EC9AA Term 3: Lectures on Economic Inequality

Debraj Ray, University of Warwick, Summer 2023

- **Slides 3**: Functional Inequality: The Falling Labor Share

The Fourth Fundamental Law of Capitalism

- We now downplay personal endowments and accumulation
  - Though still very much in the background
- Our focus: **the functional distribution across capital and labor**

The Fourth Fundamental Law of Capitalism

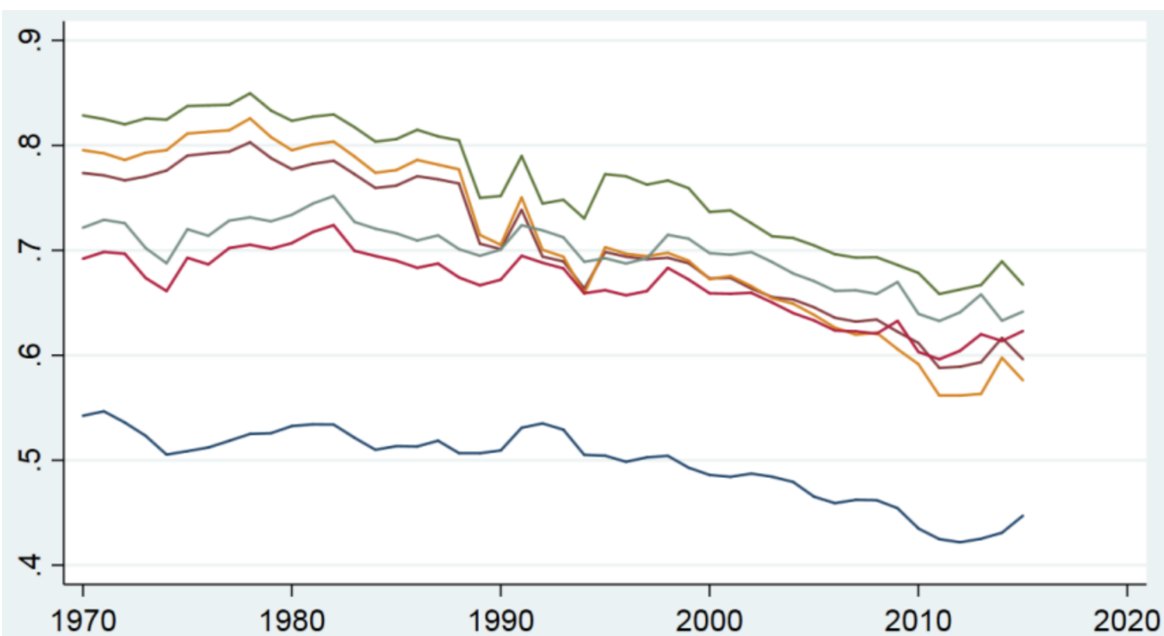
With economic growth, capital displaces labor:

The labor share in national income must progressively vanish.

- A **fundamental law**? You can't be serious.
  - It isn't even testable (though stronger versions of it are)
  - But it *is* a fundamental device for organizing our thoughts.

Death of a Kaldor Fact

The falling labor share:



Guerriero (2019)

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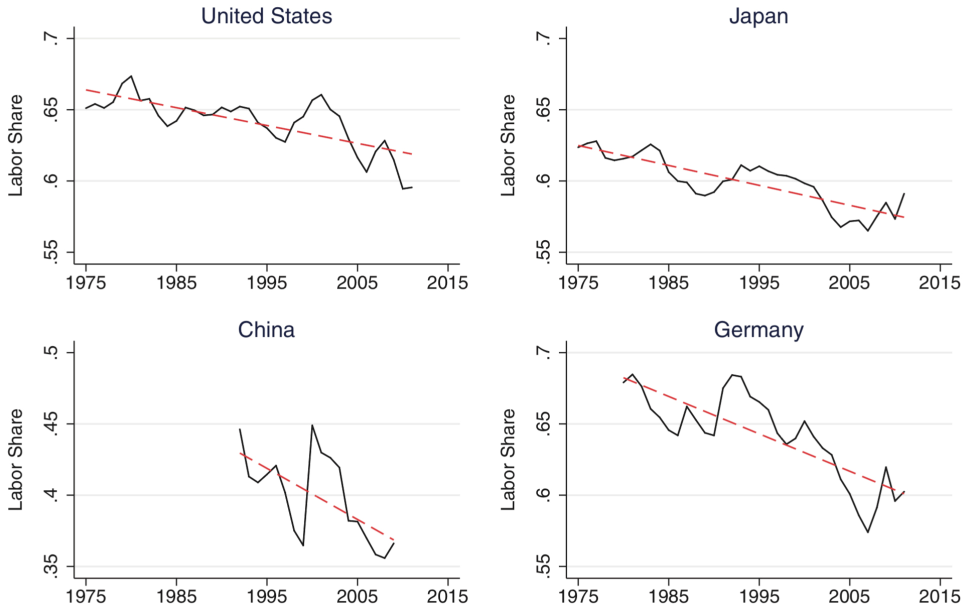

Karabarbounis and Neiman (2014). Also Harrison (2002) and Rodríguez and Jayadev (2010),

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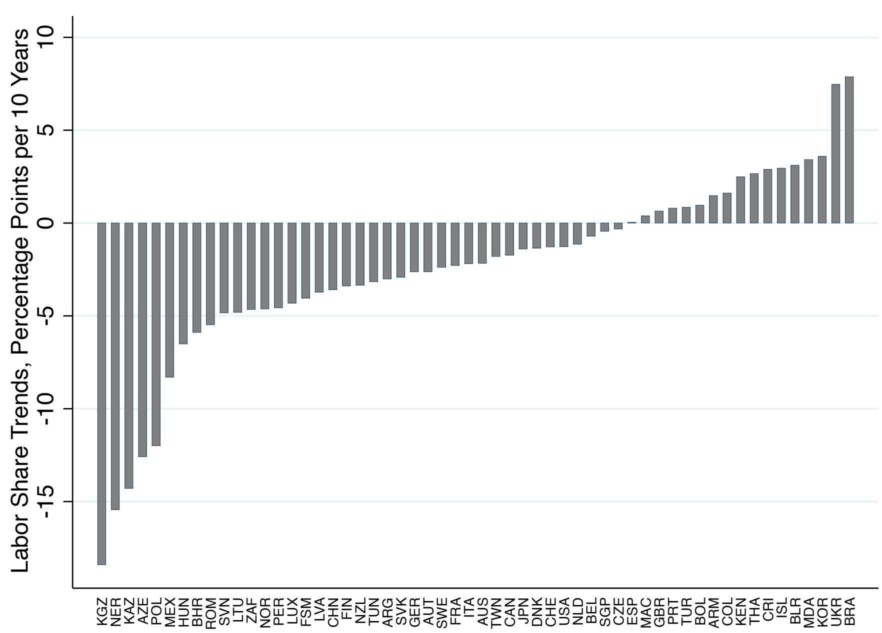

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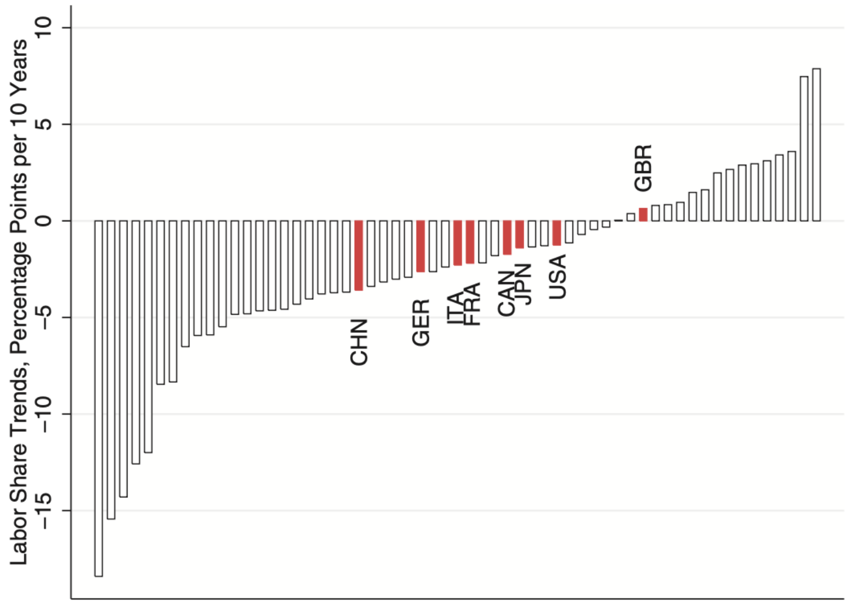

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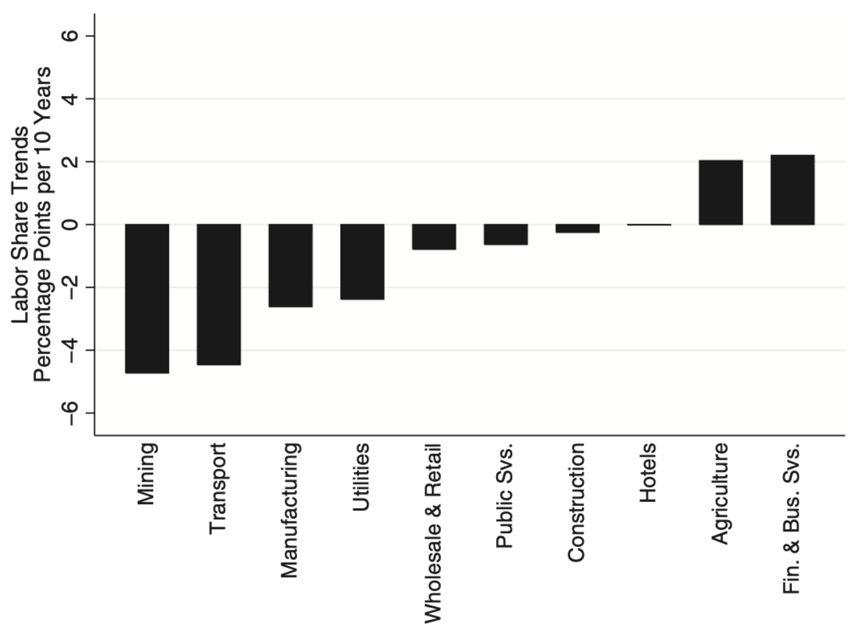


Karabarbounis and Neiman (2014).

Explanations

- **China Shock** Autor, Dorn and Hansen (2016)
  - globalization + cheap labor
  - but happening everywhere (e.g., jobless growth in India)
- **Concentration** Autor et al (2017), Azar and Vives (2019)
  - increasing product differentiation, gig economy, decaying unions
  - explanation, or outcome of declining labor power?
- **Technical progress** Acemoglu (1998, 2002), Acemoglu and Restrepo (2019)
  - robotics (hardware), machine learning (software)
  - But why is technical progress necessarily slanted to *displace* labor?
- **Covid-19**

Explanations

- **Capital-Labor Substitution**
  - Employment elasticities by sector, various regions. Kapsos (2005).

Region	Agriculture	Industry	Services
World	0.24	0.21	0.61
W. Europe	-1.08	-0.50	0.74
N. America	-0.02	0.26	0.60
Central/Eastern Europe	-0.51	0.11	0.51
East Asia (excl. Japan)	0.10	0.07	0.47
Japan	-2.04	-0.83	0.76
Australia/NZ	0.18	0.26	0.61
South-East Asia	0.01	0.82	1.08
South Asia	0.38	0.41	0.46
Latin America	-0.16	0.63	1.09
Sub-Saharan Africa	0.69	0.88	0.89

Explanations

- **Capital-Labor Substitution**
  - GDP and employment growth, some developing countries. An et al. (2017).

	Yearly, 1991–2000		Yearly, 2001–2015	
Country	GDP	EMP	GDP	EMP
Egypt	4.27	1.47	4.33	2.31
India	**5.73**	**0.60**	**7.09**	**0.61**
Indonesia	4.84	1.96	5.41	1.73
Kenya	2.09	2.20	4.38	2.00
Morocco	4.78	5.11	4.46	1.04
Nicaragua	3.17	5.61	3.66	3.19
Pakistan	4.48	1.99	4.29	2.84
Philippines	2.75	2.51	5.11	2.46
Tanzania	4.15	2.55	6.41	3.34
Vietnam	7.40	2.20	6.54	2.33

Explanations

- **Capital-Labor Substitution**
  - Intuitively compelling:
  - As growth occurs per-capita, capital becomes plentiful relative to labor
  - So it makes sense that the relative prices of capital goods fall.
- **But** ...
  - Net effect on labor share depends on the **elasticity of substitution**.
  - E.g., dividing line: Cobb-Douglas production function.
- This is what I want to try and explore further.

Our Theory: Accumulation and Automation

- **Two pillars:**

I. Human-physical asymmetry

II. Machine capital and robot capital

I. The Human-Physical Asymmetry

Mankiw-Romer-Weil 1992:

$$\dot{k}(t) = s_k y(t) + (n + \delta)k(t)$$

$$\dot{h}(t) = s_h y(t) + (n + \delta)h(t)$$

What does the second equation mean?

I. The Human-Physical Asymmetry

- Physical capital can be indefinitely replicated:
  - And so can individual claims to them.
- But human capital *cannot* be replicated in the same way.
  - always in *one* physical self **[inalienable]**.
  - To some extent, scalable within occupation or sector
  - But more fundamentally, scales across sectors.

II. Machines and Robots

- **Many sectors** indexed by j:

$$y_j = f_j(k_j, \tau_j), \text{ [sector-specific, CRS]}$$

  - where k = machines and τ = tasks.
- **Tasks produced by humans and/or robots**: $\tau_i = \tau_i(h_i, r_i)$.
  - An intermediate "production function," also CRS.
  - More generally there could be many tasks per sector.
- **So capital comes in two flavors**:
  - k: machines, complementary to labor.
  - r: robots, substitutes for labor.

II. Machines and Robots

- **The Feasibility of Automation**
- Assume $\tau_j(0, r) > 0$.
- Which does not mean that automation is optimal
- Or that it will ever fully happen; e,g.:
- $\tau_j(h, r) = \nu_j r + \mu_j h + r^{\alpha_j} h^{1-\alpha_j}$ for for $\nu_j > 0$, $\mu_j > 0$, and $\alpha_j \in (0, 1)$.
- But certainly a threat if the price is right:

"nothing humans do as a job is uniquely safe anymore. From hamburgers to healthcare, machines can be created to successfully perform such tasks with no need or less need for humans, and at lower costs than humans..." Scott Santens, *The Boston Globe*, 2016

Three Special Sectors

- **Machine capital:** $y_k = f_k(k_k, \tau_k)$, with $\tau_k = \tau_k(h_k, r_k)$.
- **Robot capital:** $y_r = f_r(k_r, \tau_r)$, with $\tau_r = \tau_r(h_r, r_r)$.
- **Education:** $y_e = f_e(k_e, \tau_e)$, with $\tau_e = \tau_e(h_e, r_e)$.
- All assumptions made earlier **apply to these sectors** as well.

A Bit More on Education

- Raw labor is given (or normalized), but **human capital grows endogenously**.
  - Initial allocation of humans across occupations.
  - Individuals can move from sector to sector (or task to task).
  - Educational cost $= e(i, j)p_e$, the endogenous price of education.

III. Preferences and Neutrality

- People have (possibly different) utility functions u and discount factors β.
  - Someone **starts** with financial wealth + wage income in sector j;
  - allocates current expenditure $z(t)$ consumption
  - gets educated [evolution of human capital];
  - invests [evolution of financial capital, which are claims on physical capital];
  - **Ends** with new wealth, maybe new sector. **Repeat**.
- **Asymptotic Homotheticity of Preferences:**
  - If $\mathbf{x}(\mathbf{p}, z)$ is demand for goods as function of current expenditure z, then

$$\lim_{z \to \infty} \frac{\mathbf{x}_m(\mathbf{p}, z)}{z} = \mathbf{d}_m(\mathbf{p}) \text{ for some function } \mathbf{d}_m(\mathbf{p}).$$

Price System

Competitive Pricing

- numeraire: rental rate on machine capital
- $\mathbf{p}$: prices, includes (p_r, p_k, p_e)
- $\mathbf{w}$: wages, includes (w_r, w_k, w_e)
- **Unit cost function for tasks** determines task price q_j by CRS:

$$q_j = q_j(w_j, p_r) = \min\left\{w_j h_j + p_r r_j | \tau_j(h_j, r_j) = 1\right\}.$$

- **Unit cost function for output** determines output price p_j by CRS:

$$p_j = c_j(1, q_j) = \min\left\{k_j + q_j \tau_j | f_j(k_j, \tau_j) = 1\right\}$$

Price System

Some Properties and Implications of Prices

- profit-maximization:
- $p_j \frac{\partial f_j(k_j,\tau_j)}{\partial \tau_j} = q_j$, $\quad p_j \frac{\partial f_j(k_j,\tau_j)}{\partial k_j} = 1$, etc.
- automation index for each sector j and relative price $\zeta_j \equiv w_j/p_r$:

$$a_j(\zeta_j) \equiv \min_{(r_j,h_j)} \left\{ \frac{r_j}{h_j \zeta + r_j} \middle| (r_j, h_j) \text{ minimizes unit cost under } \zeta_j \right\} \in [0,1].$$

- consumption-savings choices pinned down by:

$$\text{Interest rate } (t) = \frac{1 + (1-\delta) p_k(t+1)}{p_k(t)} - 1.$$

where $\delta \in (0,1)$ is the rate of depreciation.

Model Summary

Summary of Ingredients

- Asymmetry in accumulation
  - Physical capital can scale within and across sectors
  - Human capital expands across tasks/sectors **Pillar I**
- The two faces of capital
  - machines and robots **Pillar II**
- Otherwise pretty standard:
  - Homothetic preferences
  - Competitive price system;
  - Condition for growth (patience relative to technology).

The Critical Role Played by Robot Production

- **Robot production function** like any other:

$$y = f_r(k, \tau), \text{ where } \tau = \tau_r(h, r).$$

  - **Robot price** comes from unit cost function:

$$p_r = c_r(1, q_r).$$

  - **Task price** bounded by the feasibility of robot automation:

$$q_r = q_r(p_r, w_r) \leq \nu_r^{-1} p_r, \text{ where } \nu_r \equiv \tau_r(0, r)/r.$$

  - **Combining:**

$$p_r \leq c_r(1, \nu_r^{-1} p_r).$$

The Critical Role Played by Robot Production

$$p_r \leq c_r(1, \nu_r^{-1} p_r).$$

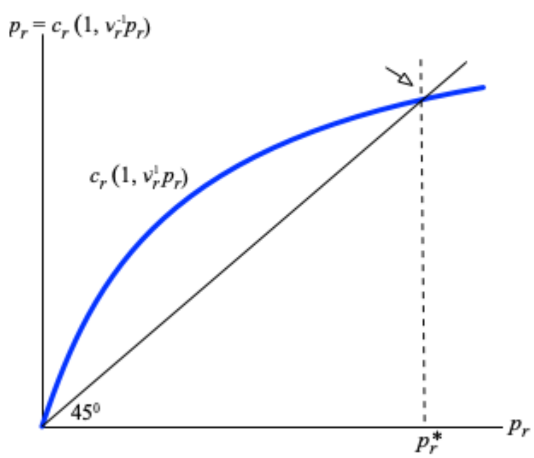
- **Big question:** given this inequality, how high can robot prices go?

  (relative to the normalized cost of machine rentals, set to 1)

  - Depends on whether $c_r(1, \nu_r^{-1} p_r)$ goes below 45° line as $p^r \uparrow$.
  - I.e., whether $c_r(1, \nu_r^{-1} p_r) < p_r$ for all large p_r.

The Critical Role Played by Robot Production

- $c_r(1, \nu_r^{-1} p_r) < p_r$ for all large p_r.



  - Equivalent to $\nu_r > \lim_{\rho \to 0} c_r(\rho, 1)$.
- **If this condition holds, then p_r must be bounded**.

The Critical Role Played by Robot Production

- **If $\nu_r > \lim_{\rho \to 0} c_r(\rho, 1)$, then p_r must be bounded.**
- Condition automatically holds for Cobb-Douglas production
  - Or for all CES production with elasticity of substitution no less than 1.
- Could fail if elasticity of substitution is below 1.
  - **Example**: $y_r = \left[\frac{1}{2} k_r^{-1} + \frac{1}{2} \tau_r^{-1}\right]^{-1}$
  - Condition holds when $\nu_r > 1/2$, fails when $\nu_r \leq 1/2$.
- Connection to self-replication in the robot sector (von Neumann).

The Critical Role Played by Robot Production

- **This boundedness of robot prices is key.**
  - It bounds machine capital prices $p_k(t)$, and therefore the average interest rate

$$\text{Interest rate } (t) = \frac{1 + (1 - \delta) p_k(t+1)}{p_k(t)} - 1.$$

- So under sufficient patience, the economy must grow.
  - Human wages rise, robot prices bounded
  - $\Rightarrow$ **automation index** $\to 1$ **in every growing sector.**

Automation and the Declining Labor Share

Theorem 1

- *Assume* (a) *high patience among some subset of population,* (b) *asymptotically homothetic preferences, and* (c) *self replication. Then:*

(i) *every sector, except possibly the machine capital and education sectors must become automated after some finite date;*

(ii) *each such sector is asymptotically fully automated in the long run;*

(iii) *the share of human labor in national income must converge to zero.*

A relative, not absolute crisis: If education costs are bounded and there is a sequence of sectors such that $\nu_i \to 0$, then every human wage goes to infinity.

Link to Piketty

Escape Hatches

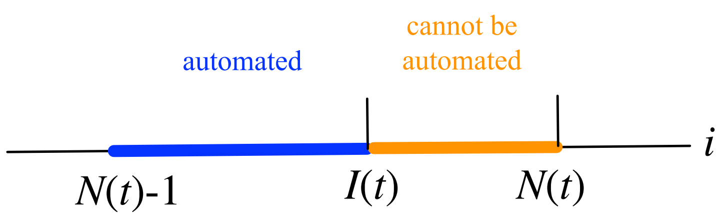
Four escape routes

- No growth:
  - With a positive measure of highly patient agents, this cannot happen.
- No self-replication:
  - This is an empirical question. It could happen.
- No homotheticity:
  - Again, an empirical question.
  - But homotheticity will need to fail *in a particular way*.
- Technical progress.

Directed Technical Progress

Directed technical progress to the rescue?

- That depends on what you choose to assume.
- Extensive Margin:
- Acemoglu and Restrepo (2018): new goods are un-automatable



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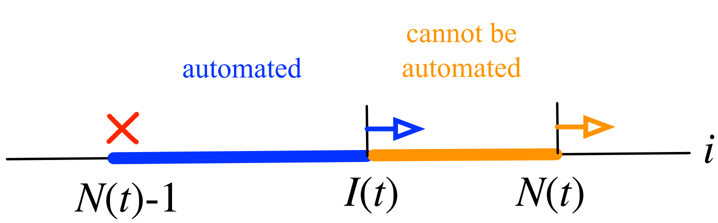

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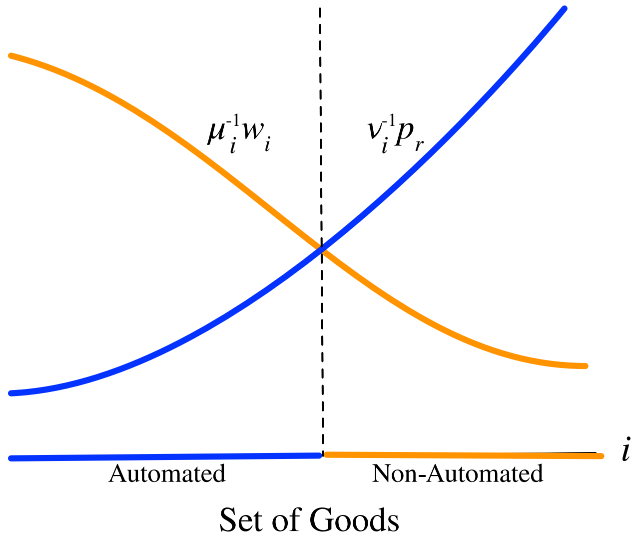

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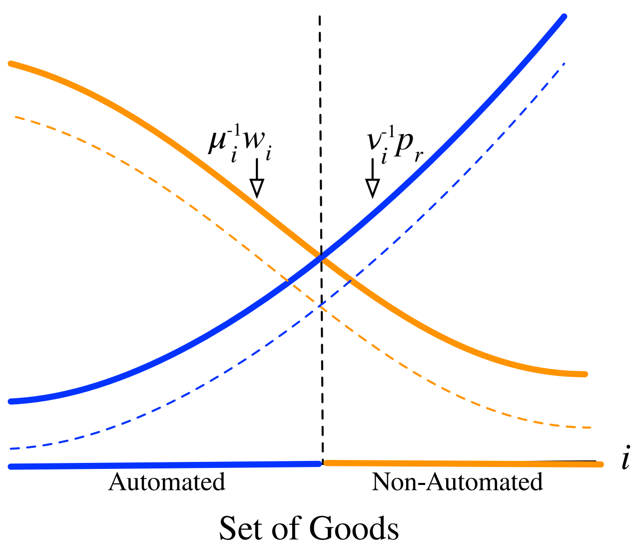


Directed Technical Progress

Production Function:

$$y_j = f_j(\theta_{jt}k_{jt}, \mu_{jt}h_{jt} + \nu_{jt}r_{jt})$$

- Productivities $\theta_{jt}, \mu_{jt}, \nu_{jt}$ all affected by R&D

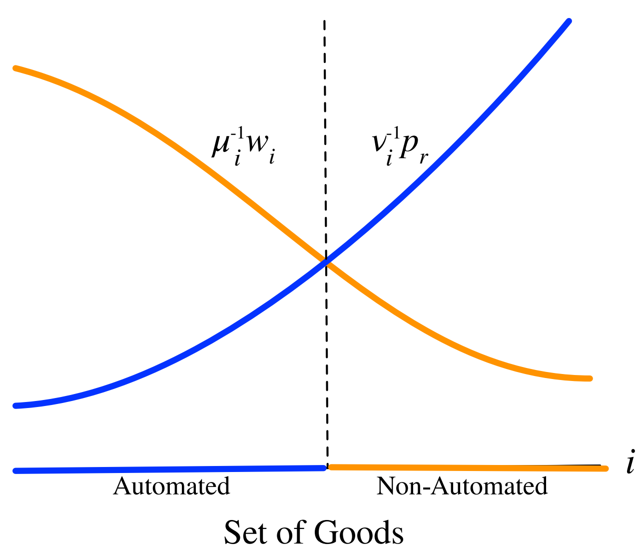
R&D:

- Inventor can advance productivity at rate ρ for any chosen factor-sector pair:
- Cost $\kappa(\rho)$ increasing, convex, prohibitive at $\bar{\rho}$, same for every factor and sector.
- Gets temporary patent protection, which she licenses to an active firm.
- After one period the advance goes public.
- Spillover fraction $\gamma > 0$ (public) for this factor in other sectors.

Directed Technical Progress

Theorem 2 (The Extended Dismal Scenario)

- *Make the same assumptions as in Theorem 1.*
- *Then in any equilibrium with capital growth, the income share of human labor must converge to zero as $t \to \infty$.*



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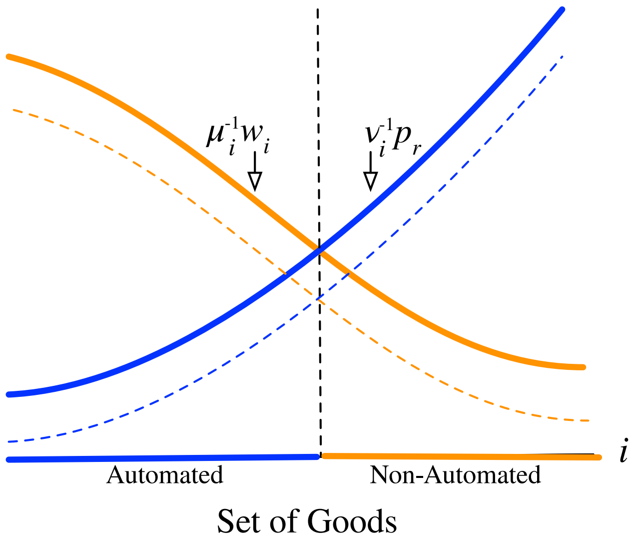

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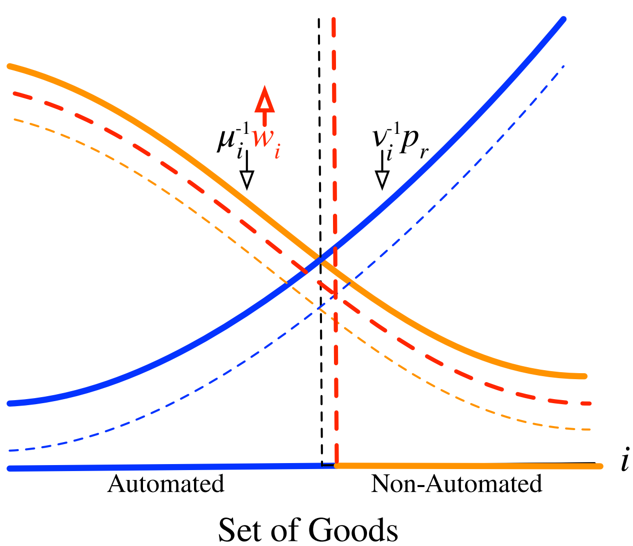

Summary

The Falling Labor Share:

- A natural consequence of any theory that rests on **two pillars**:
  - An asymmetry in physical and human capital accumulation
  - A recognition that physical capital can be machine-like or robot-like.
- **Other important features:**
  - Preference neutrality with respect to human-friendly or robot-friendly goods.
  - Enough patience for ongoing growth and capital accumulation.
  - Self-replication: production of automata by means of automata.
- **Under these conditions, labor income share $\rightarrow 0$:**
  - full automation in the long run ...
  - ...despite wages rising over time (slow automation).

Summary

An age-old anxiety: that "capital" will inherit the earth.

- But the underlying worry is about the personal distribution of income.
  - *that* will depend on how much people save, and in what *form* they save.
- Financial education is fundamentally important.
  - I'm pessimistic about the prospects of intelligent, informed savings in equity
  - but probably this is the only way to avoid a long-run crisis

Social Alternatives:

- universal basic income (e.g. *Ideas for India* special issue, *Economic Survey*)
- social stock portfolios (e.g., Ghosh and Ray 2020 on the India Fund)
- See **Supplement to Slides 3**.