Labor Demand Through The Ages:
Automation, News Tasks and Work

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Time of Plenty?

- According to some, we've never had it so good. The future is bright with brilliant, amazing technologies.

  "Artificial intelligence will reach human levels by around 2029. Follow that out further, say to 2045, we will have multiplied the intelligence, the human biological machine intelligence of our civilization a billion-fold."

  Ray Kurzweil

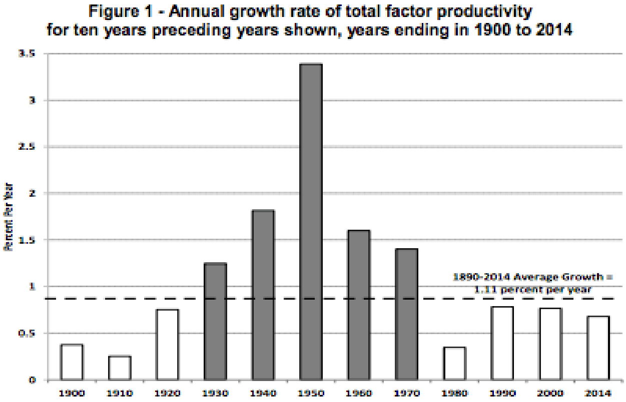
- But so far, it's not Ray Kurzweil, but economist Bob Solow who got it right with his statement in 1987:

  "You can see the computer age everywhere but in the productivity statistics."

  Bob Solow

- One place you don't see these brilliant technologies is in wages.

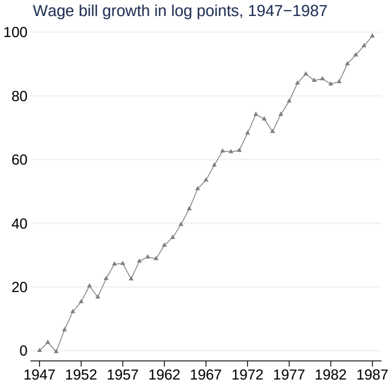
A Bleak Record

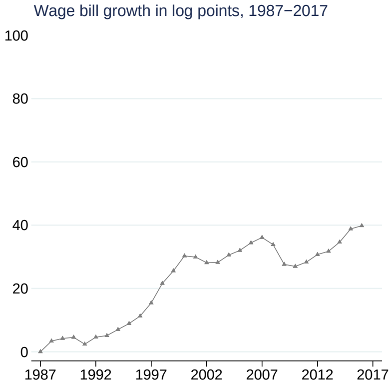


(Gordon, 2016)

- Difficult to explain these trends with mismeasurement of productivity.
- What is going on?

Even Worse in the Labor Market

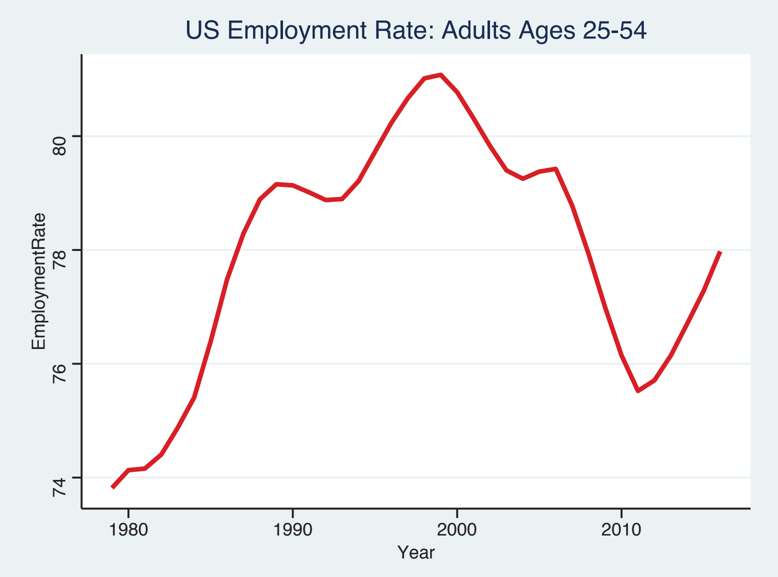




- The data points to anemic growth of labor demand from 1987 to 2017.
- Labor demand roughly stagnant since 2000.

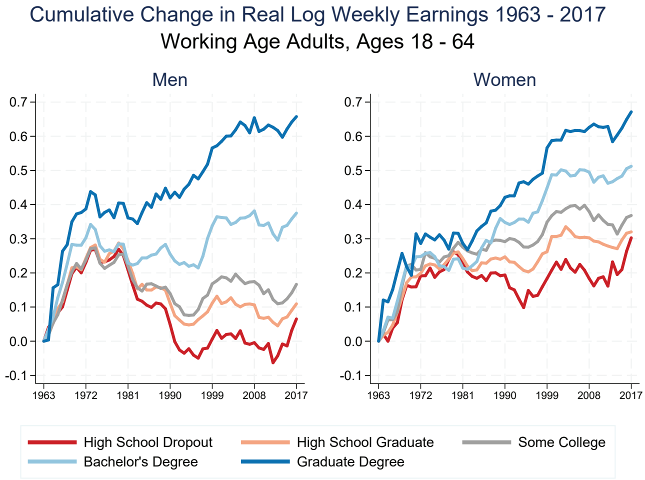
Employment and the Labor Share

- Indeed, not only is the labor share declining, but overall employment has too.



Wages

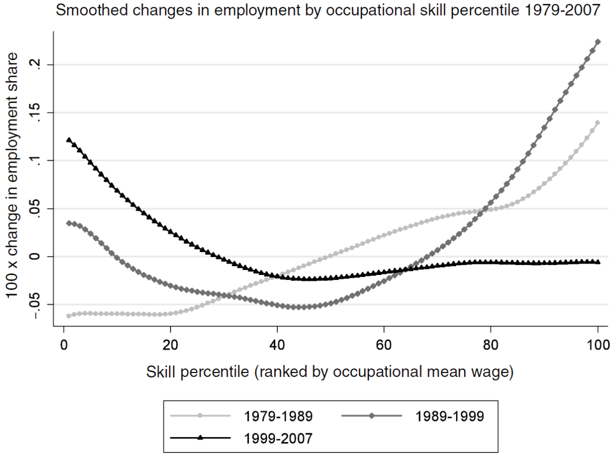
- Technology of the last several decades, as opposed to what we used to have, looks nothing like a tide lifting all boats.



(Autor, 2019)

Employment Trends: Displacement of Jobs

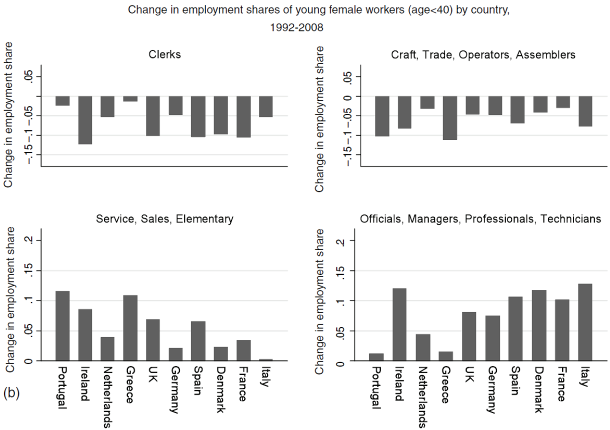
- This isn't because the demand for skills is growing.



(Acemoglu and Autor, 2011)

Displacement: Not Just a US Phenomenon

- Similar polarization of employment— but not of wages, indicating an important role for labor market institutions.



(Acemoglu and Autor, 2011)

Thinking in Terms of Tasks: Motivation

- Production requires a range of tasks or industrial processes.
- Automation in history: machines and computers used to substitute for human labor in an expanding range of tasks:
    1. In agriculture, horse-powered reapers, harvesters, and threshing machines replaced manual labor working with rudimentary tools.
    2. Machine tools, such as lathes and milling machines, replaced labor-intensive production techniques relying on skilled artisans.
    3. Industrial robotics automated remaining labor-intensive processes in some industries: welding, machining, assembly, and packaging.
    4. Software automated routine tasks performed by white-collar workers in clerical and sales jobs.
- But at the same time, new tasks in which labor has a comparative advantage have created employment opportunities.

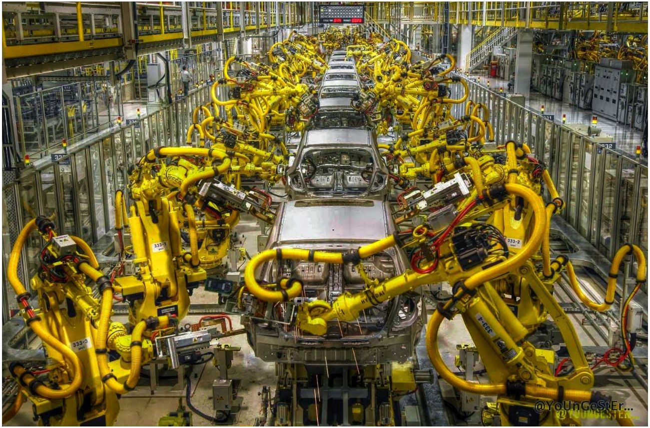
Thinking in Terms of Tasks: Motivation

- These transformative events are hard to map to our traditional aggregate production functions.
- Usual representation of technology

$$Y = F(A_L L, A_K K).$$

- Not clear how the examples we described map to $\{A_L, A_K\}$.
- $\{A_L, A_K\}$ capture capital and labor being more productive at the tasks they currently perform, but do not capture the fact that capital and labor now able to perform a different set of tasks.
- Technologies that changed the task content of production, such as automation and creation of new tasks, have very different effects than factor-augmenting technologies.
- We present such a framework building on Zeira (1998), Acemoglu and Autor (2011), and Acemoglu and Restrepo (2018).

Thinking in Terms of Tasks: Automation



- Examples of automated tasks: assembly, switchboard operation, mail sorting, packing, stock trading, dispensing cash, operating machines.

Thinking in Terms of Tasks: Just a Tiny Bit of Math

- Output produced according to

$$Y = \left(\int_{N-1}^{N} Y(z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}},$$

where $Y(z)$ denotes the output of task z for $z \in [N-1, N]$ and $\sigma \geq 0$ is the elasticity of substitution between tasks.

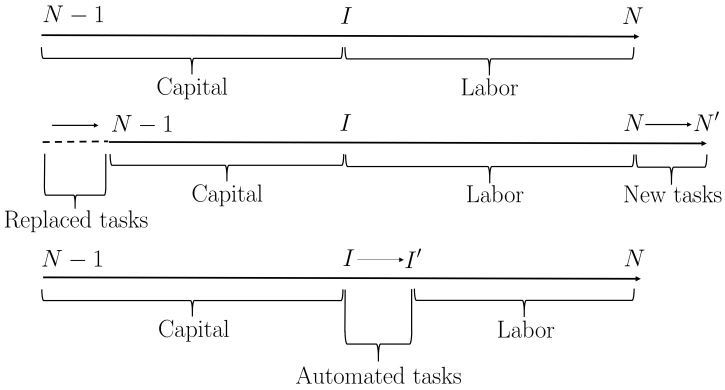
- Tasks can be produced using capital or labor:

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

- $I =$ automation; $N =$new tasks.
- $\gamma^L(z)/\gamma^K(z)$ is increasing in z, so that labor has a *comparative advantage* in higher-indexed tasks, and that $\gamma^L(z)$ increasing in z.
- Assume new tasks are used immediately and capital used up to task I.

Thinking in Terms of Tasks: Automation and New Tasks

- Capital, K, used on tasks $[N-1, I]$; labor, L, used on tasks $(I, N]$.



- Automation squeezes labor into a smaller set of tasks.
- The creation of new tasks in which labor has a comparative advantage expands the set of tasks for labor.

Thinking in Terms of Tasks: Framework

- Output given by

$$Y(L,K;\theta) = \left(\left(\int_{N-1}^{I} \gamma^K(z)^{\sigma-1} dz \right)^{\frac{1}{\sigma}} (A^K K)^{\frac{\sigma-1}{\sigma}} + \left(\int_{I}^{N} \gamma^L(z)^{\sigma-1} dz \right)^{\frac{1}{\sigma}} (A^L L)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

- The labor share is given by

$$s^L(W,R;\theta) = \frac{\Gamma(N,I)(W/A^L)^{1-\sigma}}{(1-\Gamma(N,I))(R/A^K)^{1-\sigma} + \Gamma(N,I)(W/A^L)^{1-\sigma}}$$

  where

$$\Gamma(N,I) = \frac{\int_I^N \gamma^L(z)^{\sigma-1} dz}{\int_{N-1}^{I} \gamma^K(z)^{\sigma-1} dz + \int_I^N \gamma^L(z)^{\sigma-1} dz}$$

  denotes the task content of production.

- Two forces shaping labor share: task content and substitution across tasks (governed by σ and effective factor prices W/A^L and R/A^K).

Thinking in Terms of Tasks: Automation

- We focus on an inclusive measure of labor demand, the wage bill, WL.
- Effect of automation on the labor demand:

$$\frac{\partial \ln WL^d(L,K;\theta)}{\partial I} = \frac{\partial \ln Y(L,K;\theta)}{\partial I} \qquad \text{(Productivity effect)}$$

$$+ \frac{1}{\sigma}\frac{1-s^L}{1-\Gamma(N,I)}\frac{\partial \ln \Gamma(N,I)}{\partial I} \qquad \text{(Displacement effect)}$$

- The productivity effect is given by

$$\frac{\partial \ln Y(L,K;\theta)}{\partial I} = \frac{1}{\sigma-1}\left[\left(\frac{R}{A^K\gamma^K(I)}\right)^{1-\sigma} - \left(\frac{W}{A^L\gamma^L(I)}\right)^{1-\sigma}\right] > 0.$$

- In practice, displacement effect can be large and productivity effect small, with bad outcomes for labor demand.
- Worst-case scenario for labor: "so-so technologies," large displacement effect and small productivity gains.

Thinking in Terms of Tasks: Automation

- Effect of automation on the labor demand:

$$\text{Effect of automation on labor demand } = \text{Productivity effect} + \text{Displacement}$$

- The displacement effect is always negative.
- Without the displacement effect, the labor share would remain constant. With the displacement effect, the labor share declines.
- If the displacement effect is large, labor demand declines even though we have technological progress.
- Worst-case scenario for labor: "so-so technologies," large displacement effect and small productivity gains.

Thinking in Terms of Tasks: New Tasks

- The effects of creation of new tasks in which labor has a competitive advantage—an expansion in N—can be determined similarly.

$$\frac{\partial \ln WL^d(L,K;\theta)}{\partial N} = \frac{\partial \ln Y(L,K;\theta)}{\partial N} \quad \text{(Productivity effect)}$$
$$+ \frac{1}{\sigma}\frac{1-s^L}{1-\Gamma(N,I)}\frac{\partial \ln \Gamma(N,I)}{\partial N} \quad \text{(Reinstatement effect)}$$

- The productivity effect is now given by

$$\frac{\partial \ln Y(L,K;\theta)}{\partial N} = \frac{1}{\sigma-1}\left[\left(\frac{W}{A^L\gamma^L(N)}\right)^{1-\sigma} - \left(\frac{R}{A^K\gamma^K(N-1)}\right)^{1-\sigma}\right] > 0.$$

Thinking in Terms of Tasks: New Tasks

- The effects of creation of new tasks in which labor has a competitive advantage—an expansion in N—can be determined similarly.

$$\text{Effect of new tasks on labor demand} = \text{Productivity effect} + \text{Reinstatement}$$

- The reinstatement effect is always positive.
- Without the reinstatement effect, the labor share in value added would remain constant.
- With the reinstatement effect, the labor share always increases.

Thinking in Terms of Tasks: Factor-Augmenting Techs

- For factor-augmenting technologies, we have

$$\begin{aligned}\frac{\partial WL^d(L,K;\theta)}{\partial \ln A^L} =& s^L && \text{(Productivity effect)}\\ &+ \frac{\sigma-1}{\sigma}(1-s^L) && \text{(Substitution across tasks)},\\ \frac{\partial WL^d(L,K;\theta)}{\partial \ln A^K} =& (1-s^L) && \text{(Productivity effect)}\\ &+ \frac{1-\sigma}{\sigma}(1-s^L) && \text{(Substitution across tasks)}.\end{aligned}$$

- No displacement or reinstatement; no reallocation of tasks to factors.
- For realistic values of σ, substitution across tasks is small and factor-augmenting techs affect labor demand via productivity effect.
- One implication is that factor-augmenting technological progress tends to increase labor demand.

Multi-Sector Economy: Decomposition

- We index sectors by subscript i and let $\mathcal{I}$ represent the set of industries.
- Factor prices are denoted by W_i and R_i. χ_i denotes share of sector i in value added and s_i^L its labor share.

$$
\begin{aligned}
d\ln(WL) =& d\ln Y && \text{(Productivity effect)}\\
&+ \sum_{i\in\mathcal{I}} \left(\frac{s_i^L}{s^L} - 1\right) d\chi_i && \text{(Composition effect)}\\
&+ \sum_{i\in\mathcal{I}} \ell_i (1-\sigma)(1-s_i^L) d\ln\left(\frac{W_i/A_i^L}{R_i/A_i^K}\right) && \text{(Subs across tasks)}\\
&+ \sum_{i\in\mathcal{I}} \ell_i \frac{1-s_i^L}{1-\Gamma_i} d\ln\Gamma_i && \text{(Change task content)}
\end{aligned}
$$

Multi-Sector Economy: Summary

- Consider a multi-sector economy.
- Changes in economy-wide labor demand, WL, can be decomposed as:

Overall change in labor demand = Productivity effect
+ Composition effect
+ Substitution effects
+ Change in task content

Patterns in Labor Share 1947-1987

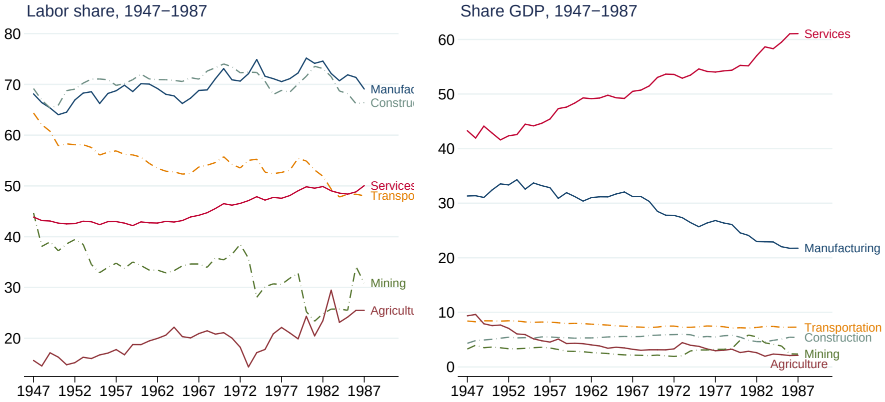


Figure: The labor share and sectoral evolutions, 1947-1987.

Decomposing Labor Demand, 1947-1987

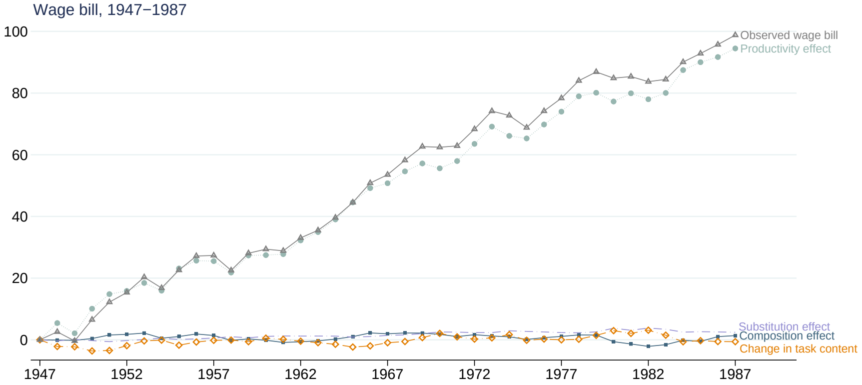
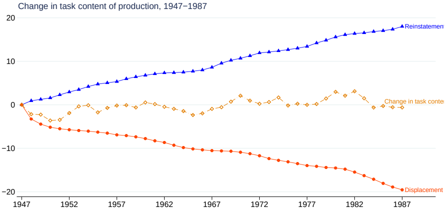


Figure: Sources of changes in labor demand, 1947-1987.

Displacement and Reinstatement, 1947-1987

- Change in task content=displacement + reinstatement.
- Requires two additional assumptions:
  1. no technological regress
  2. at a point in time, an industry either automates or creates new tasks



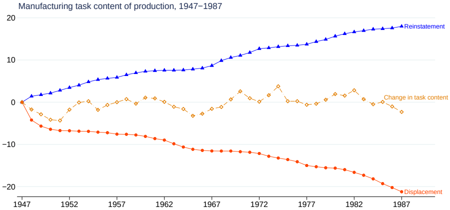
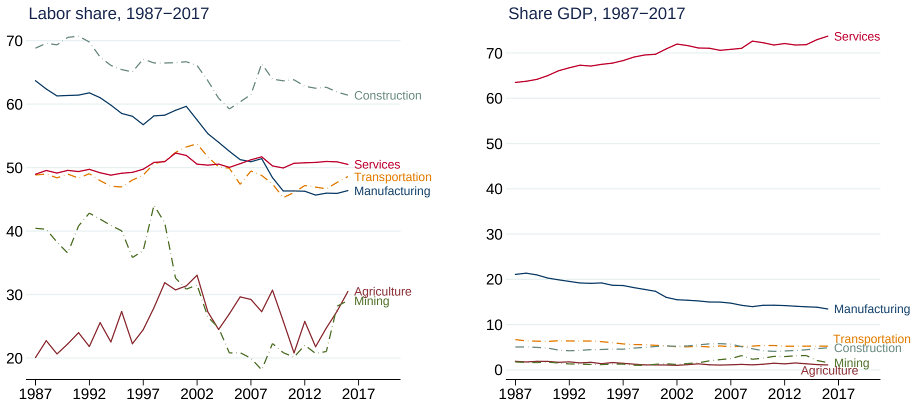


Figure: Estimates of the displacement and reinstatement effects, 1947-1987.

Patterns in Labor Share, 1987-2017



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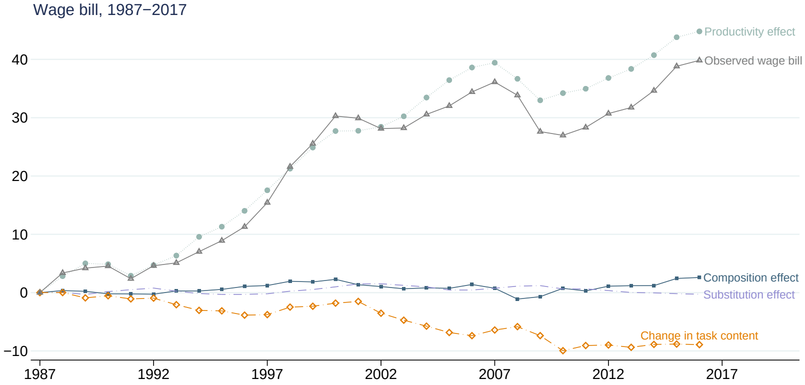

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Displacement and Reinstatement, 1987-2017

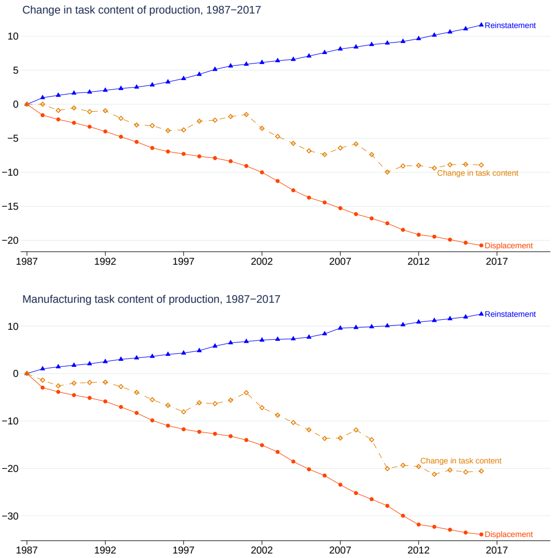


Figure: Estimates of the displacement and reinstatement effects, 1987-2017.

Explaining Changes in Task Content: Automation

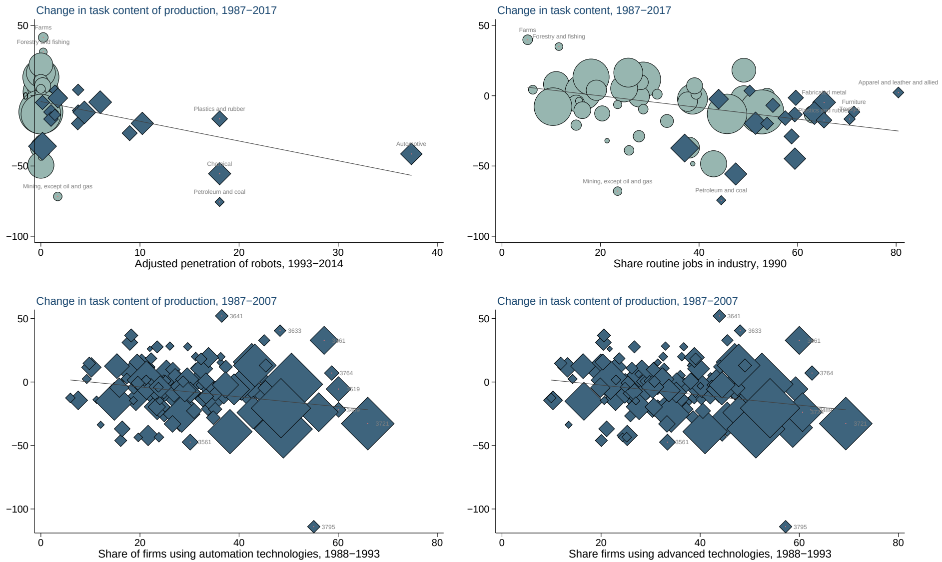


Figure: Automation technologies and change in the task content of production.

Explaining Changes in Task Content: New Tasks

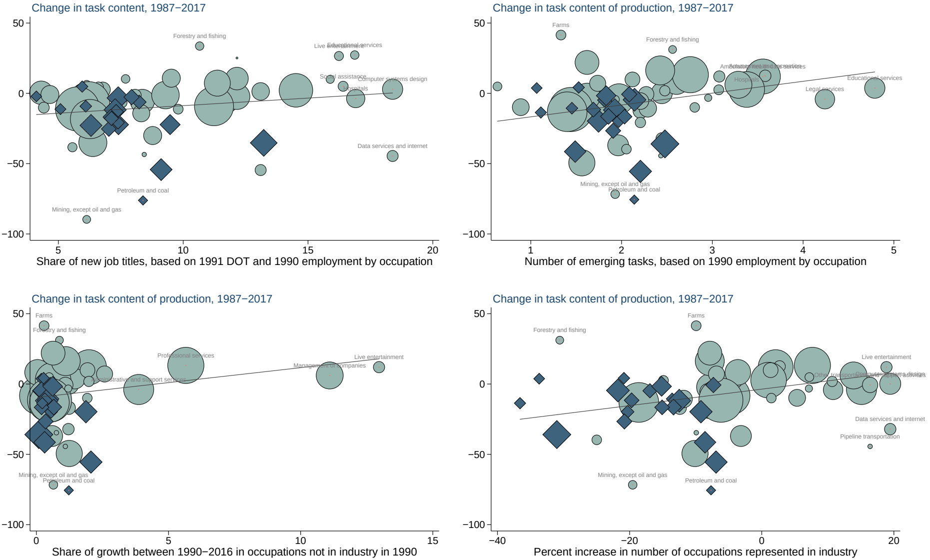


Figure: New tasks and change in task content of production.

Decomposing Labor Demand: Decomposition, 1850-1910

Figure: The labor share, sectoral evolutions, and the sources of labor demand, 1850-1910.

Why Has Productivity Growth Been so Bad Lately?

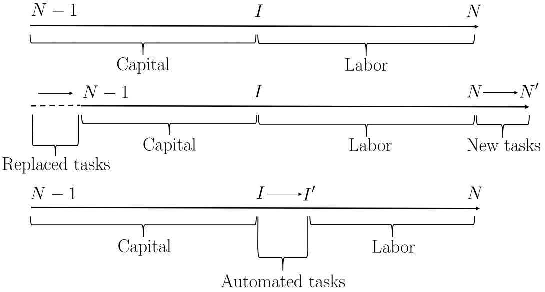
- Prospects for future productivity growth?
- The pessimistic view: because the new technologies are not worth that much (e.g., Gordon).

  ...But then why are firms adopting them and shedding labor?
- The optimistic view: it's all temporary.

  ...But this has been going on for quite a while as we have seen.
- Three possibilities in a world of replacing technologies:
  1. **so-so technologies;**
  2. **the wrong kinds of innovation**;
  3. **bottlenecks**.

The Wrong Kinds of Innovation

- **New tasks**: source of comparative advantage for labor and productivity growth:



- But if we are devoting too much resources to replace tasks and not enough for creating new tasks, both labor and productivity will suffer.
    - Most evident in the area of AI, which can be used not just for replacement but for creating new tasks and functions.

Directed Technological Change Perspective

- From Acemoglu and Restrepo (AER, 2018): balance between automation and new tasks responds to profits and institutions.
- Natural forces that equilibrate automation and new tasks: a lot of automation reduces labor share and makes new tasks more profitable.
- But no guarantee that this equilibrating force will bring the labor share to a level consistent with full employment or shared prosperity.
- In fact, in general a tendency for too much automation. Excessive automation caused both by policy and labor market imperfections.
- Moreover, both automation and new tasks can be a force towards greater inequality.
- This calls for a more systematic discussion of policy interventions in the age of automation, a topic which we will discuss in the later lectures.

Bottlenecks

- Various types of bottlenecks:
  - *Technological bottlenecks:* Not all inputs are improving at the same rate, creating bottlenecks. Resolving these bottlenecks will be a very slow process, but at some point we may see productivity growth.
  - *Organizational bottlenecks:* Our organizations are not ready for new technologies.
  - *Institutional bottlenecks:* Our institutions, safety net, and fiscal system are not ready for new technologies.
  - *Skill bottlenecks:* Our workforce is not ready for new technologies, because our schools are not ready for new technologies.
    - We are getting ready for the technologies of the 21st century with an educational system that was designed in the mid-20th century, and has been going backwards ever since.

Engel's Pause: Bottlenecks Again?

- Parallels to "Engel's pause": No wage growth from the beginning of the Industrial Revolution around 1760 to about 1850 despite very rapid technological change and technology adoption in Britain.
  - Why? Partly because the demand for labor did not build up sufficiently or new technologies were not properly implemented while employers were experimenting with the new technologies.
  - But all of the above bottlenecks were important also — the real productivity gains were not fully realized until many sectors started improving together; organizations changed; there was an institutional revolution, including major democratizations and bureaucratic reforms and the beginnings of the fiscal state; and **mass schooling**.
- Perhaps our progress will be as in the case of Engel's pause, or will it?

Political Bottlenecks

- Reform and change are not easy. They are political decisions.
- Every ensemble of political, social and economic arrangements creates its own constituency, which will typically oppose change.
  - History is full of examples of elites blocking the adoption of new technologies, like the Habsburg Empire and Russia in the first half of the 19th century steadfastly refusing to allow railways and industrial technology.
- Lack of a clear roadmap complicates matters.
  - What type of new schooling system? What type of new fiscal system?
  - In fact, we are not even asking the right questions — what types of skills will be necessary in the labor market of the future? More numeracy skills? Communication skills? Soft skills? Teamwork? Fluidity?
  - What type of social safety net? What type of redistribution? Universal basic income? What about jobs?

Conclusion

- New technologies based on the silicon chip have revolutionized the labor market as well as our society. This process is ongoing with robots and AI.
- Though we still have much to understand about what is happening (and has happened in the past), the basic lesson is also a clear one:
  - Great potential gains from robotics and AI.
  - But this potential can only be realized if we make a range of complementary investments.
  - This necessitates identifying and investing in new tasks complementary skills (as well as adapting our organizations and other technologies to mesh well with AI and robotics).
  - A much more flexible, adaptable education system to prepare workers for the new turbulent labor market, and a much better safety net.
  - But lots of roadblocks on the way there.