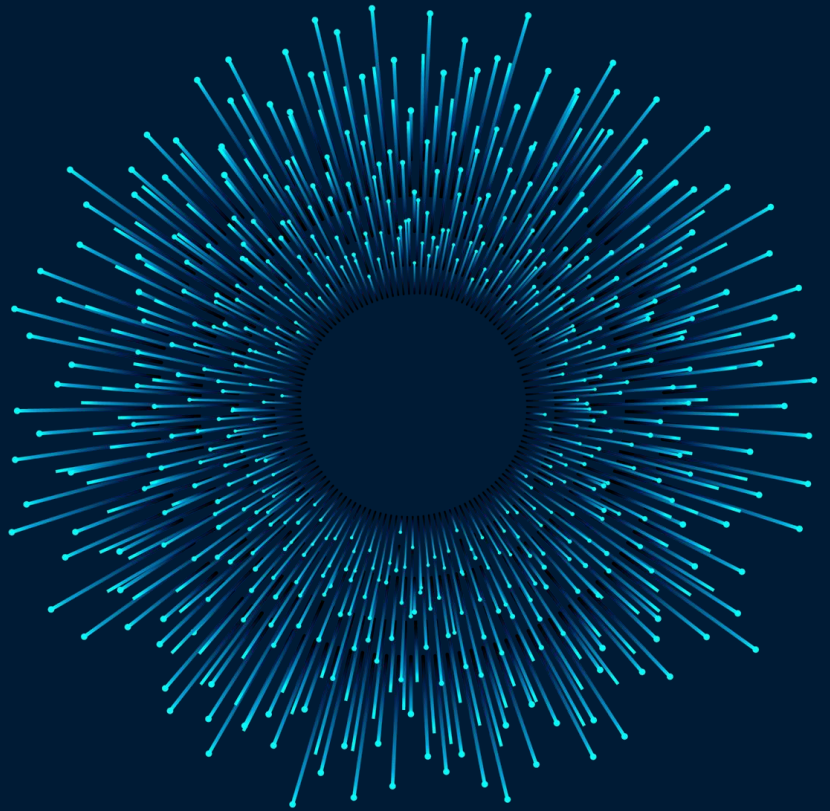
The AI Awakening:
What Does It Mean for the Economy?



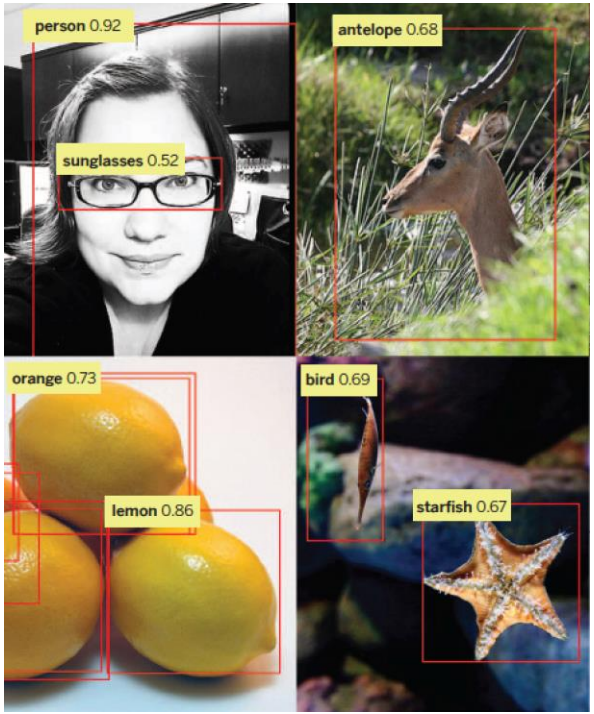
ERIK BRYNJOLFSSON

OECD International Conference on Artificial Intelligence in Work, Innovation, Productivity and Skills

2021.02.01

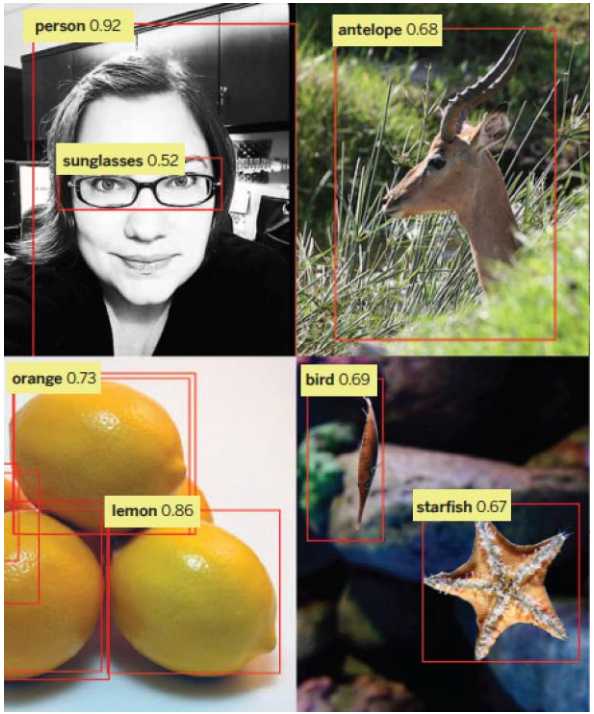
STANFORD
DIGITAL ECONOMY LAB

We’ve crossed a key threshold



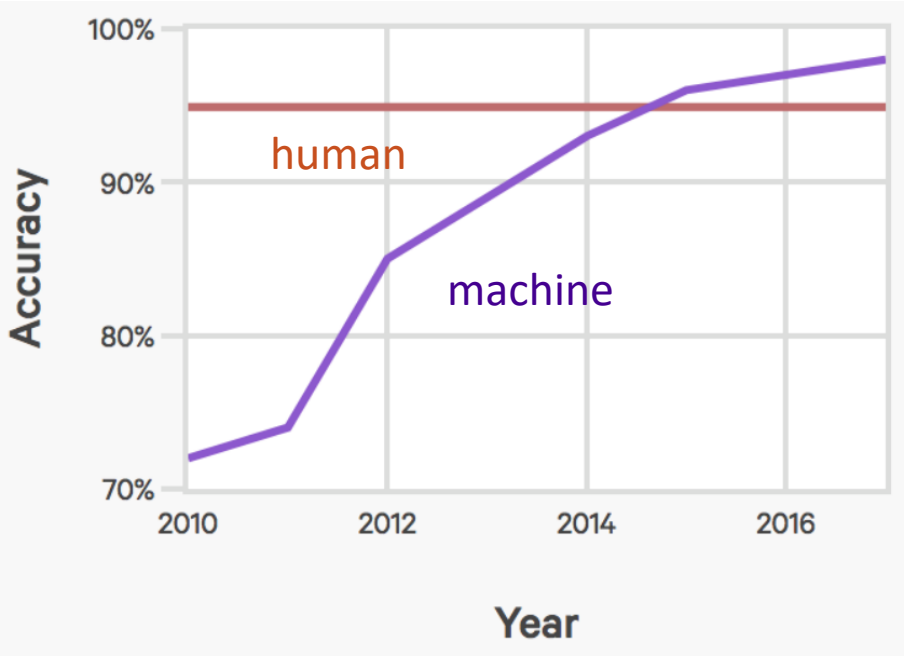
ImageNet Visual Recognition Challenge

We’ve crossed a key threshold



ImageNet Visual Recognition Challenge

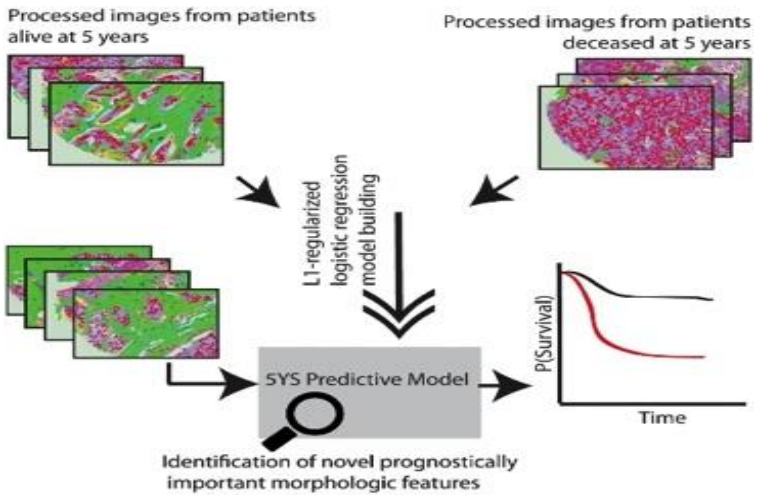
Accuracy of ML system



source: The AI Index

Problem solving

Most of the recent progress in machine learning involves mapping from a set of inputs to a set of outputs



INPUT X	OUTPUT Y	APPLICATION
Voice recording	Transcript	Speech recognition
Historical market data	Future market data	Trading bots
Photograph	Caption	Image tagging
Drug chemical properties	Treatment efficacy	Pharma R&D
Store transaction details	Is the transaction fraudulent?	Fraud detection
Recipe ingredients	Customer reviews	Food recommendations
Purchase histories	Future purchase behavior	Customer retention
Car locations and speed	Traffic flow	Traffic lights
Faces	Names	Face recognition

Source: Brynjolfsson, Erik, and Andrew McAfee. "The Business of Artificial Intelligence." *Harvard Business Review* (2017).

Policy challenges

Policy challenges

1 **Understanding the modern productivity paradox**

2 The transformation of work

Where's the AI productivity boom?

The disappointing recent reality

Productivity growth has *slowed* everywhere

- We are more than one decade into a slowdown in the U.S. and OECD countries

United States:

- 1995-2004: 2.8% per year
- 2005-2019: 1.3% per year

OECD: 29 of 30 countries saw similar-sized slowdowns after 2004

Alternative explanations for the paradox

1

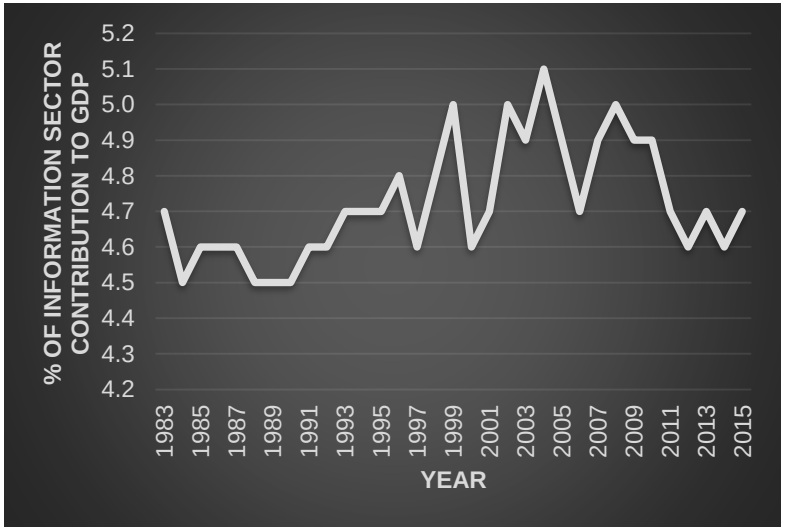
Mismeasurement

Reality better than measured

Free goods: Many digital goods and services

Explosion of free digital goods

Information goods as a share of GDP



GDP-B: A new measure of the economy

Brynjolfsson, Collis & Eggers (*PNAS* 2019) propose an approach to directly estimate consumer welfare by running massive online choice experiments.

1. **We run incentive compatible discrete choice experiments**
   - "Incentive compatible" => participants risk losing access to the good
   - Recruit a representative sample of the US internet population via online survey panel
   - Use data to estimate the consumer valuation of Facebook

2. **Quantify the adjustment term to real GDP growth (GDP-B) for the contribution of Facebook**

3. **Run additional incentive compatible discrete choice experiments to estimate the consumer valuation of several popular digital goods**
   - Instagram, Snapchat, Skype, WhatsApp, digital Maps, Linkedin, Twitter, and Facebook
   - Conducted in a lab in the Netherlands

4. **Explore the welfare gains from new goods: case study of smartphone cameras**

Alternative explanations for the paradox

1 Mismeasurement
Reality better than measured

2 **Implementation and restructuring lags**
Technology requires complementary innovation

Computerization > Computers

Technology
(10%)

Complementary Skills
and Processes
(90%)

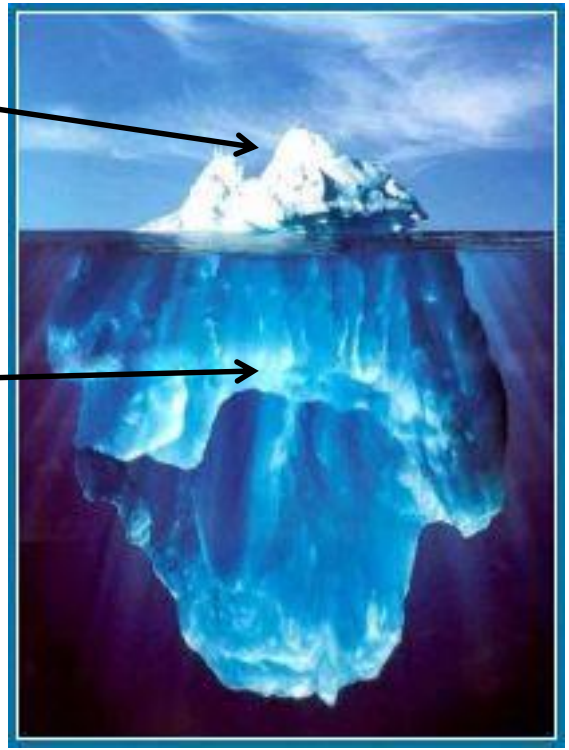
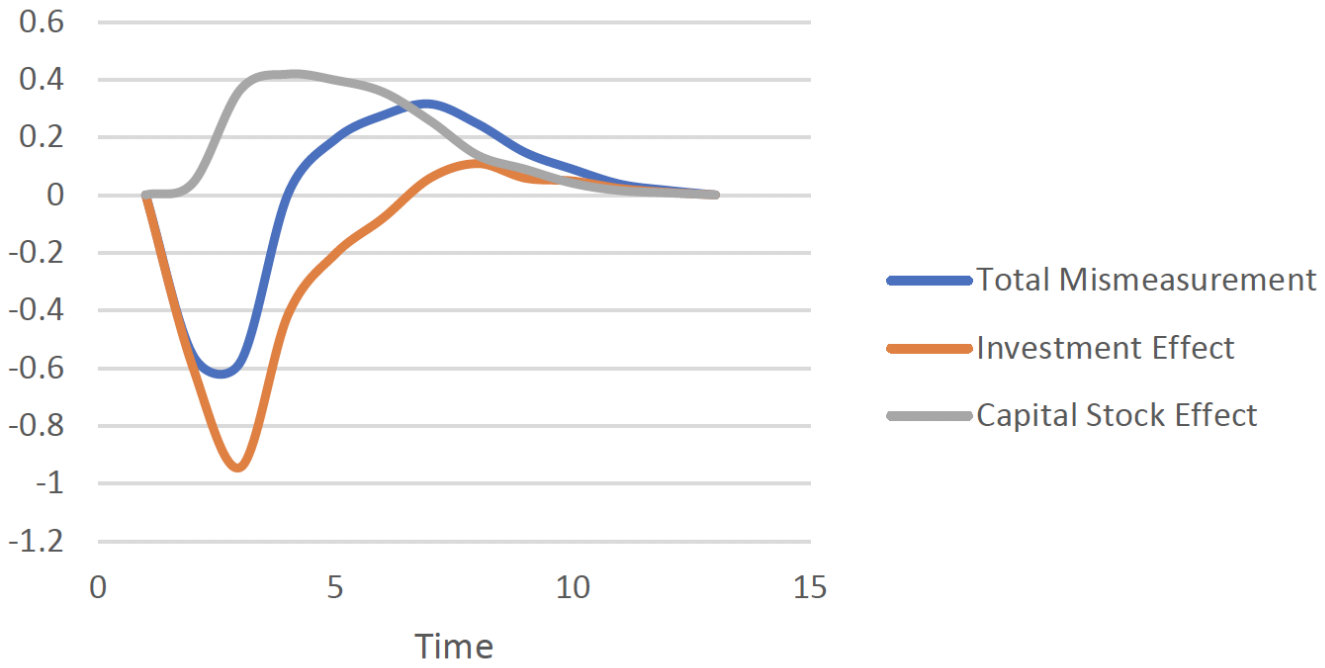


Image by Ralph Clevenger

Source: Brynjolfsson and Hitt, Beyond Computation, *J. Econ. Perspectives*, 2001.

The Productivity J-Curve



Source: Brynjolfsson, Rock and Syverson, “The Productivity J-Cuve” *American Economic Journal: Macroeconomics*, January 2021

Growth Accounting

- **With unmeasured intangible capital, growth accounting equation becomes:**

$$g_Y = \left(\frac{pF_K K}{Y}\right)\left(\frac{\dot{K}}{K}\right) + \left(\frac{pF_N N}{Y}\right)\left(\frac{\dot{N}}{N}\right) + \left(1 - \frac{\lambda}{z}\right)\left(\frac{zI}{Y}\right)\left(\frac{\dot{I}}{I}\right) + \left(\frac{F_t}{F}\right)$$

- Key component is the ratio of the shadow price of investment to the purchase price of capital (details in appendix)
- Physical / marketed component may be small relative to the required investments in org change, training, etc.

Source: Brynjolfsson, Rock and Syverson, "The Productivity J-Cuve" *American Economic Journal: Macroeconomics*, January 2021

Policy challenges

1 Understanding the modern productivity paradox

2 **The transformation of work**

Machine learning, workforce, and wages

How does technology affect wages?

1. Substitution

Machine learning, workforce, and wages

How does technology affect wages?

1. Substitution
2. Complementarities
3. Demand elasticity
4. Income elasticity
5. Supply elasticity
6. New tasks via invention and transformation

Source: Brynjolfsson and Mitchell “What can Machines Learn?” *Science*, 2017

Which tasks will be done by machine learning?

ML is far from AGI

We create a “Suitability for Machine Learning” (SML) rubric to assess tasks

- We apply it to 2,059 Detailed Work Activities in O*NET, 18,112 occupation-specific tasks, and 950 occupations (weighted by task importance)
- Questions are rated on five-point scale from “strongly disagree” to “strongly agree”
- Each DWA is scored by 10 different people

Brynjolfsson, Mitchell and Rock, “What Can Machines Learn and What Does It Means for Occupations and the Economy, *AEA P&P*, 2018.

O*Net: Tasks Done by Radiologists (27 tasks)

Sample Tasks (out of 27 tasks):

1. Provide advice on types or quantities of radiology equipment needed to maintain facilities.
2. Perform interventional procedures such as image-guided biopsy, percutaneous transluminal angioplasty, transhepatic biliary drainage, or nephrostomy catheter placement.
3. Administer or maintain conscious sedation during and after procedures.
4. Interpret images using computer-aided detection or diagnosis systems.
5. Develop treatment plans for radiology patients.
6. Treat malignant internal or external growths by exposure to radiation from radiographs (x-rays), high energy sources, or natural or synthetic radioisotopes.
7. Conduct physical examinations to inform decisions about appropriate procedures.

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Total wage value of high SML, high measurability activities is $713 Billion in the United States

Method: Take the task weights supplied by O*NET and multiply them by the occupational *wage*.

- This is the *wage attributable to the task*
- Calculate the *average wage attributable to the task over occupations*
- Sum the wage bill attributable to the task over all occupations
    - This is the total wage bill in a given task (or activity)

Also calculate the high SML wage value, job-specific wage value

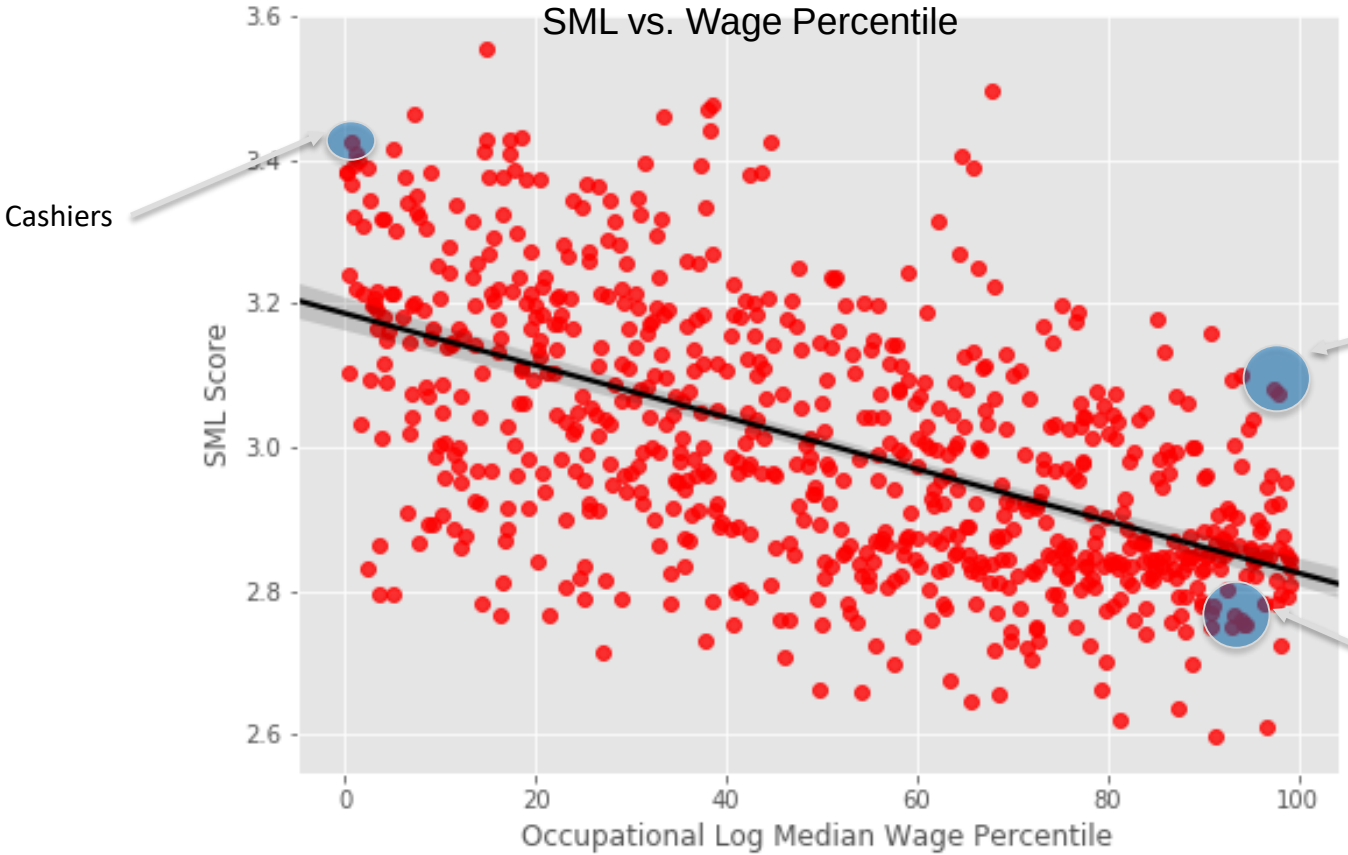
- *High SML, High Measurability wage value:* wage attributable to SML Tasks that are >90th Percentile and >4 Measurability
    - This total is $713 billion
- *Job-specific low SML wage proportion*: (Value of low SML Activity in Job / Value of those Activities in overall economy)

Good News, but Also Challenges

Digital progress makes the economic pie bigger.

But there is no economic law that everyone, or even most people, will benefit.

ML will affect all groups, but especially lower wage workers



Regression of SML on Wages
Slope: -0.0034, t-stat: 18.5

Search by Country

FILTER BY TECHNOLOGY

Machine Learning

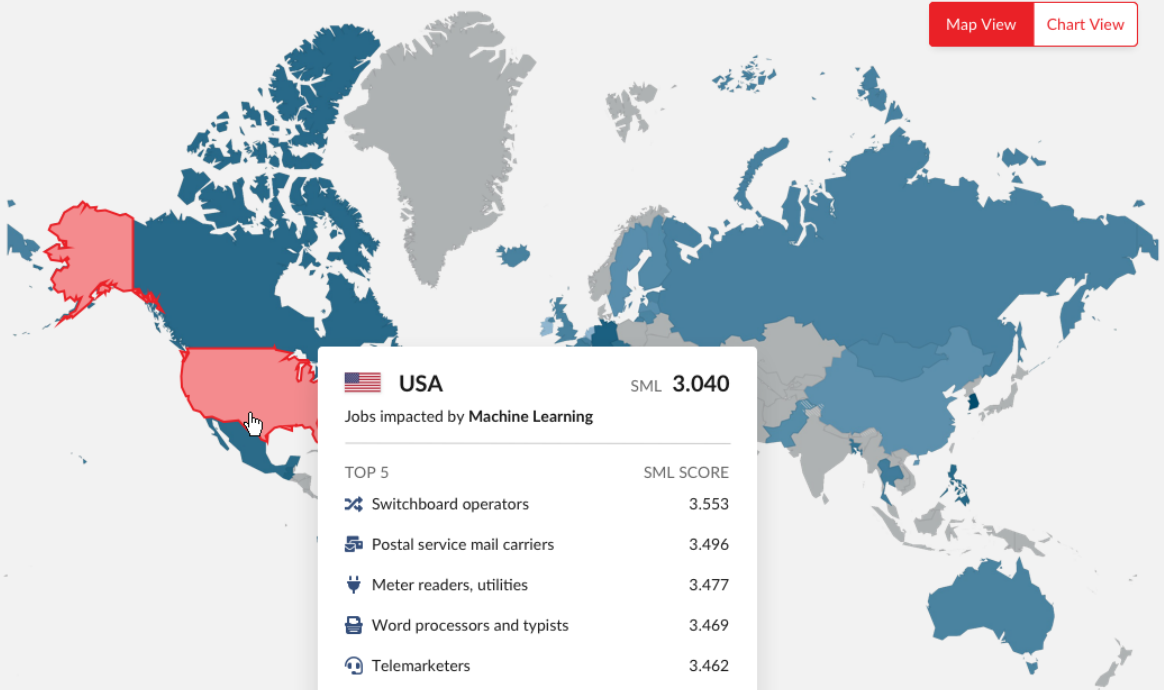
Prediction | Speech Data | Text Data | Image Data | Chatbot | Structured

Overall SML Score

TOP 5 COUNTRIES	SML SCORE
South Korea	3.089
Paraguay	3.080
Brazil	3.077
Colombia	3.077
South Africa	3.065

BOTTOM 5 COUNTRIES	SML SCORE
Burkina Faso	2.828
Ireland	2.937
Netherlands	2.943
Spain	2.968
Nigeria	2.975

Map View | Chart View



USA SML **3.040**

Jobs impacted by **Machine Learning**

TOP 5	SML SCORE
Switchboard operators	3.553
Postal service mail carriers	3.496
Meter readers, utilities	3.477
Word processors and typists	3.469
Telemarketers	3.462

BOTTOM 5	SML SCORE
Psychologists	2.597
Lawyers	2.609
Clinical, counseling, and school psychologists	2.620
Industrial-organizational psychologists	2.637
Forensic science technicians	2.647

5

Suitability

Which Economies Can Best Benefit from Machine Learning?

Back

USA SML 3.040

Summary

Machine Learning	3.040
Prediction	2.456
Speech Data	3.200
Text Data	3.669
Image Data	3.030
Chatbot	3.100
Structured	3.384

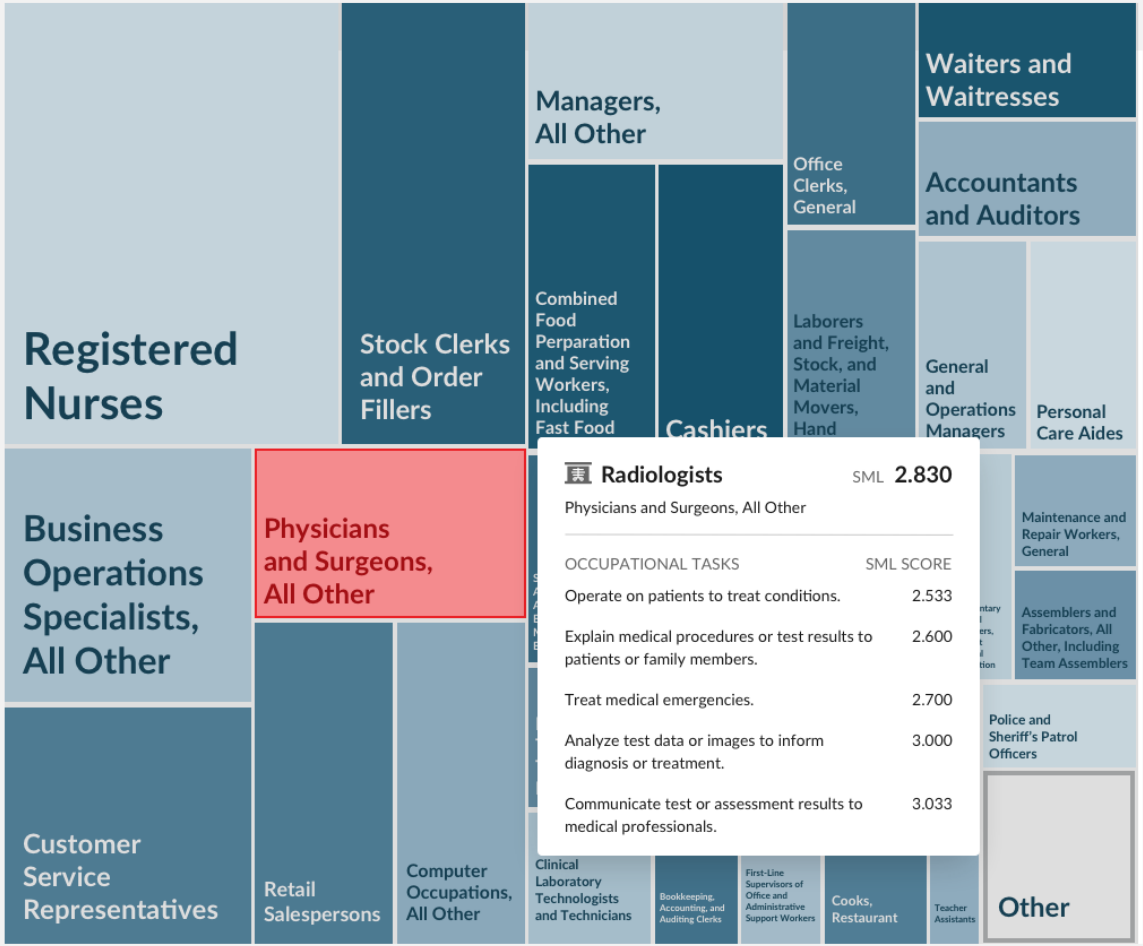
TOP 5	SML SCORE
Switchboard operators	3.553
Postal service mail carriers	3.496
Meter readers, utilities	3.477
Word processors and typists	3.469
Telemarketers	3.462

All Jobs | Average Comparison

Download as .csv

1 2 3 4 5

Low Suitability — High Suitability

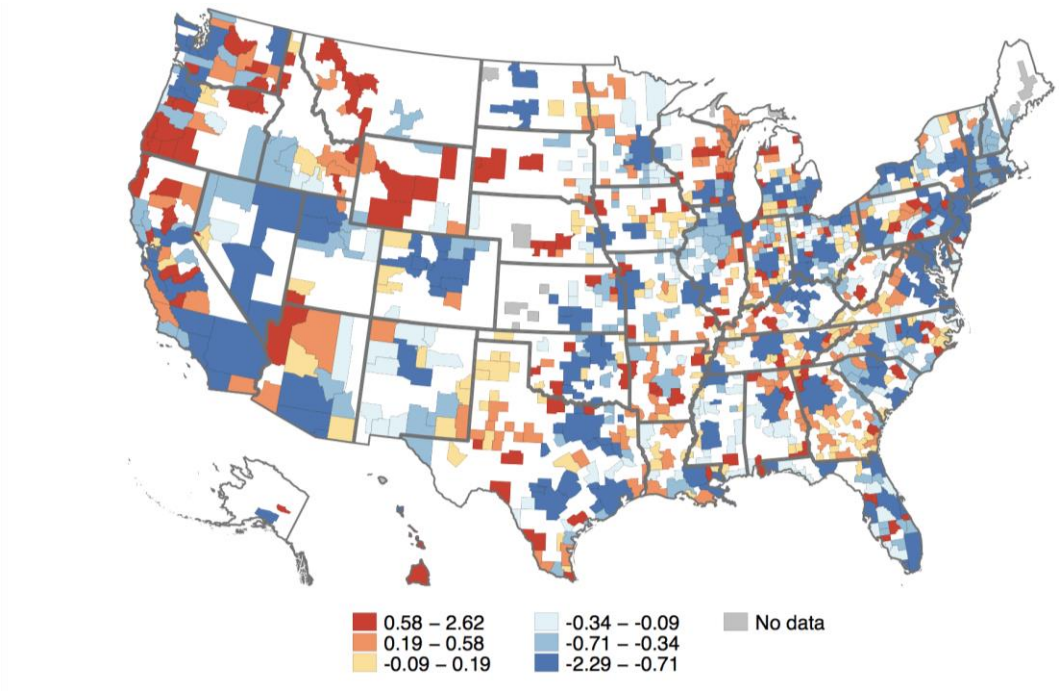


Radiologists SML 2.830

Physicians and Surgeons, All Other

OCCUPATIONAL TASKS	SML SCORE
Operate on patients to treat conditions.	2.533
Explain medical procedures or test results to patients or family members.	2.600
Treat medical emergencies.	2.700
Analyze test data or images to inform diagnosis or treatment.	3.000
Communicate test or assessment results to medical professionals.	3.033

Regions vary in ML exposure



SML Standardized Score by Metro Area

The New Grand Challenge

- **Digital technologies will continue to accelerate**
- **Our skills, organizations and institutions are lagging**
- **Business as usual won't solve this problem**

How can we reinvent our economy and society to keep up with accelerating technology?

- *New Metrics*
- *New Skills*
- *New Business Processes*
- *New Institutions*

To Learn More:

AI & Future of Work Resources:
https://digitaleconomylab.stanford.edu/AIfowResources

Measuring the Economy:
https://www.measuringtheeconomy.org/

Stanford Digital Economy Lab:
https://digitaleconomy.stanford.edu/

Erik Brynjolfsson:
https://www.brynjolfsson.com/

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HAI Stanford University Human-Centered Artificial Intelligence