Artificial Intelligence, Automation, and Work

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The Economics of Artificial Intelligence, June 2019
NBER Conference Volume, Chapter 8

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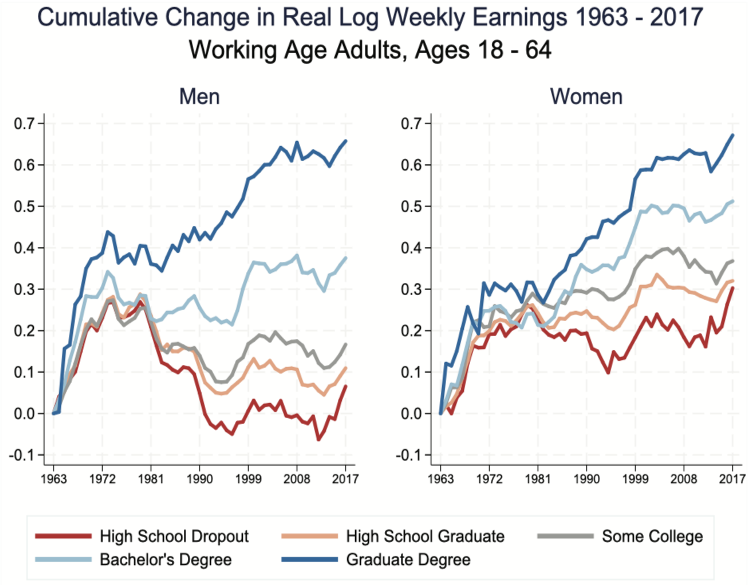
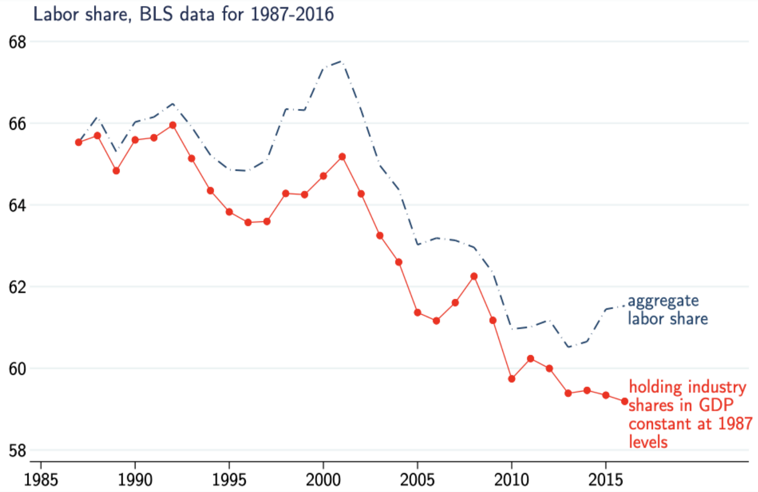
8.3. A Model of Automation, Tasks, and the Demand for Labor


Cumulative Change in Real Log Weekly Earnings 1963 - 2017
Working Age Adults, Ages 18 - 64
Men
Women
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1963
1972
1981
1990
1999
2008
2017
High School Dropout
High School Graduate
Some College
Bachelor's Degree
Graduate Degree



Labor share, BLS data for 1987-2016
68
66
64
62
60
58
1985
1990
1995
2000
2005
2010
2015
aggregate labor share
holding industry shares in GDP constant at 1987 levels

Motivation (Acemoglu & Restrepo [18])

- **2-factor CRS production functions assuming factor-augmenting technological change** pose important problems and puzzles.
- **Capital-augmenting** technological change cannot explain declining wages for some workers or the recent fall in the labor share for realistic parameter values.
- **Labor-augmenting** technological change cannot explain declining wages for realistic parameter values.
- It could explain the recent fall in the labor share for realistic parameter values, but it is not very convincing conceptually.

8.3 A model of automation, tasks, and the demand for labor

Production technology

- Static environment with a unique final good, Y.
- Y is produced with a continuum of tasks on the unit interval $[N-1, N]$ with N an exogenous parameter.
- Cobb-Douglas technology mapping tasks into the final good:

$$Y = \exp\left[\int_{N-1}^{N} \ln y(z)dz\right] \tag{1}$$

  where $y(z)$ is the service or production of task z.
- The final good is the numeraire, $P \equiv 1$.

The frontier of automation possibilities

Assumptions

- Tasks $z \in [N-1, N]$ are ranked such that they become increasingly more difficult for machines to do.
- Assume an exogenous threshold I which is the frontier of automation possibilities.
- All tasks $z \leq I$ can (and will) be automated, and all tasks $z > I$ can only be done by labor.
- An increase in I willl capture automation.

Supply of labor and capital to tasks

- Task z can be produced by labor, $l(z)$ or by capital, $k(z)$, according to equation (2) given by:

$$y(z) = \begin{cases} A^L \gamma^L(z) l(z) + A^K \gamma^K(z) k(z) \text{ if } z \in [N-1, I] \\ A^L \gamma^L(z) l(z) \text{ if } z \in (I, N] \end{cases}$$

  where:

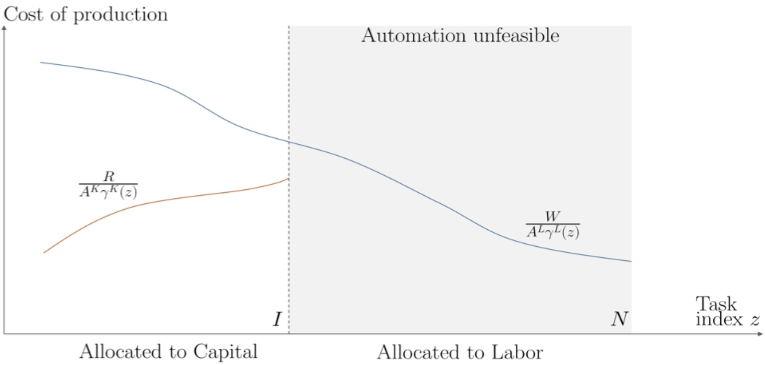
  - A^L, A^K are factor-augmenting technologies
  - $\gamma^L(z), \gamma^K(z)$ are task productivity schedules
  - $l(z), k(z)$ are the number of each factor allocated to task z

Comparative advantage in task production

Assumption

$\gamma^L(z)/\gamma^K(z)$ is strictly increasing in z.

- This is an assumption about the *relative* productivity of labor and capital in doing different tasks.
- This assumption drives their allocation across tasks based on comparative advantage (as in Roy [51]).
- All tasks $z \in [N-1, I]$ will be done by capital and all tasks $z \in (I, N]$ will be done by labor.



Allocation of tasks to factors

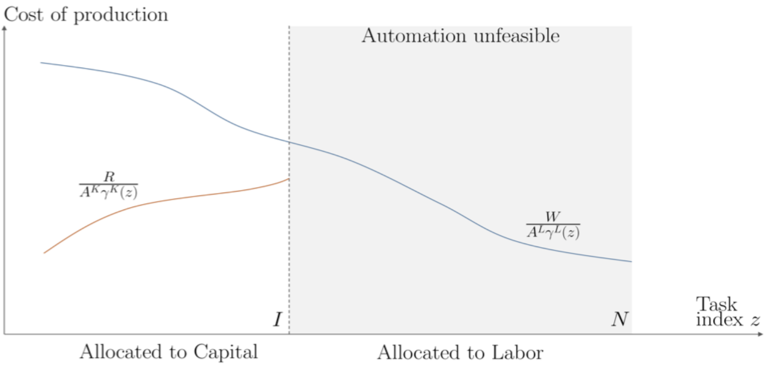
Clearing factor markets

- Labor and capital are supplied inelastically by L and K respectively.
- Labor markets clearing requires:

$$\int_{N-1}^{N} l(z)dz = L \text{ and } \int_{N-1}^{N} k(z)dz = K$$

- In this environment, we can look at:
    - Types of technologies and equilibrium (sections 8.3.2-8.3.3)
    - Technology and labor demand (section 8.4)
    - Flies in the ointment (section 8.5)

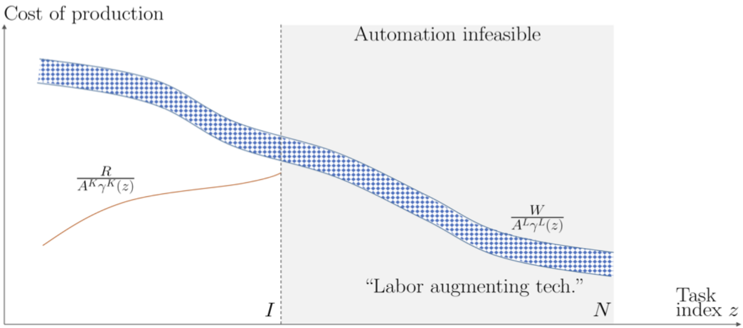
8.3 A model of automation, tasks, and the demand for labor



Allocation of tasks to factors

Types of technological change

1. **Labor-augmenting technological change**:
   $A^L \uparrow$ or $\gamma^L(z) \uparrow$ for all z
2. **Automation (at the extensive margin)**:
   Automation possibility frontier $I \uparrow$
3. **Deepening of automation (at the intensive margin)**:
   $A^K \uparrow$ or $\gamma^K(z) \uparrow$ for all $z < I$
4. **Creation of new labor-intensive tasks**:
   $N \uparrow$ which increases the bounds of the unit interval of tasks ranked by labor's comparative advantage



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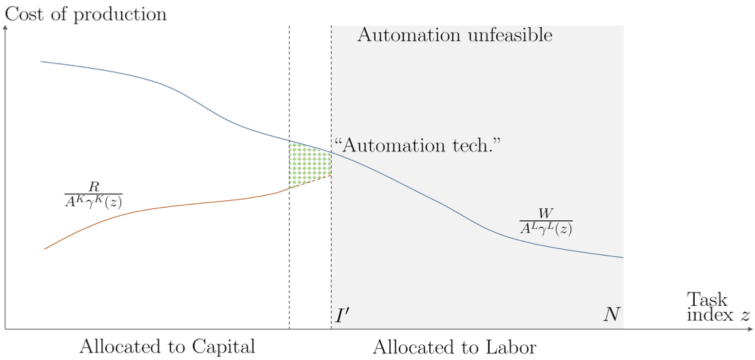
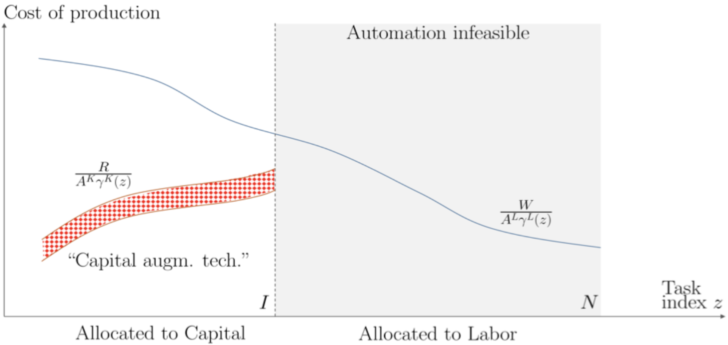
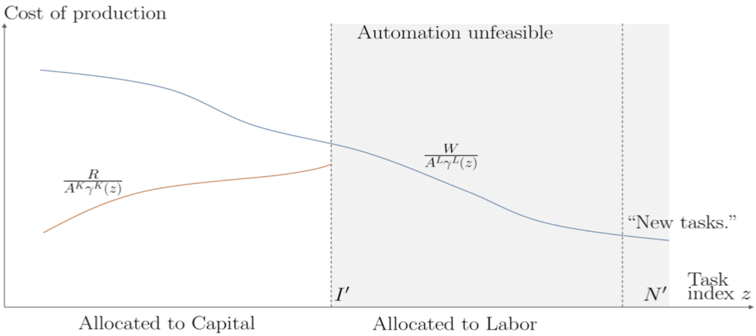


2. **Automation (at the extensive margin)**:

Automation possibility frontier $I \uparrow$



3. **Deepening of automation (at the intensive margin)**:
$A^K \uparrow$ or $\gamma^K(z) \uparrow$ for all $z < I$



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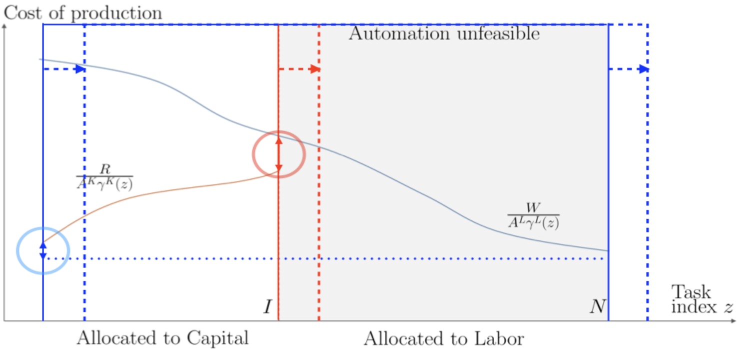
8.3 A model of automation, tasks, and the demand for labor



Efficiencies at marginal tasks: equilibrium assumptions

Efficiencies at marginal tasks: equilibrium assumptions

- Denote the equilibrium wage rate by W and rental rate by R.
- Further assume that in any equilibrium:

$$\frac{A^L \gamma^L(I)}{A^K \gamma^K(I)} < \frac{W}{R} < \frac{A^L \gamma^L(N)}{A^K \gamma^K(N-1)} \tag{A1}$$

- First inequality implies that all tasks $z \in [N-1, I]$ will be produced by capital and that an increase in I increases Y.
- Second inequality implies that an increase in N increases Y.
- We return to these equilibrium assumptions below.

Task demands

- Cobb-Douglas mapping a unit interval of tasks:

$$Y = \exp\left[\int_{N-1}^{N} \ln y(z)dz\right] \text{ implies that } \forall z : p(z)y(z) = Y$$

- Demand for task z is therefore given by:

$$y(z) = Y/p(z)$$

with the price of task z, $p(z)$, given by:

$$p(z) = \begin{cases} \frac{R}{A^K \gamma^K(z)} \text{ if } z \in [N-1, I] \\ \frac{W}{A^L \gamma^L(z)} \text{ if } z \in (I, N] \end{cases}$$

Factor demands in tasks

- Using that $y(z) = A^K \gamma^K(z) k(z)$ for $z \in [N-1, I]$:

$$k(z) = \begin{cases} \frac{Y}{R} \text{ if } z \in [N-1, I] \\ 0 \text{ if } z \in (I, N] \end{cases}$$

  which gives demand for capital in each task z.

- Using that $y(z) = A^L \gamma^L(z) l(z)$ for $z \in (I, N]$:

$$l(z) = \begin{cases} 0 \text{ if } z \in [N-1, I] \\ \frac{Y}{W} \text{ if } z \in (I, N] \end{cases}$$

  which gives labor demand in each task z.

Aggregate factor demands

- The market clearing condition for capital is:

$$K = \int_{N-1}^{N} k(z)dz = \frac{Y}{R}\int_{N-1}^{I} dz = \frac{Y}{R}[I - N + 1]$$

- The market clearing condition for labor is:

$$L = \int_{N-1}^{N} l(z)dz = \frac{Y}{W}\int_{I}^{N} dz = \frac{Y}{W}[N - I]$$

- Solving and re-arranging terms gives:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I]$$

Equilibrium rental rate, wage and factor shares

- The equilibrium rental rate and wage are given by:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I] \qquad (5)$$

- Factor shares in equilibrium are given by:

$$s_K = \frac{RK}{Y} = I - N + 1 \text{ and } s_L = \frac{WL}{Y} = N - I \qquad (6)$$

- **Sneak preview**: Automation and new tasks (i.e. an increase in I and N) affect the labor share (whereas factor-augmenting technological change does not affect the labor share).

Aggregate output in equilibrium

- Profit maximization and the final good as the numeraire imply:

$$P = MC = \exp\left[\int_{N-1}^{N} \ln(p(z))dz\right] \equiv 1$$

- Using expressions for $p(z)$ gives:

$$\ln P = \int_{N-1}^{I} [\ln(R) - \ln(A^K \gamma^K(z))]dz + \int_{I}^{N} [\ln(W) - \ln(A^L \gamma^L(z))]dz = 0$$

Aggregate output in equilibrium

- Using expressions for R and W in equation (5):

$$\begin{aligned}\ln P = &\int_{N-1}^{I} [\ln(Y) - \ln(K/[I-N+1]) - \ln(A^K \gamma^K(z))] dz \\ &+ \int_{I}^{N} [\ln(Y) - \ln(L/[N-I]) - \ln(A^L \gamma^L(z))] dz = 0\end{aligned}$$

- Re-arranging terms gives:

$$\begin{aligned}\ln Y = &\int_{N-1}^{I} \ln(\gamma^K(z)) dz + \int_{I}^{N} \ln(\gamma^L(z)) dz \\ &+ [I-N+1] \ln(\frac{A^K K}{I-N+1}) + [N-I] \ln(\frac{A^L L}{N-I})\end{aligned}$$

A microfounded aggregate production function

$$Y = \Pi(I,N)\left[\frac{A^K K}{1-\Gamma(I,N)}\right]^{1-\Gamma(I,N)}\left[\frac{A^L L}{\Gamma(I,N)}\right]^{\Gamma(I,N)} \tag{3}$$

with **task content of production** given by:

$$\Pi(I,N) \equiv \exp\left[\int_{N-1}^{I} \ln(\gamma^K(z))dz + \int_{I}^{N} \ln(\gamma^L(z))dz\right]$$

$$\Gamma(I,N) \equiv N - I \text{ and } 1-\Gamma(I,N) = I - N + 1 \tag{4}$$

with **factor-augmenting** technological change given by:

$A^K \uparrow$ if capital-augmenting and $A^L \uparrow$ if labor-augmenting

A microfounded aggregate production function

- The aggregate production function could be re-written as:

$$Y = \Pi(I,N)\left[\frac{A^K K}{1-\Gamma(I,N)}\right]^{1-\Gamma(I,N)}\left[\frac{A^L L}{\Gamma(I,N)}\right]^{\Gamma(I,N)}$$

- This can be summarized by:

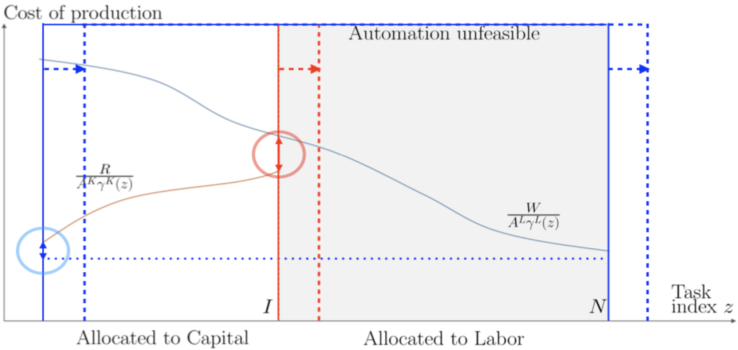
$$Y = \Pi(I,N) F(A^K K, A^L L; \Gamma(I,N))$$

where **technological change** works through:

1. **Changing task content** through a TFP term $\Pi(I,N)$ and the distribution parameter $\Gamma(I,N) \in (0,1)$
2. **Factor-augmenting** through $A^K \uparrow$ or $A^L \uparrow$

A microfounded aggregate production function

- We have derived an aggregate production function where differential technological change works through different channels.
- In particular, technological progress changes the distribution parameter and the Hicks-neutral TFP term.
- Task models provide microfoundations for changes in the distribution parameter and TFP due to technical progress.
- It assumes that automation of labor tasks and the creation of new labor-intensive tasks results in a reallocation of factors across tasks and overall productivity effects.



Efficiencies at marginal tasks: equilibrium assumptions

Equilibrium assumptions revisited

- We assumed that:

$$\frac{A^L \gamma^L(I)}{A^K \gamma^K(I)} < \frac{W}{R} < \frac{A^L \gamma^L(N)}{A^K \gamma^K(N-1)} \qquad \text{(A1)}$$

- This is equivalent to assuming **intermediate values of** K/L:

$$\frac{K}{L} \in (\underline{\kappa}, \overline{\kappa}) \qquad \text{(A2)}$$

with:

$$\underline{\kappa} \equiv \frac{I-N+1}{N-I} \frac{\gamma^L(I)}{\gamma^K(I)} \text{ and } \overline{\kappa} \equiv \frac{I-N+1}{N-I} \frac{\gamma^L(N)}{\gamma^K(N-1)}$$

Equilibrium assumptions revisited

- We had that:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I] \qquad (5)$$

- Combining both equations gives:

$$\frac{W}{R} = \frac{K}{L}\frac{N - I}{I - N + 1}$$

- Defining:

$$\underline{\kappa} \equiv \frac{I - N + 1}{N - I}\frac{\gamma^L(I)}{\gamma^K(I)} \text{ and } \overline{\kappa} \equiv \frac{I - N + 1}{N - I}\frac{\gamma^L(N)}{\gamma^K(N - 1)}$$

then assumption (A2) is equivalent to assumption (A1).

8.4 Technology and Labor Demand

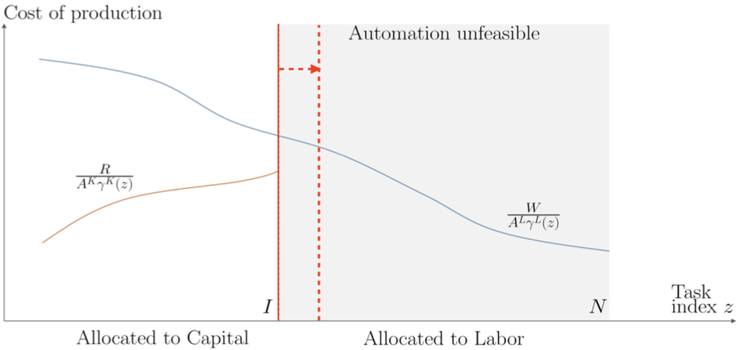
Technological change and labor demand

- Types of technological change were (excluding labor augmenting technological change):

  1. **Automation (at the extensive margin)**:
     Automation possibility frontier $I \uparrow$
  2. **Deepening of automation (at the intensive margin)**:
     $\uparrow$ in A^K or $\gamma^k(z)$ for all $z < I$
  3. **Creation of new labor-intensive tasks**:
     $N \uparrow$ which increases the bounds of the unit interval of tasks ranked by labor's comparative advantage

- Different types of technological change have different effects on labor demand and the labor share.

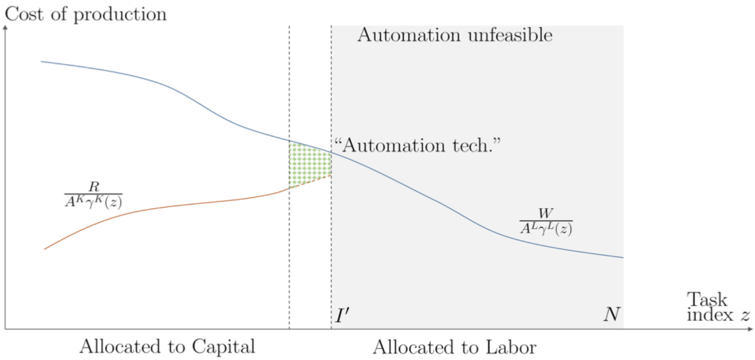
8.4 Technology and labor demand



1. **Automation (at the extensive margin)**:
$\rightarrow$ Displacement effect that $\downarrow$ labor demand

Automation in history

- Tasks and automation are at the center of technological change throughout the last 200 years.
- Machines and computers have substituted for human labor:
  - Horse-powered threshing machines replaced manual labor
  - Machine-tools replaced labor-intensive artisan techniques
  - Industrial robots automated assembly lines
  - Software automated tasks by office clerks



1. **Automation (at the extensive margin)**:
   → Productivity effect that ↑ labor demand

The ambiguous impact of automation on labor demand

- We had that:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I] \tag{5}$$

- Differentiating $\ln(W)$ wrt I gives:

$$\frac{d\ln(W)}{dI} = \underbrace{\frac{d\ln(N-I)}{dI}}_{\text{Displacement effect}<0} + \underbrace{\frac{d\ln(Y/L)}{dI}}_{\text{Productivity effect}>0} \tag{7}$$

- The impact on labor demand is ambiguous because a negative displacement effect is counteracted by a positive productivity effect.

The ambiguous impact of automation on labor demand

- Using equations (3)-(5), the productivity effect is given by:

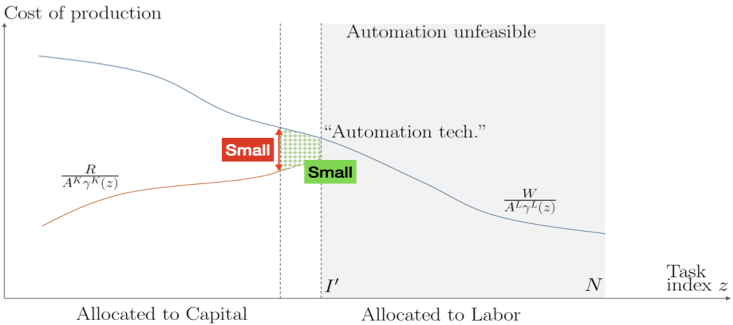
$$\frac{d\ln(Y/L)}{dI} = \ln\left(\frac{W}{A^L\gamma^L(I)}\right) - \ln\left(\frac{R}{A^K\gamma^K(I)}\right) > 0$$

- Substituting into equation (7) gives equation (8):

$$\frac{d\ln(W)}{dI} = \underbrace{-\frac{1}{N-I}}_{\text{Displacement effect}<0} + \underbrace{\ln\left(\frac{W}{A^L\gamma^L(I)}\right) - \ln\left(\frac{R}{A^K\gamma^K(I)}\right)}_{\text{Productivity effect}>0}$$

- Displacement effect will dominate the productivity effect if:

$$\frac{W}{A^L\gamma^L(I)} \approx \frac{R}{A^K\gamma^K(I)}$$



Automation when new technologies are "so-so":
Displacement effect dominates productivity effect such that labor demand ↓

Capital accumulation in the long-run

- We had that:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I] \tag{5}$$

- An increase in I (and Y) increases R in the short-run.
- This increase in R leads to an increase in K in the long-run (assuming that R is constant in the long-run).
- Through q-complementarity, capital accumulation results in an increase in labor demand in the long-run that further counteracts the negative displacement effect.

Automation reduces the labor share

- We had that:

$$s_L = \frac{WL}{Y} = N - I = 1 - s_K \tag{6}$$

- Differentiating s_L wrt I gives:

$$\frac{ds_L}{dI} = -1 < 0 \tag{9}$$

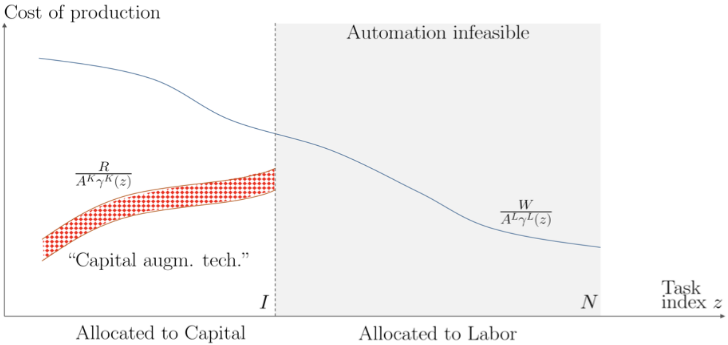
- Automation always increases productivity more than the wage:

$$\frac{d\ln(W)}{dI} - \underbrace{\frac{d\ln(Y/L)}{dI}}_{\text{Productivity effect}>0} = \underbrace{-\frac{1}{N-I}}_{\text{Displacement effect}<0} < 0 \tag{7}$$

Automation, labor demand and the labor share

- Automation has an ambiguous effect on labor demand because of:
  1. a negative displacement
  2. a positive productivity effect.
- Labor demand decreases when new technologies result in "so-so automation".
- Automation always reduces the labor share because it increases productivity more than the wage.

8.4 Technology and labor demand



2. **Deepening of automation (at the intensive margin)**:
   $\rightarrow$ Capital deepening that $\uparrow$ labor demand

Deepening of automation increases labor demand

- We had that:

$$Y = \Pi(I, N) \left[\frac{A^K K}{I - N + 1} \right]^{I-N+1} \left[\frac{A^L L}{N - I} \right]^{N-I} \qquad (3)$$

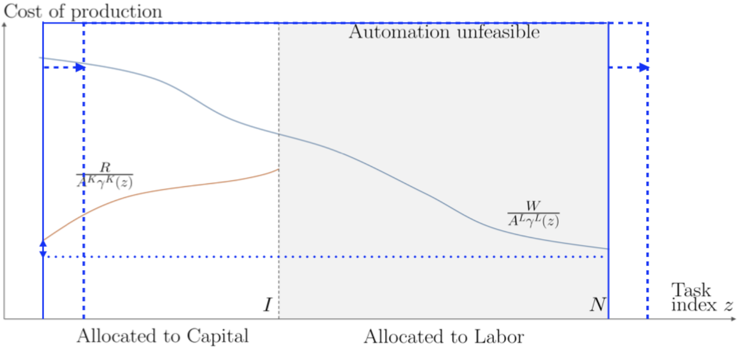
- Assuming $A^K \uparrow$, we get that labor demand increases:

$$d \ln(W) = d \ln(Y/L) = [I - N + 1] d \ln(A^K) > 0$$

  because of q-complementarity.

- There is no impact on the labor share because wages and productivity increase proportionately.

8.4 Technology and labor demand



3. **Creation of new labor-intensive tasks**:

$\rightarrow$ Reinstatement and productivity effect that $\uparrow$ labor demand

New labor-intensive tasks increase labor demand

- We had that:

$$R = \frac{Y}{K}[I - N + 1] \text{ and } W = \frac{Y}{L}[N - I] \tag{5}$$

- Differentiating $\ln(W)$ wrt N gives:

$$\frac{d\ln(W)}{dN} = \frac{1}{N-I} + \frac{d\ln(Y/L)}{dN}$$

- Differentiating $\ln(Y/L)$ wrt N gives equation (10):

$$\frac{d\ln(W)}{dN} = \underbrace{\frac{1}{N-I}}_{\text{Reinstatement effect}>0} + \underbrace{\ln\left(\frac{R}{A^K\gamma^K(N-1)} \Big/ \frac{W}{A^L\gamma^L(N)}\right)}_{\text{Productivity effect}>0}$$

New labor-intensive tasks increase the labor share

- We had that:

$$s_L = \frac{WL}{Y} = N - I = 1 - s_K \tag{6}$$

- Differentiating s_L wrt N gives:

$$\frac{ds_L}{dN} = 1 > 0$$

- New tasks always increase the wage more than productivity:

$$\frac{d\ln(W)}{dN} - \underbrace{\frac{d\ln(Y/L)}{dN}}_{\text{Productivity effect}>0} = \underbrace{\frac{1}{N-I}}_{\text{Reinstatement effect}>0} > 0$$

Automation, new tasks, and the labor share

- Because $s_L = N - I$ we have that:

$$ds_L = dN - dI$$

- Automation decreases the labor share (despite productivity effects) whereas the creation of new labor-intensive tasks increases the labor share.

- A constant labor share suggests that both forces balance each other out, a falling labor share suggests that automation is more important than the creation of new labor intensive tasks.
- This could also explain why the labor share was constant before 2000 (but not afterward).

Balanced growth and directed technological change

- A full model endogenizes capital accumulation and the direction of research toward automation, dI, and the creation of new tasks, dN.
- Acemoglu & Restrepo [18] show that there exists a stable balanced growth path in which $dI = dN$.
- In steady-state, real wages grow because automation and new task creation happen simultaneously but are labor-augmenting on net because labor becomes more productive in new tasks.
- What these new labor task exactly are remains "dark matter" (i.e. forceful but unknown).

8.4 Technology and labor demand

A false dichotomy

- The public debate is often centered around the false dichotomy between disastrous and totally benign effects of automation.
- A task-based framework is more nuanced.
- It underscores that automation could reduce wages, employment, and the labor share.
- There is a lot of theoretical and empirical research on the way that is digging deeper into these nuances.

8.5 Flies in the Ointment

Flies in the ointment

- In the baseline model, the reallocation of capital and labor across tasks due to dI and dN is frictionless.
- The baseline model underplays the importance of adjustment costs and inefficiencies.
- In this section, we focus on the impact of dI on dY assuming several inefficiencies.
- We could also look at the impact of dN assuming the same or other inefficiences.

Models of automation with inefficiencies

- We adjust the baseline model of automation by adding either of three inefficiencies:
    1. Technology-skill mismatch
    2. Biased taxes that subsidize capital relative to labor
    3. Labor market imperfections that result in wage rents
- Inefficiencies in these models result in the misallocation of factors in equilibrium. In particular, demand for capital relative to labor is too high (near I).
- These inefficiencies mitigate the positive impact of dI on dY and their rise could explain missing productivity growth.

8.5 Flies in the Ointment

8.5.1 Mismatch of technologies and skills

8.5.2 Biased taxes that subsidize capital relative to labor

8.5.3 Labor market imperfections with wage rents

A model with technology-skill mismatch

Assume that:

1. Low-skill workers supply L and high-skill workers supply H.
2. Low-skill workers can only perform tasks below a threshold $S \in (I, N)$ with lower S capturing higher technology-skill mismatch (high-skilled workers can still do all tasks).
3. Productivity of low-skill and high-skill workers is given by $A^L \gamma^L(z)$ (differential advantages are possible, but the more restrictive assumption here is 2).
4. Low-skill workers earn a wage W^L and high-skill workers earn a wage $W^H > W^L$ in equilibrium.

Technology-skill mismatch and wage inequality

- Following the same steps as in the baseline model gives:

$$R = \frac{Y}{K}[I - N + 1] \ ; \ W^H = \frac{Y}{H}[N - S] \ ; \ W^L = \frac{Y}{L}[S - I]$$

- Differentiating $\ln(W^H/W^L)$ wrt I gives:

$$\frac{d\ln(W^H/W^L)}{dI} = \frac{1}{S - I} > 0$$

- This increase is larger if S is lower, i.e. if technology-skill mismatch is higher, because displaced low-skilled workers will be squeezed into an even smaller set of tasks.

Technology-skill mismatch and productivity

- Following the same steps as in the baseline model:

$$\frac{d\ln(Y/L)}{dI} = \ln\left(\frac{W^L}{A^L\gamma^L(I)}\right) - \ln\left(\frac{R}{A^K\gamma^K(I)}\right) > 0$$

- We also have that:

$$\frac{W^L}{R} = \frac{S-I}{I-N+1}\frac{K}{L}$$

- A worse mismatch (lower S) and therefore lower W^L/R reduces the productivity gains from automation.

Policy implications

- Technology-skill mismatch (i.e. $S < N$) results in a misallocation because unskilled workers do too few tasks given their limited task mobility.
- If dI automates the task of workers with limited mobility, the productivity gains from automation are lower.
- Policies that increase S are education, training, and active labor market policies targeted to displaced workers.
- E.g. Productivity growth from automation in the early 20th-century was aided by the "high-school movement".

8.5 Flies in the Ointment

A model with taxes that subsidize capital relative to labor

- Assume that:
    1. Capital K is no longer fixed but produced as an intermediate good at fixed cost R, using the final good as an input.
    2. The use of capital K in final good production receives a marginal subsidy of $\tau > 0$ such that the rental rate is $[1 - \tau]R$.
    3. Subsidy τ can be a tax credit for investments or income taxes that subsidizes capital (relative to labor).
- There will be too much capital produced by the intermediate sector (which requires resources), and this will mitigate the impact of dI on $d(GDP \equiv Y - RK)$.

Capital subsidies, automation and productivity

- Define GDP as value-added output:

$$GDP \equiv Y - RK$$

with Y the value of final goods production and RK the cost of producing capital.

- The impact of automation on GDP is then given by:

$$\frac{dGDP}{dI} = \frac{dY}{dI}|_K + [1-\tau]R\frac{dK}{dI} - R\frac{dK}{dI}$$

- The first term gives the impact of dI on Y for given K as in the baseline model, and the last two terms account for the impact of dI on capital accumulation.

Capital subsidies, automation and productivity

- The change in value added GDP due to automation was:

$$\frac{dGDP}{dI} = \frac{dY}{dI}\Big|_K + [1-\tau]R\frac{dK}{dI} - R\frac{dK}{dI}$$

- The first term in the right-hand side is a productivity effect as in the baseline model:

$$\frac{dGDP}{dI} = \underbrace{\left[\ln\left(\frac{W}{A^L\gamma^L(I)}\right) - \ln\left(\frac{[1-\tau]R}{A^K\gamma^K(I)}\right)\right]Y}_{\text{Productivity effect } >0} \underbrace{-\tau R\frac{dK}{dI}}_{\text{Capital subsidy effect } <0}$$

where the last term is negative given that $dK/dI > 0$.

Policy implications

- Automation increases productivity, but taxes that subsidize capital relative to labor could lower this productivity gain.
- The reason is that tax codes that subsidize capital relative to labor result in capital accumulation that could be costly.
- Current tax codes heavily favor capital income and capital investments over payroll taxes.
- A more titled playing field leads to a slowdown in productivity growth.

8.5 Flies in the Ointment

A model with wage rents

- Assume that L_A workers in tasks (I, J) with $J \in (I, N)$ earn a marginal wage rent $\omega > 0$, such that their wage is $[1 + \omega]W$ compared to $L - L_A$ workers in tasks $[J, N]$ who earn W.
- Rents $\omega > 0$ could capture unionized jobs or sectors, efficiency wages, or result from other labor market frictions (but we have to be on the labor demand curve).
- Wage rents imply that L_A will be too low relative to $L - L_A$ from a social point of view.
- Automation of tasks done by L_A workers will worsen this misallocation.

Wage rents and the misallocation of labor

- Following similar steps as in the baseline model, the demand for L_A is given by:

$$L_A = \frac{Y}{[1+\omega]W}[J-I]$$

- Demand for $L - L_A$ is given by:

$$L - L_A = \frac{Y}{W}[N-J]$$

- Relative demand for L_A is given by:

$$\frac{L_A}{L - L_A} = \frac{1}{1+\omega}\frac{J-I}{N-J}$$

which is decreasing in ω and I.

Wage rents, automation and productivity

- The change in Y due to automation is given by:

$$\frac{dY}{dI} = \frac{dY}{dI}\Big|_{L_a} + [1+\omega]W\frac{dL_A}{dI} + W\frac{d[L-L_A]}{dI}$$

- The first term in the right-hand side is a productivity effect as in the baseline model:

$$\frac{dY}{dI} = \underbrace{\left[\ln\left(\frac{[1+\omega]W}{A^L\gamma^L(I)}\right) - \ln\left(\frac{R}{A^K\gamma^K(I)}\right)\right]Y}_{\text{Productivity effect } >0}$$

$$\underbrace{+\omega W\frac{dL_A}{dI}}_{\text{Excessive displacement of labor effect } <0}$$

where the last term is negative given that $dL_A/dI < 0$.

Policy implications

- Automation increases output, but wage rents in automated jobs lower this productivity gain.
- The reason is that wage rents result in too few workers in automatable jobs where labor productivity is higher and too many workers in other jobs where labor productivity is lower.
- Automation makes this misallocation worse by displacing workers from high productivity to low productivity jobs.
- Increasing wage rents in automatable jobs create a slowdown in productivity growth.

Automation, new tasks and missing productivity growth

A deep puzzle is missing productivity growth. Task-based frameworks give several possible explanations:

1. $\underline{dI, dN, d[A^K\gamma^K], d[A^L\gamma^L] \downarrow}$: Technological progress is $\downarrow$
2. $\underline{dI \uparrow \text{ and } dN \downarrow}$ and the productivity gains from dI are less than from dN (e.g. so-so automation).
3. $\underline{dN \uparrow \text{ and } dI \downarrow}$ and the productivity gains from dN are less than from dI (e.g. new "green jobs").
4. Technology-skill mismatch $\uparrow$
5. Subsidization of capital relative to labor $\uparrow$
6. Wage rents for workers in automatable jobs $\uparrow$

8.6 Conclusions

Conclusions

- Discussions about automation and the future of work lack a conceptual framework.
- A task-based framework provides such a conceptual framework.
- It is a rich environment that includes factor-augmenting technologies, automation at the extensive and intensive margin, and the creation of new labor-intensive tasks.
- It (better) explains why wages of some workers have declined, and why the labor share has been falling.
- It illustrates how several inefficiencies can be a drag on productivity growth.