

Future of Productivity and Work

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A 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

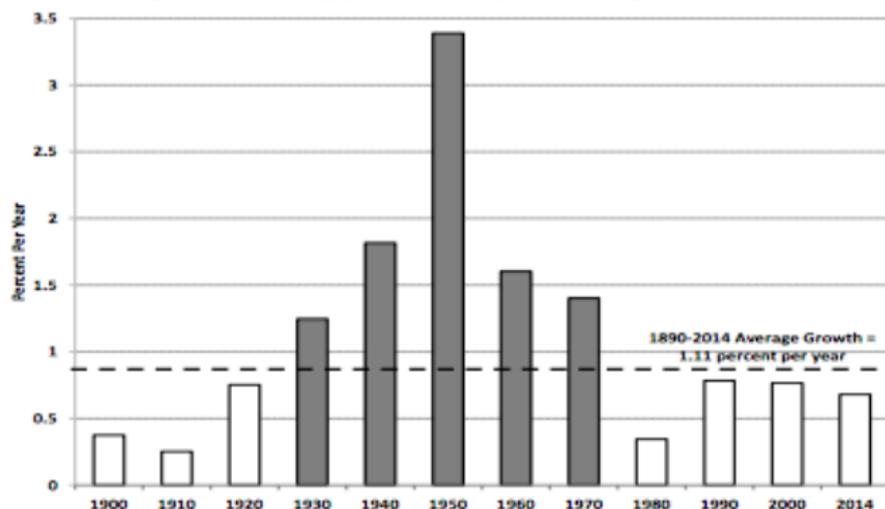
- ▶ But so far, it's not Ray Kurzweil, but economist Bob Solow who got it right with his statement in 1987:

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

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

A Bleak Record

Figure 1 - Annual growth rate of total factor productivity for ten years preceding years shown, years ending in 1900 to 2014

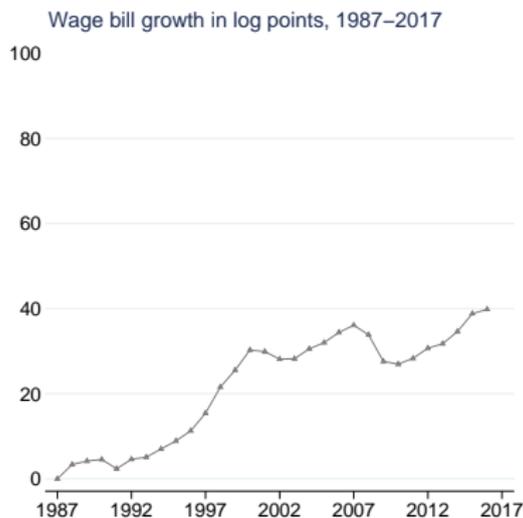
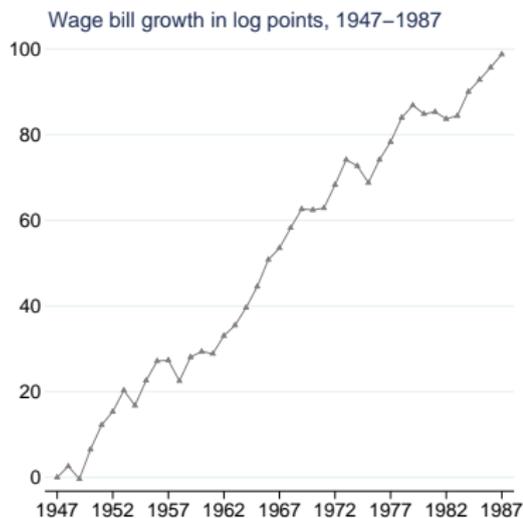


(From Gordon, 2016)

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

Even Worse in the Labor Market

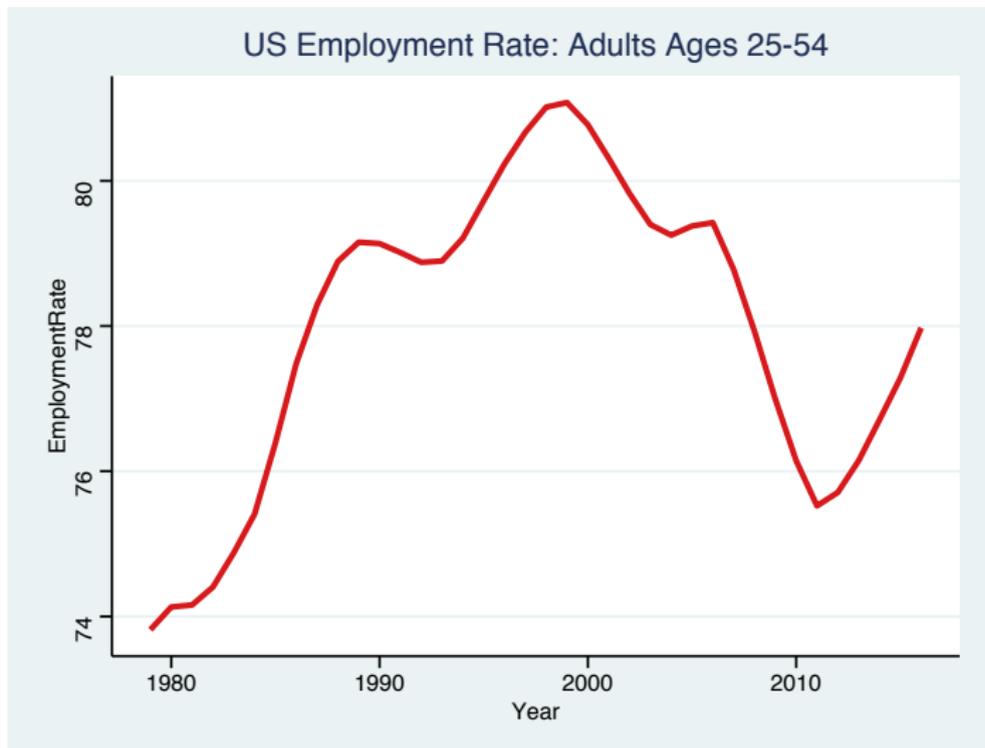
- ▶ The data points to anemic growth of labor demand from 1987 to 2017.



- ▶ Is this because of automation?
- ▶ **Answer:** It's all about the task content of production.
- ▶ Automation technologies change the task content adversity for labor, but can be counterbalanced by **new tasks**.

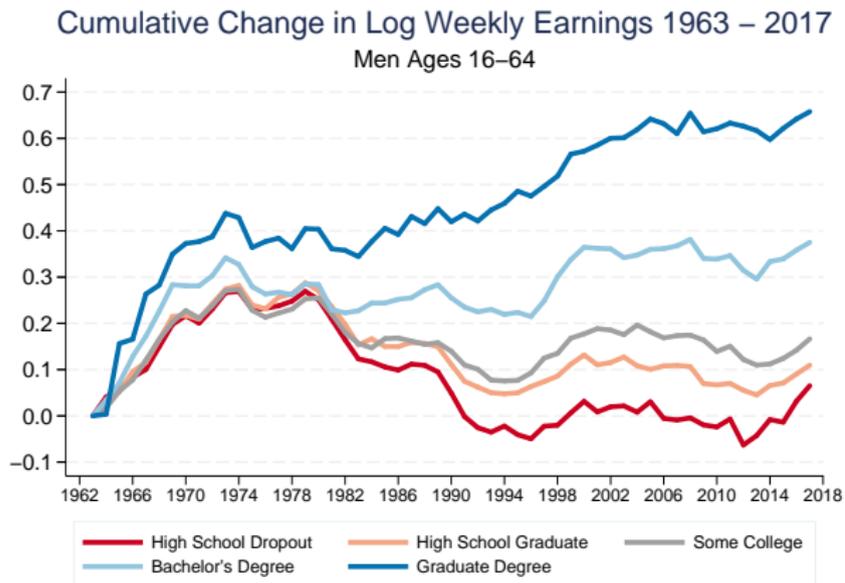
Employment

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



Wages

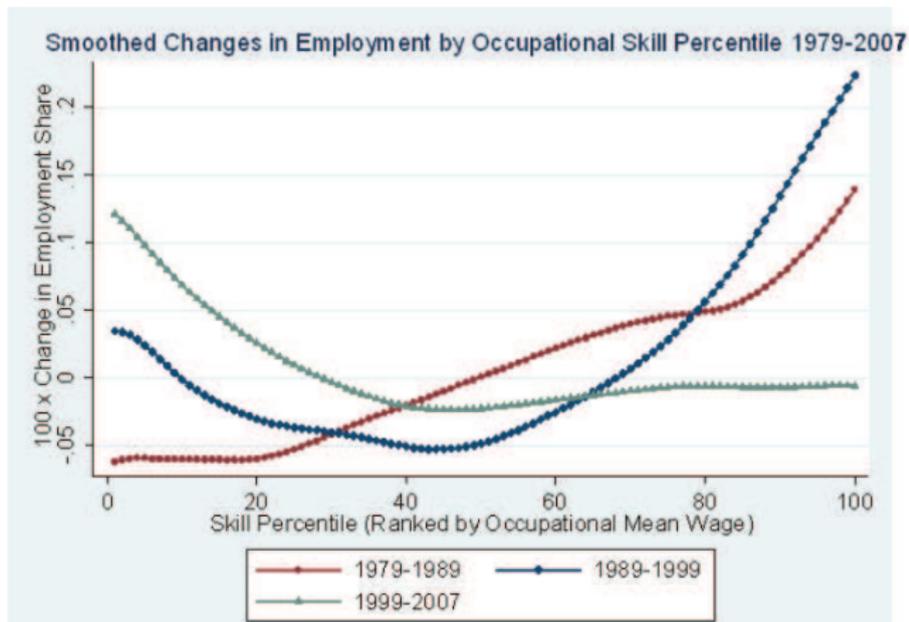
- ▶ Technology of the last several decades, as opposed to what we used to have, looks nothing like a tide lifting all boats.



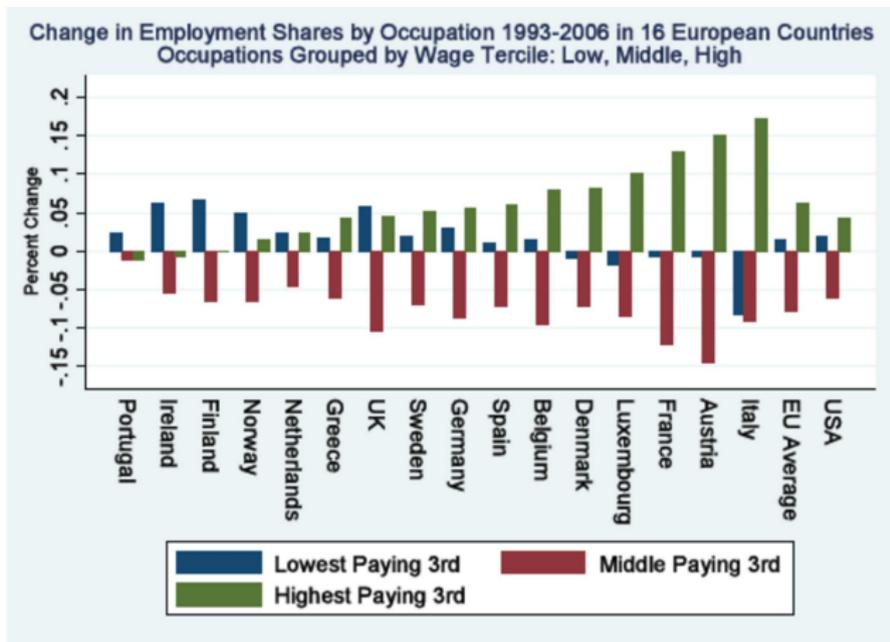
(Acemoglu and Autor, 2011)

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.

Enabling and Replacing Technologies

- ▶ Two different types of technologies that increase productivity, but with very different labor market implications:¹

1. *Enabling (or augmenting)*: they complement and increase the productivity of certain types of skills:

$$\text{Output} = F(\text{Technology} \times \text{Labor})$$

2. *Replacing (or automation)*: they take over **tasks** previously performed by labor:

$$\text{Output} = \int \text{Task}(i) \, di$$

$$\text{Task}(i) = \begin{cases} \text{Can be produced by machines} & \text{if Task}(i) \text{ automated} \\ \text{Has to be produced by labor} & \text{if Task}(i) \text{ not automated} \end{cases}$$

- ▶ Technological progress in part about expanding automated tasks.
- ▶ Reality of course more complicated: many actual technologies combine enabling and replacing elements.

¹Acemoglu and Autor (2011); Acemoglu and Restrepo (2016).

Example of Replacing Technology: Industrial Robots



- ▶ Other examples: assembly tasks, switchboard operation, mail sorting, packing, stock trading, dispensing cash, operating machines, etc.

Enabling Versus Replacing Technologies

- ▶ A main contrast: *implications for the labor market.*
- ▶ Enabling technologies, because they complement workers and enable them to be more productive, increase wages and labor demand.

$$\frac{d \text{ Wage}}{d \text{ Technology}} \geq 0.$$

- ▶ Similar implications for **employment**.
- ▶ Not so for **replacing technologies**:

$$\frac{d \text{ Wage}}{d \text{ Technology}} < 0.$$

- ▶ In fact, replacing technologies always reduce the labor share.

How to Make Sense of These Issues?

- ▶ Task-based framework building on Zeira (1998), Acemoglu and Autor (2011) and Acemoglu and Restrepo (2018):
 1. Conceptually, **automation technologies** and **the creation of new tasks** differ from other technologies, like factor-augmenting ones.
 2. All technologies increase productivity and via this channel tend to raise labor demand.
 3. In addition, automation generates a **displacement effect** which tends to reduce the demand for labor. New tasks generate a **reinstatement effect** in the opposite direction.
 4. Displacement and reinstatement are changes in the **task content of production**—the allocation of tasks to factors—with first-order effects on labor demand.
 5. Sectoral composition effects and substitution effects do not affect the task content of production and have more limited effects on labor demand.

Agenda for the Rest of the Talk

1. Task framework with a single sector.
2. Multi-sector model that we use to connect with data.
3. Evidence on the displacement effect of automation/replacement technologies.
4. Labor demand decomposition, 1987-2017.
5. Correlates of change in task content.
6. Labor demand decomposition, 1947-1987 and 1850-1910.
7. Why productivity growth has been so bad lately?
8. Concluding remarks.

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 based on 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: Framework

- ▶ 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.

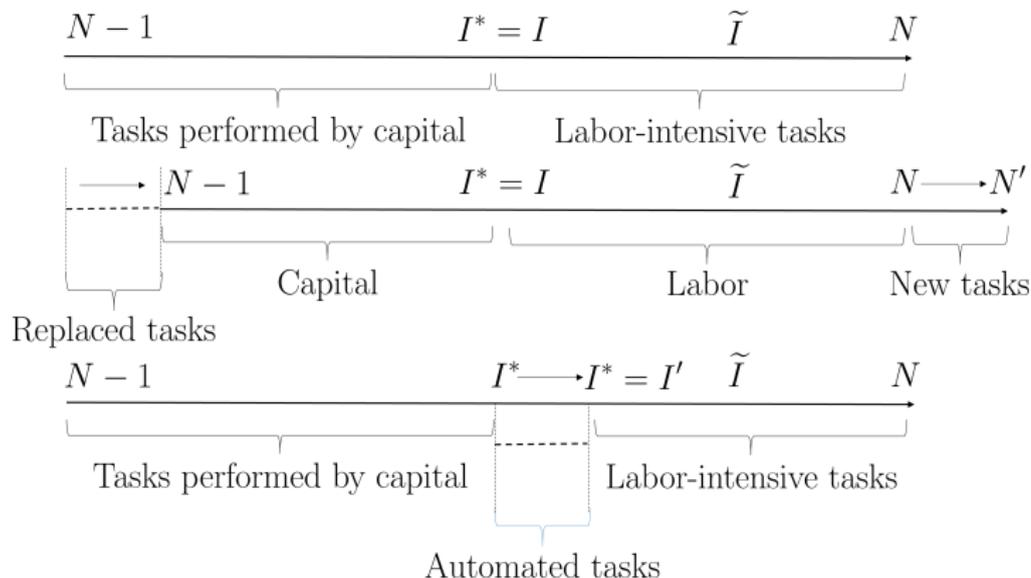
- ▶ Tasks can be produced using capital or labor:

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

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



- ▶ 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: Labor Share and Demand

- ▶ Output given by
- ▶ The labor share in value added 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 and demand: **task content** and **substitution across tasks** (governed by σ and effective factor prices W/A^L and R/A^K).
- ▶ In the special case where $\sigma = 1$, then

$$\Gamma(N, I) = N - I.$$

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:

Effect of automation on labor demand = Productivity effect + Displacement

- ▶ The displacement effect always negative.
- ▶ Without the displacement effect, the labor share in value added would remain constant. With the displacement effect, the labor share always 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

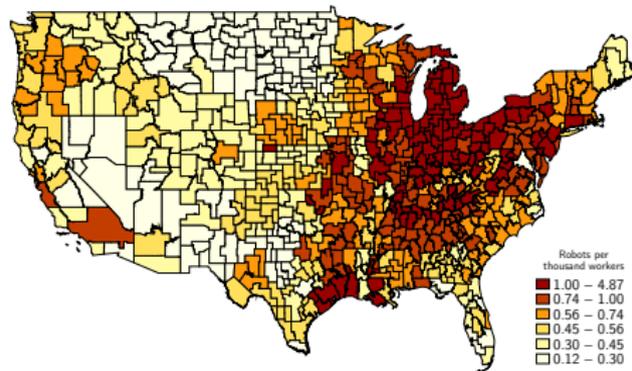
- ▶ The effects of creation of new tasks in which labor has a competitive advantage—an expansion in N —can be determined similarly.

Effect of new tasks on labor demand = Productivity effect + Reinstatement

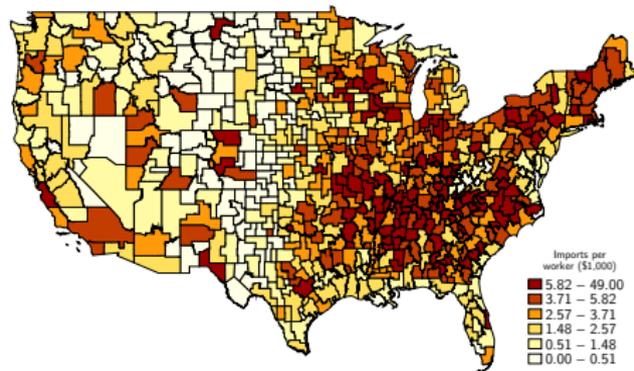
- ▶ The reinstatement effect always positive.
- ▶ Without the reinstatement effect, the labor share in value added would remain constant. With the reinstatement effect, the labor share always increases.

Evidence of the Effects of Automation: Robots

A. Exogenous exposure to robots from 1993 to 2007

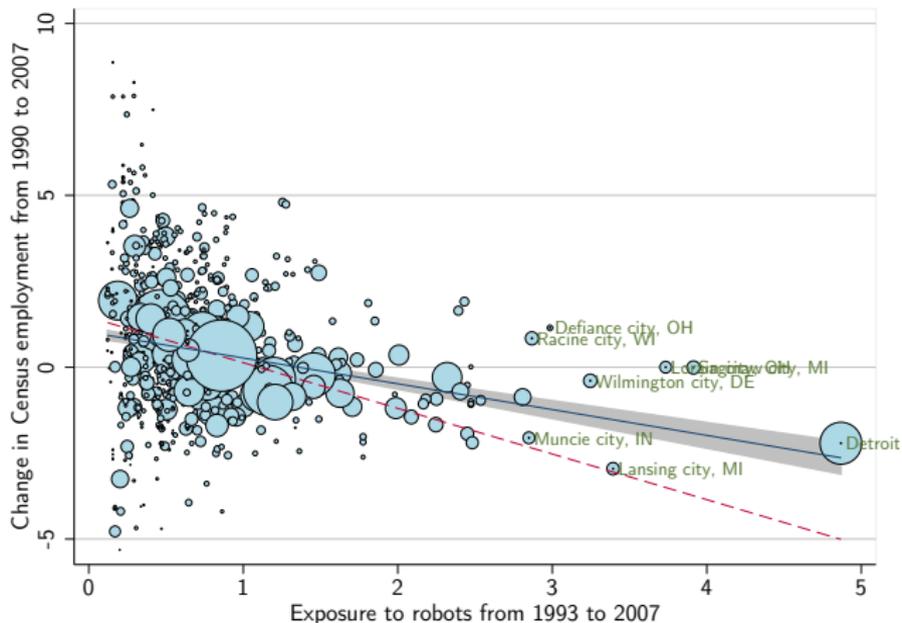


C. Exposure to Chinese imports from 1990 to 2007



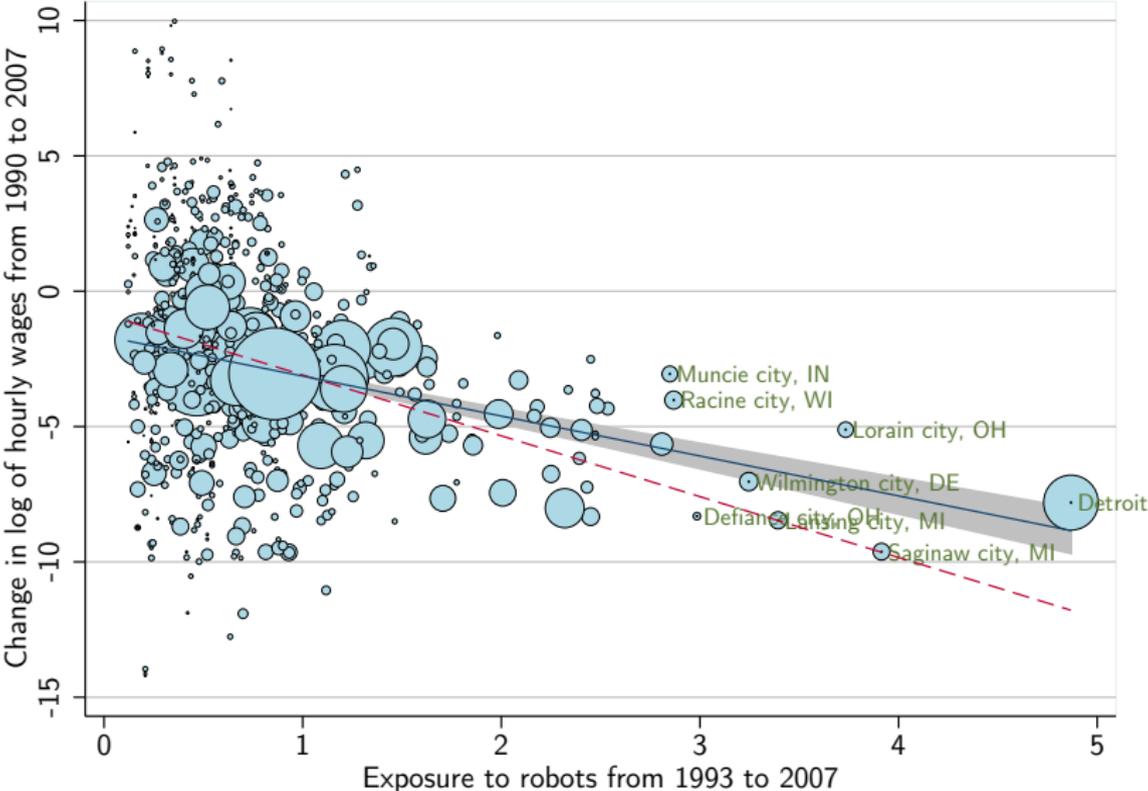
(Acemoglu and Restrepo, 2018)

Robots and Employment



- ▶ One more robot reducing employment by 3 or 4 workers.

Robots and Wages



Robots and the Labor Market: Recap

- ▶ Negative effects on employment and wages as implied by the replacing technologies perspective.
- ▶ We have about a 0.25% decline in employment to population ratio in 15 years because of industrial robots.
- ▶ So clear evidence that automation technologies, in particular, robotics, are reducing labor demand, wages and employment, even though productivity is increasing.
- ▶ But note, magnitudes nowhere large enough to support “end of work” claims of some. We have displacement and a failure to create shared prosperity, but we are not heading to an economy without human labor anytime soon.

Decomposing Labor Demand in a Multi-Sector Economy

- ▶ Now consider a multi-sector economy.
- ▶ Then change in economy-wide labor demand, WL , can be decomposed as:

$$\begin{aligned} \text{Overall change in labor demand} &= \text{Productivity effect} \\ &+ \text{Composition effect} \\ &+ \text{Substitution effects} \\ &+ \text{Change in task content} \end{aligned}$$

Decomposing Labor Demand: Implementation and Data

- ▶ From Acemoglu and Restrepo (2018b). Data for 60-61 industries between 1947 and 2017.
- ▶ Estimate the change in task content at the industry level:

$$\Delta \text{task content}_{i,t} = \Delta \ln s_{i,t}^L - (1 - \sigma)(1 - s_{i,t}^L)[(\Delta \ln(W_{i,t}/R_{i,t}) - \Delta \ln(A_{i,t}^L/A_{i,t}^K)]$$

where $s_{i,t}^L$ is the share of labor in value added in industry i at time t .

- ▶ We take a baseline value for σ of 0.8 (Oberfield and Raval, 2014).
- ▶ The change in the task content of the entire economy is then given by

$$\text{Change in task content}_t = \sum_{i \in \mathcal{I}} \ell_{i,t} \Delta \text{task content}_{i,t},$$

where $\ell_{i,t}$ is the share of labor and industry i .

Patterns in Labor Share 1947-1987

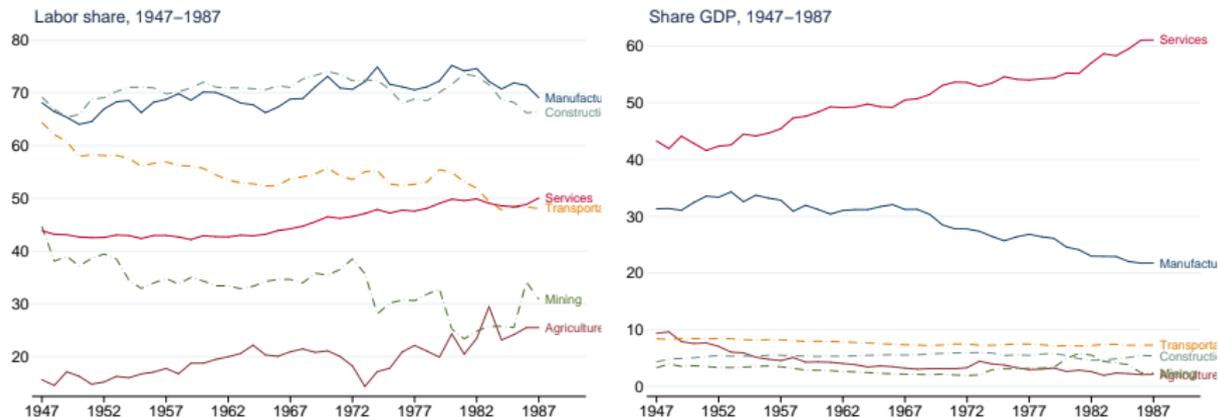


Figure: THE LABOR SHARE AND SECTORAL EVOLUTIONS, 1947-1987.

Decomposing Labor Demand: Decomposition, 1947-1987

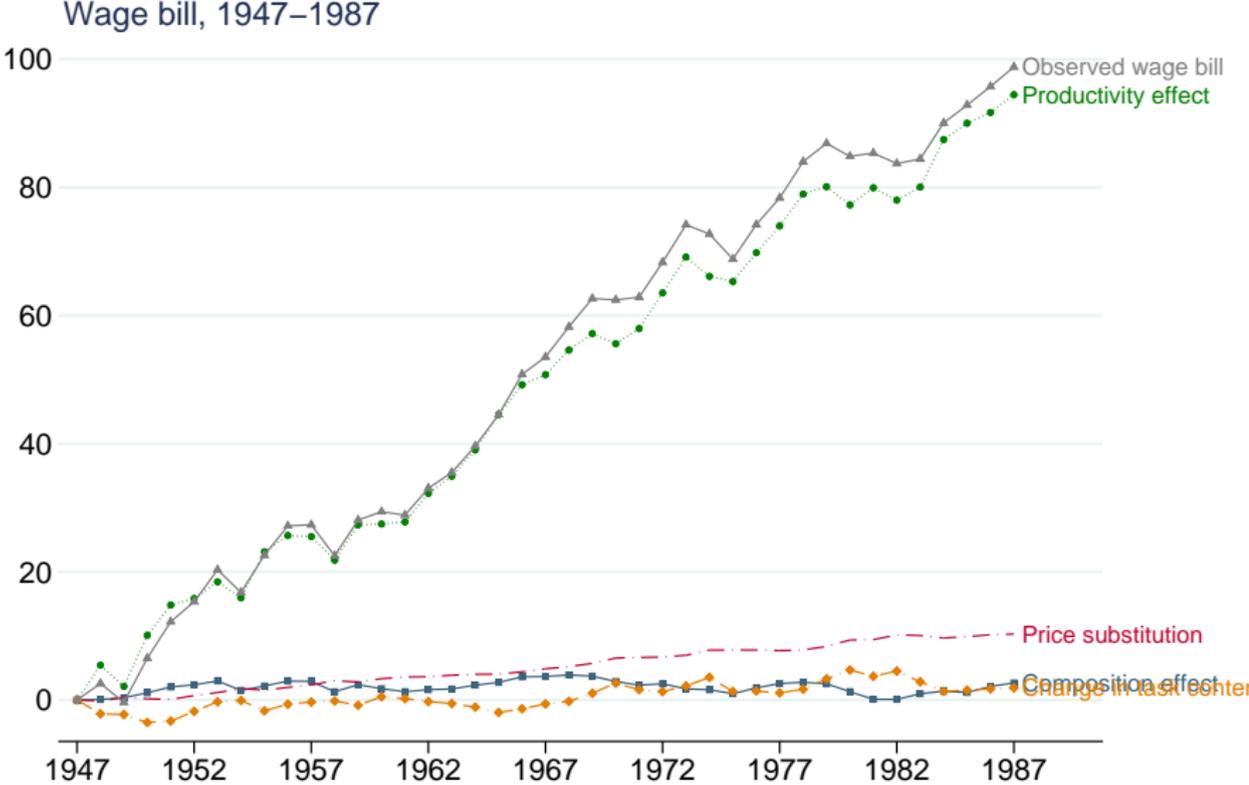


Figure: SOURCES OF CHANGES IN LABOR DEMAND, 1947-1987.

Decomposing Labor Demand: Displacement and Reinstatement, 1947-1987

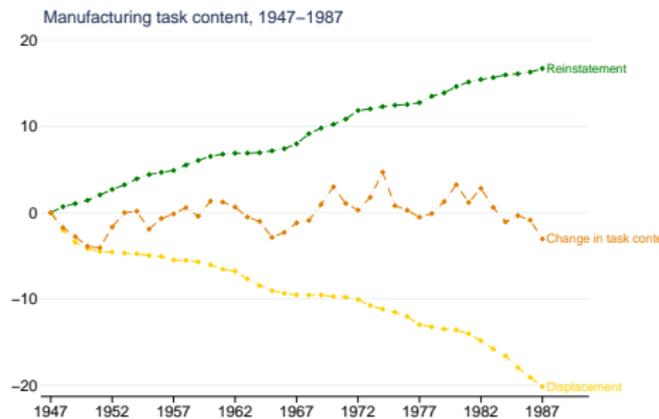
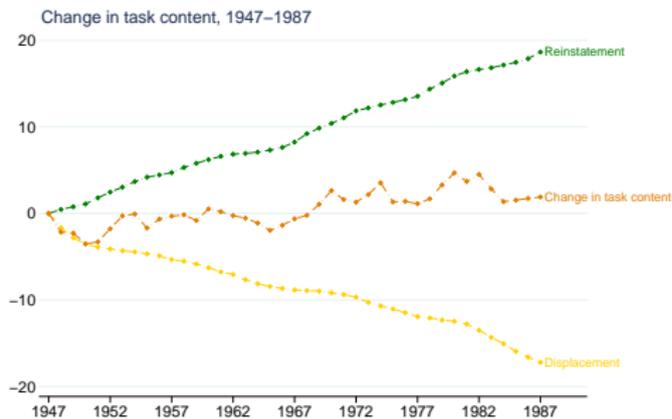


Figure: ESTIMATES OF THE DISPLACEMENT AND REINSTATEMENT EFFECTS, 1947-1987.

Patterns in Labor Share, 1987-2017

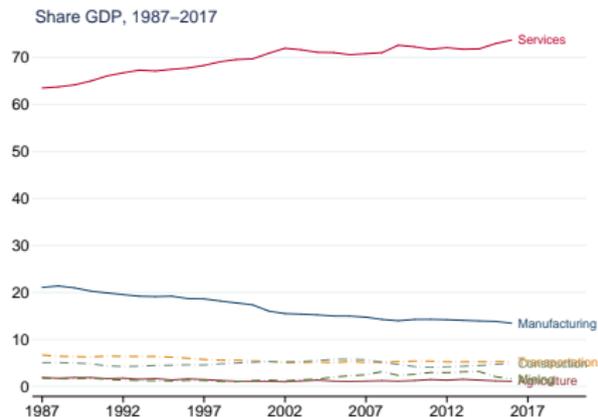
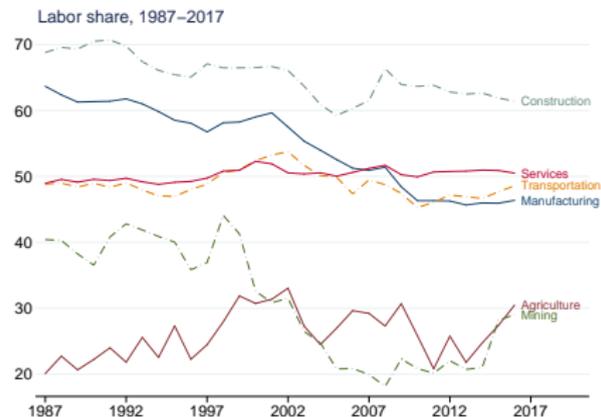


Figure: THE LABOR SHARE AND SECTORAL EVOLUTIONS, 1987-2017.

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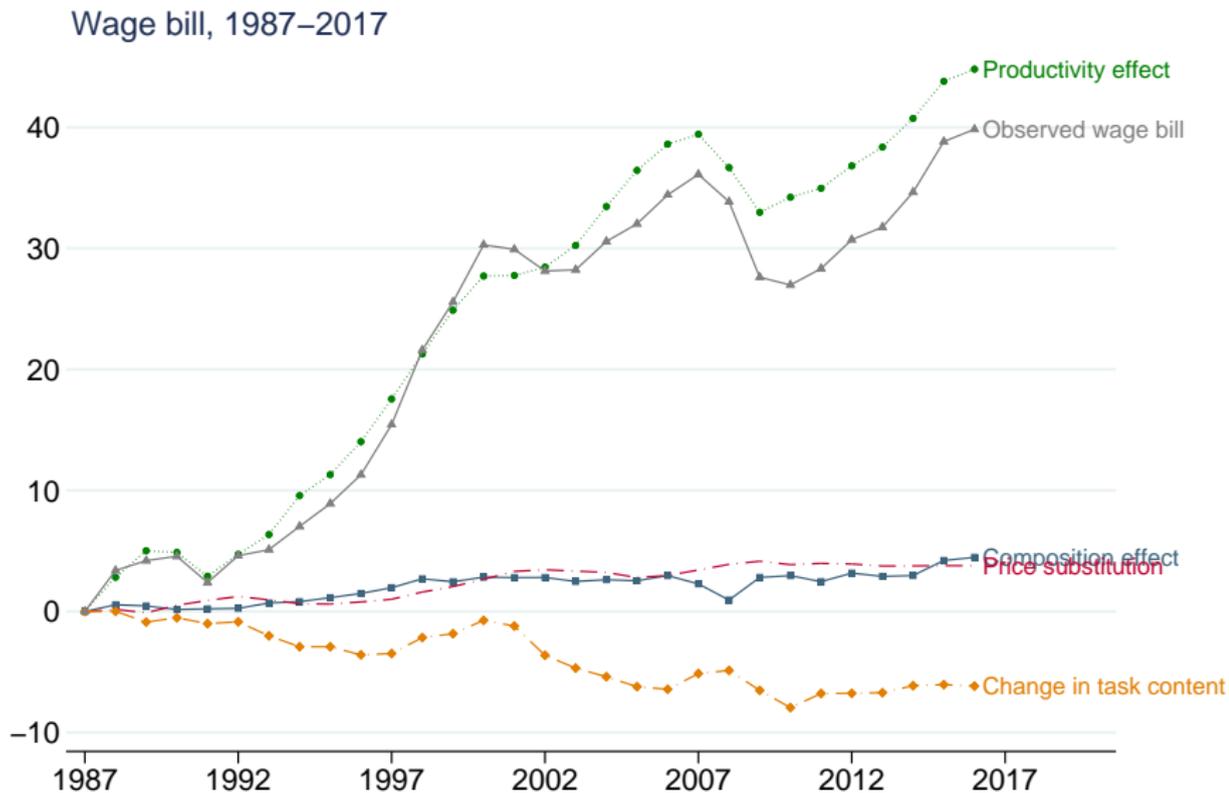


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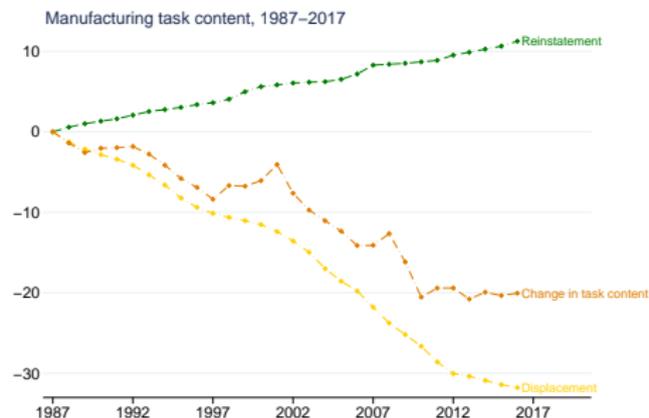
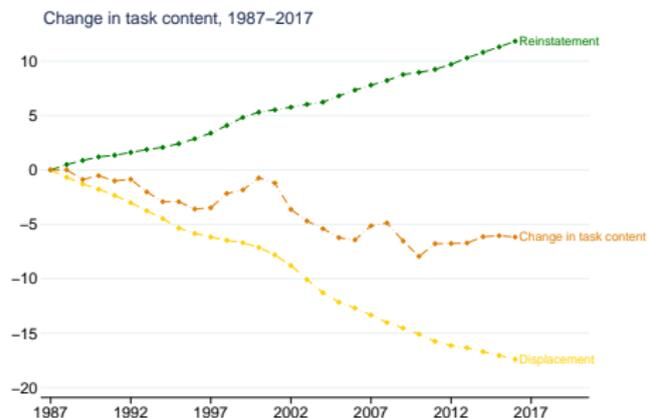


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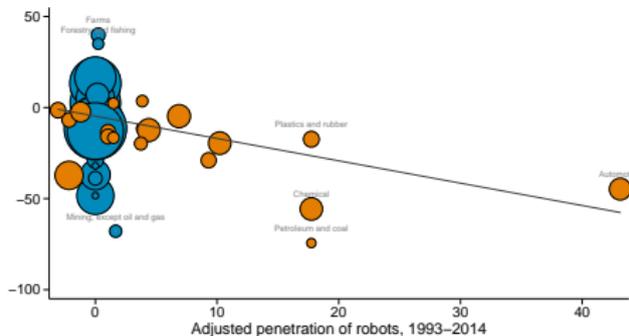
Decomposing Labor Demand: Taking stock, 1987-2017

- ▶ 1987-2017 exhibited a **strong displacement, weak reinstatement and anemic productivity**, which resulted in a slowdown in labor demand.
- ▶ In our framework, telltale sign of **so-so automation technologies**: strong displacement and anemic productivity effect from automation technologies.
- ▶ But also very small composition effects (which would be predicted by explanations emphasizing structural transformation, cost disease and international trade).
- ▶ Changes in task content are crucial. One would need gargantuan changes in productivity to explain the data using factor-augmenting technologies and appealing to the substitution across tasks.
- ▶ Manufacturing experienced an absolute decline in labor demand, partly because of the displacement effect (automation) and partly because of the decline in the relative price of manufacturing goods (which weakens productivity effect but does not impact the task content of production).

Explaining Changes in Task Content: Automation

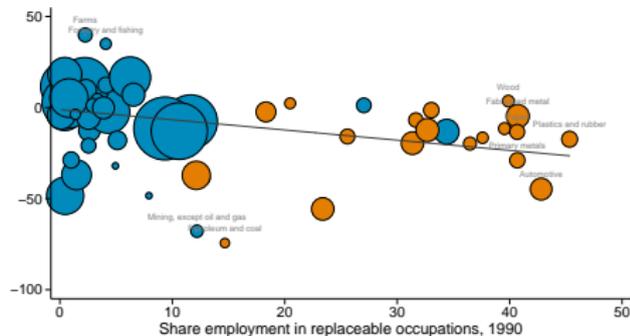
Change in task content, 1987–2017

Estimate: -1.23 (se: 0.34)



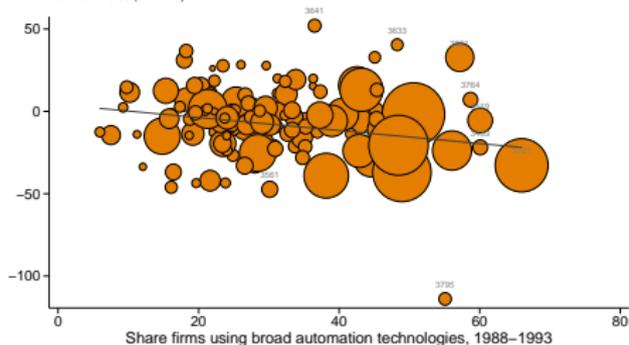
Change in task content, 1987–2017

Estimate: -0.56 (se: 0.18)



Change in task content, 1987–2007

Estimate: -0.39 (se: 0.16)



Change in task content, 1987–2007

Estimate: -0.40 (se: 0.15)

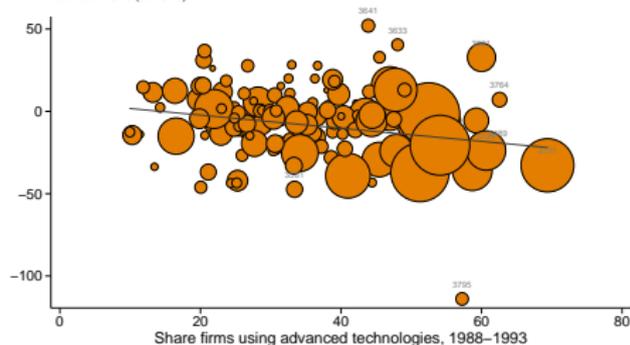


Figure: AUTOMATION TECHNOLOGIES AND CHANGE IN THE TASK CONTENT OF PRODUCTION.

Explaining Changes in Task Content: New Tasks

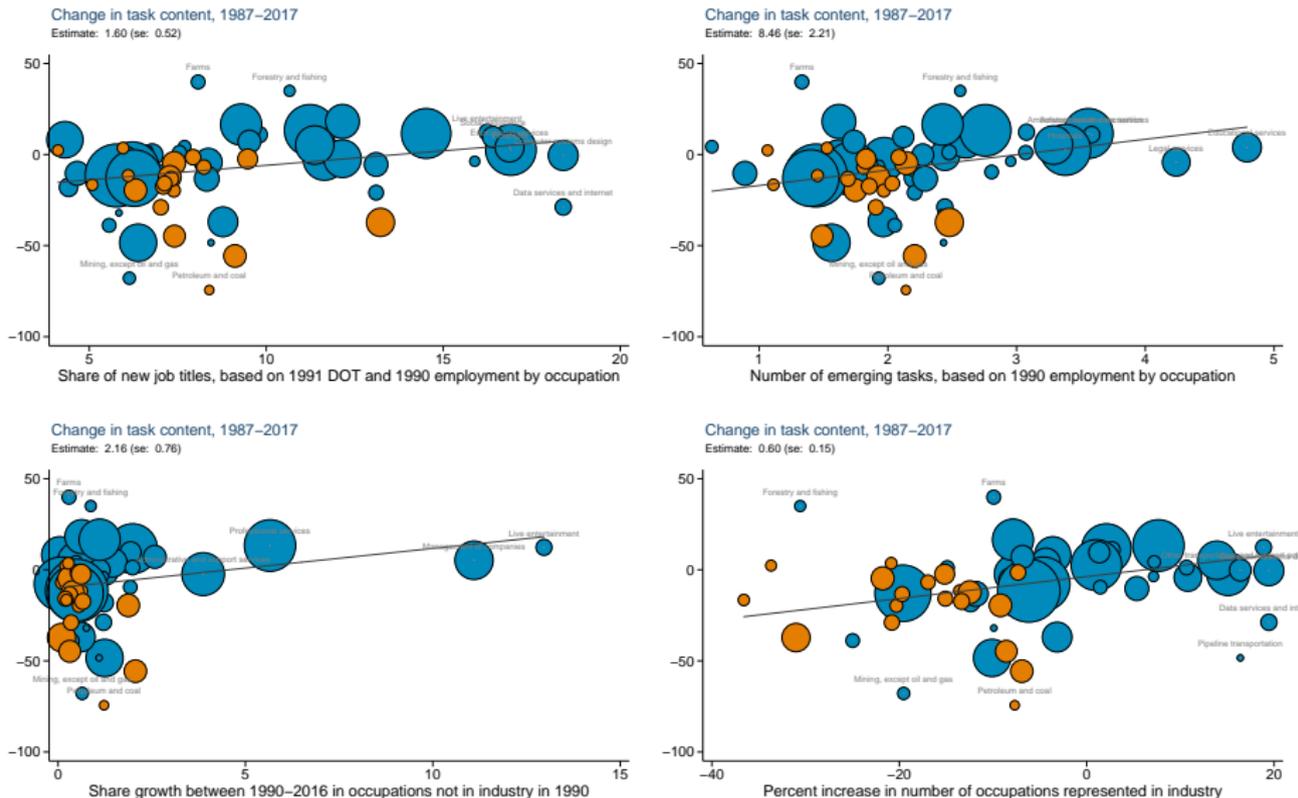


Figure: NEW TASKS AND CHANGE IN TASK CONTENT OF PRODUCTION.

Explaining Changes in Task Content: Automation

	RAW DATA	CONTROLLING FOR MANUFACTURING	CONTROLLING FOR CHINESE IMPORTS AND OFFSHORING
	(1)	(2)	(3)
<i>Proxies of automation technologies:</i>			
Adjusted penetration of robots, 1993-2014	-1.227 (0.341)	-0.817 (0.297)	-0.949 (0.239)
Observations	61	61	61
R-squared	0.17	0.23	0.23
Share employment in replaceable occupations, 1990	-0.560 (0.181)	-0.171 (0.318)	-0.126 (0.347)
Observations	61	61	61
R-squared	0.14	0.18	0.18
<i>Detailed manufacturing industries (from SMT):</i>			
Share firms using broad automation technologies, 1988-1993	-0.395 (0.165)		-0.471 (0.150)
Observations	148		139
R-squared	0.08		0.14
Share firms using advanced technologies, 1988-1993	-0.399 (0.152)		-0.483 (0.137)
Observations	148		139
R-squared	0.09		0.16

Decomposing Labor Demand: Decomposition, 1850-1910

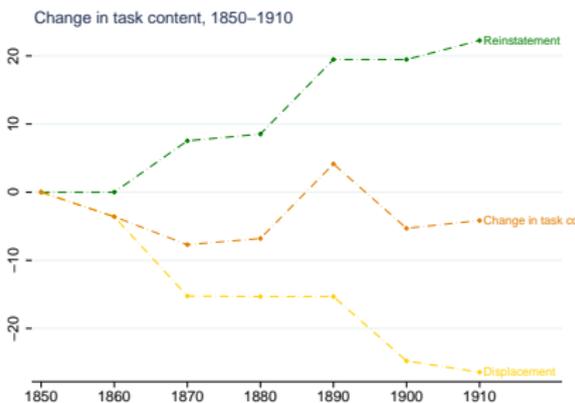
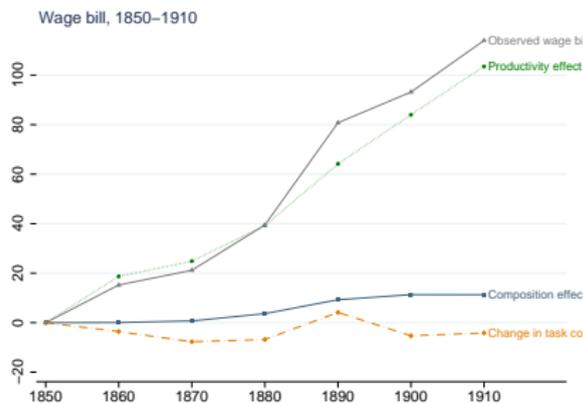
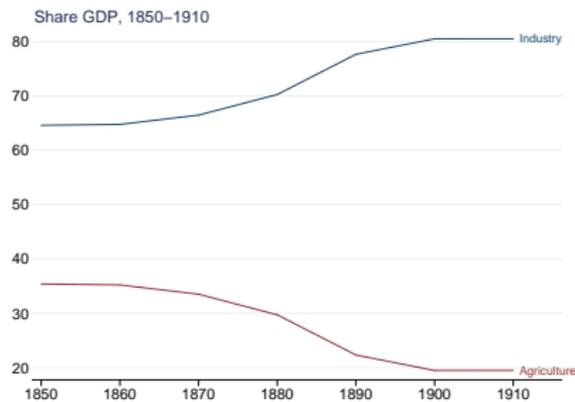
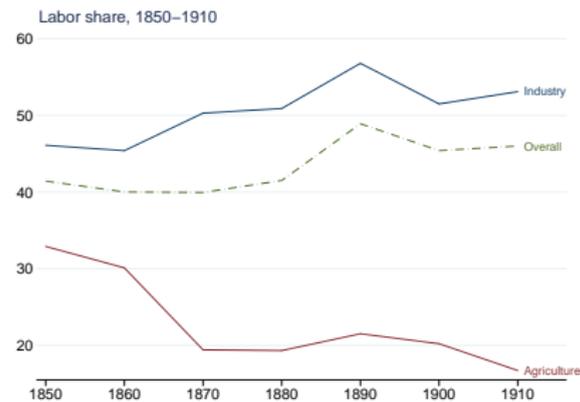


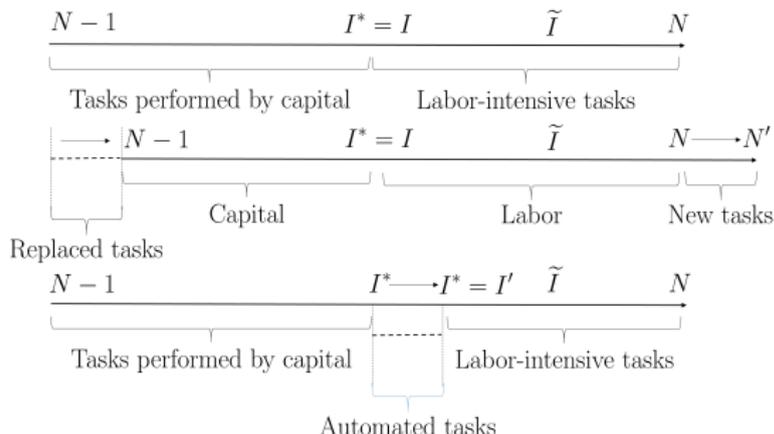
Figure: THE LABOR SHARE, SECTORAL EVOLUTIONS, AND THE SOURCES OF LABOR DEMAND,

Why Has Productivity Growth Been so Bad Lately?

- ▶ So-so technologies
- ▶ Prospects for future productivity growth? It depends what has been holding productivity back.
- ▶ 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? A mystery.
- ▶ The optimistic view: it's all temporary.
- ▶ But this has been going on for quite a while as we have seen.
- ▶ Two other possibilities in a world of **replacing technologies**:
 - ▶ **the wrong kinds of innovation**;
 - ▶ **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.

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. May be wishful thinking. . .
 - ▶ *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”: There was essentially 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. First and foremost, 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 also 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

- ▶ No doubt that 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 what 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.