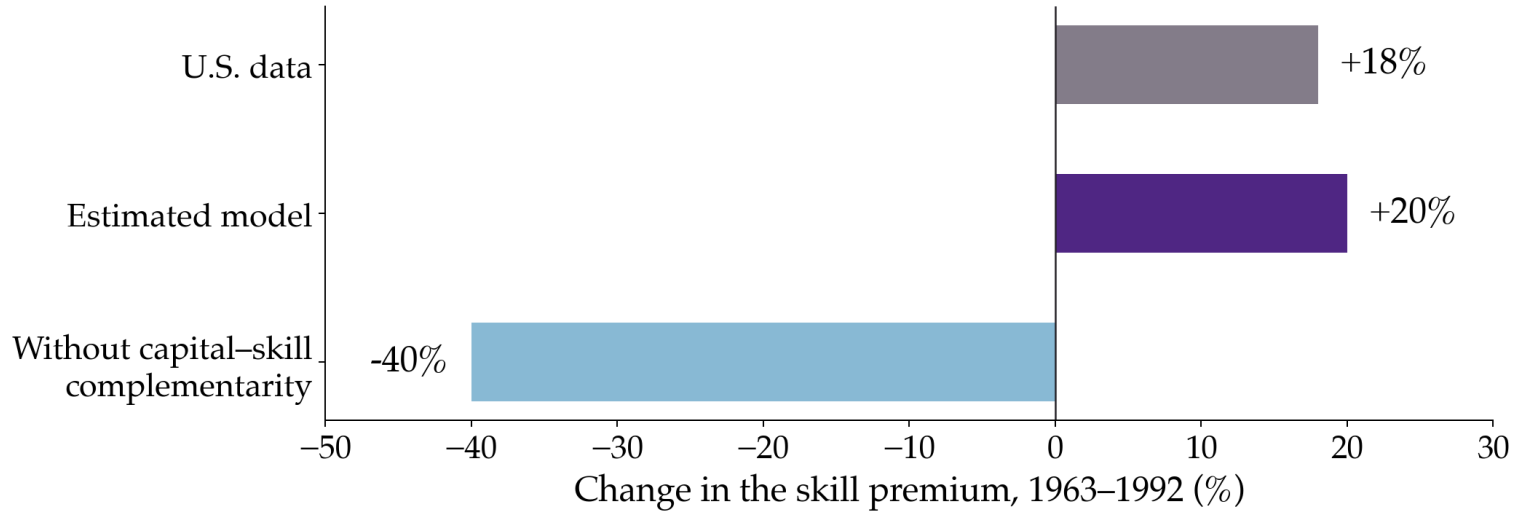
Sector / period	Actual TFP growth (% / year)	TFP growth lost (pp / year)	Lost / actual growth
Private business (1950–2023)	1.2	1.3	108%
Computers (1987–2017)	12.8	3.2	25%
Retail trade (1987–2017)	1.7	4.1	242%

Model accounting, Table 7: averages across subperiods; shares use unrounded calculations. Paper: full table + assumptions

> Machines improve fastest: automation moves more tasks onto that growth path.
> Contributions can exceed 100% when other forces offset automation's gains.

Back to weak links

Equipment complements skilled labour



Skill premium = college-graduate wage / non-graduate wage. Reported changes, 1963–1992.

Equipment substitution elasticity	Estimate
With unskilled labour	1.67
With skilled labour	0.67

Paper: original estimates · Back to main results

Task displacement predicts relative wage declines

Object	Construction
Observation	500 groups: education, sex, age, race & nativity
Task displacement	Initial industry/task specialization × subsequent automation-related task losses
Wage outcome	Change in real hourly wages, 1980–2016
Direct wage relationship	Task displacement accounts for 50–70% of variation in wage changes

> Routine-task workers lose relative pay in rapidly automating industries.
> The full model adds productivity, task reallocation and industry-composition effects.

Observed versus model-predicted wages · Back to main results

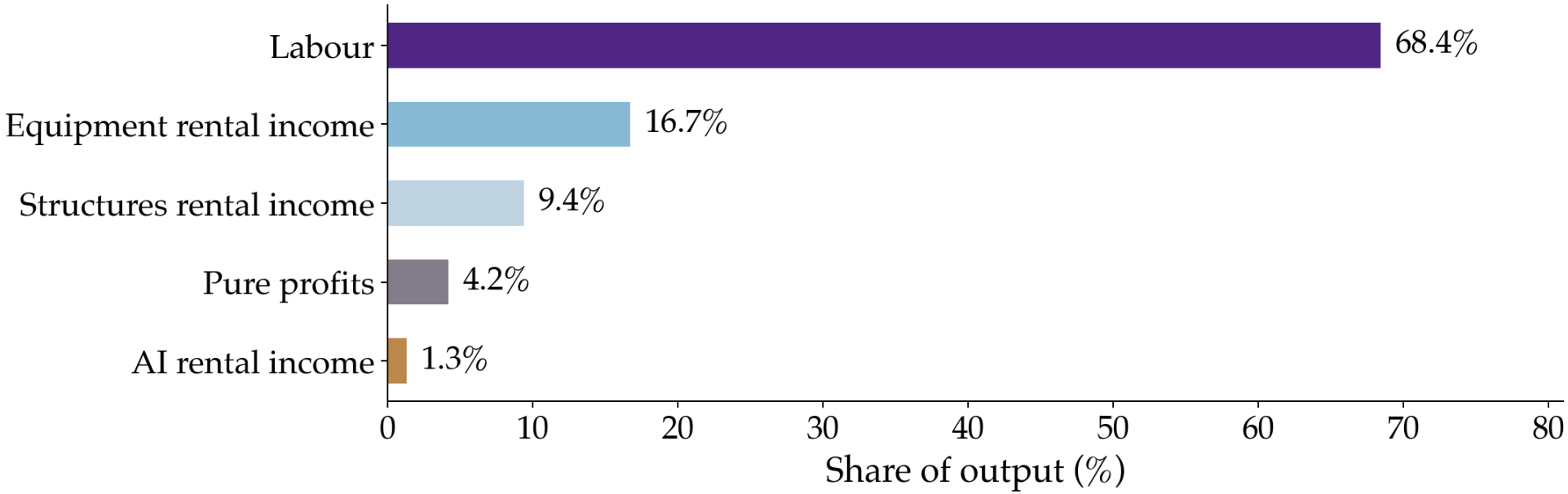
Large wage inequality effects can accompany modest efficiency gains

Outcome, 1980–2016	U.S. data	Automation model
College wage premium: 100 × Δlog	25.51	21.02
Population in groups with declining wages	53.10%	42.26%
TFP: 100 × Δlog	35.00	3.42
Labour share change	-8.00 pp	-10.41 pp

> The full model accounts for about 47% of wage-structure changes.
> Automation has large distributional effects, with limited TFP gains.
> The model's labour-share decline exceeds the observed drop.

Paper: original Table VIII · Back to main results

AI capital is a small part of the estimated baseline



Luduvice–Pinheiro, Table 4. Calibrated baseline shares of output; capital rental income includes depreciation.

> AI is 2.6% of capital value and receives 1.3% of output as rental income.
> This baseline is far from the all-work AGI limit.

Estimated complementarity and original table · Back to main results

More AI use and cheaper AI are different shocks

Estimated complementarity: AI and the skilled-labour/equipment composite have substitution elasticity ≈ 0.89.

New steady state	Double AI weight	Halve AI price
Output change	-1.87%	+1.00%
AI capital stock change	+81%	+89%
Skilled/unskilled wage ratio	1.73	1.85

Initial wage ratio: 1.82. AI production weight: 2.4% $\longrightarrow$ 4.8% in the first experiment.

> A higher weight puts more demand on scarce complementary AI.
> Cheaper AI relaxes that constraint and raises the skill premium.

Paper: counterfactual tables · Back to main results

What the results say about capital and labour shares

Exercise	Labour / capital result	Interpretation
Task displacement Acemoglu–Restrepo	Labour share: -8 pp in data; -10.41 pp in model	Large share shifts; modest TFP gains
Estimated AI baseline Luduvice–Pinheiro	Labour: 68.4%; AI rental income: 1.3%	Current AI is small in this model
Weak-link scenarios Jones–Tonetti	Capital share can rise, fall or stay stable	Remaining human tasks can retain scarcity value
Conditional AGI limit Restrepo	Labour share $\longrightarrow 0$; compute share $\longrightarrow 1$	Positive wages can persist; ownership becomes central

> A smaller labour share does not by itself imply lower wages.
> Combine productivity, wage levels and asset ownership to assess living standards.

Back to inequality