AI and Productivity: A General Purpose Technology Approach

or

Do androids recognise eclectic sheep?

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ECB, Conference on The Transformative Power of AI: Economic Implications and Challenges

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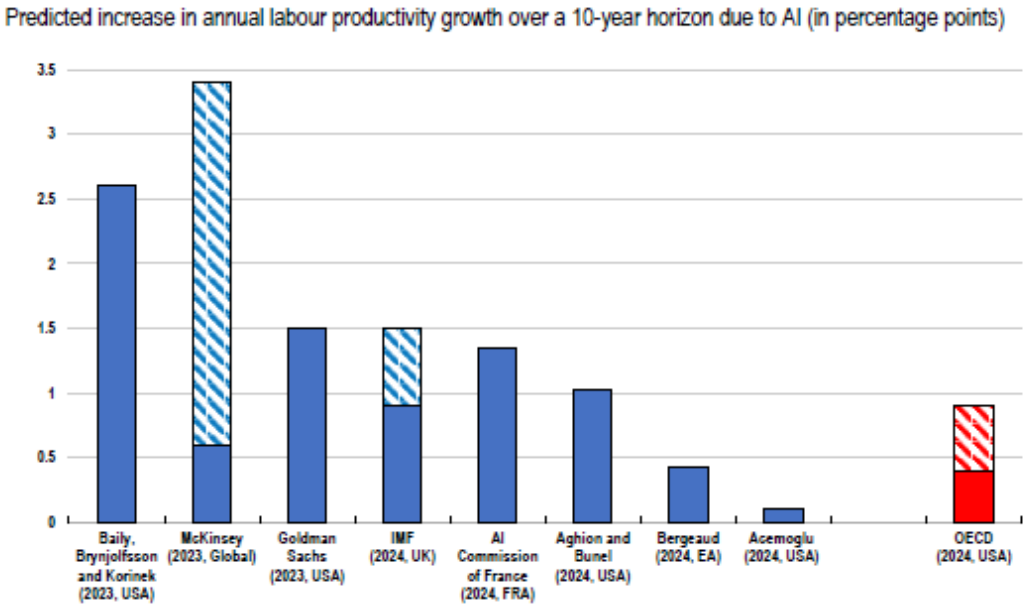
Joint work as part of EUKLEMS-INTANProd project with Filippo Bontadini, Carol Corrado, Cecilia Jona-Lasinio

Wide estimates of the effect of AI on labour productivity and TFPG….



- Gains to TFP
  - Acemoglu = 0.064pppa
  - Gal et al = 0.14-0.38pppa
- Source: Gal et al, Table 2, Acemoglu, p.41.

Notes: effect on TFP and implied capital deepening
Source: Gal et al, Figure A10.

Where do these estimates come from? The "task-based" approach

- Assumption: AI will reduce costs of labour on certain tasks "labour saving technical change"
- Implied cost reduction is then

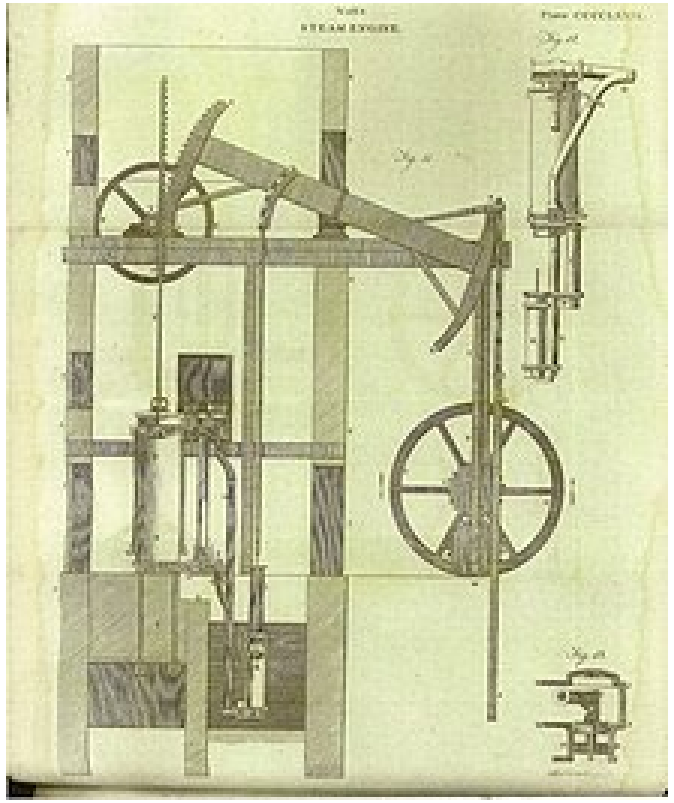
$$d(tfp)' = \frac{P_L L}{P_V V}\left(\sum_{s\in T} \underbrace{\frac{P_{L_s} L_s^T}{P_L L}}_{\text{Wage share, tasks exposed to AI}} \underbrace{\phi}_{\text{Share exposed tasks profitably automated in Y years}} \underbrace{d\theta_s^{T,AI}}_{\text{Cost saving over Y years}} \underbrace{\frac{1}{Y}}_{\text{Convert to saving per annum}}\right)$$

0.06%pa	0.5	0.2	0.23	0.27	1/10

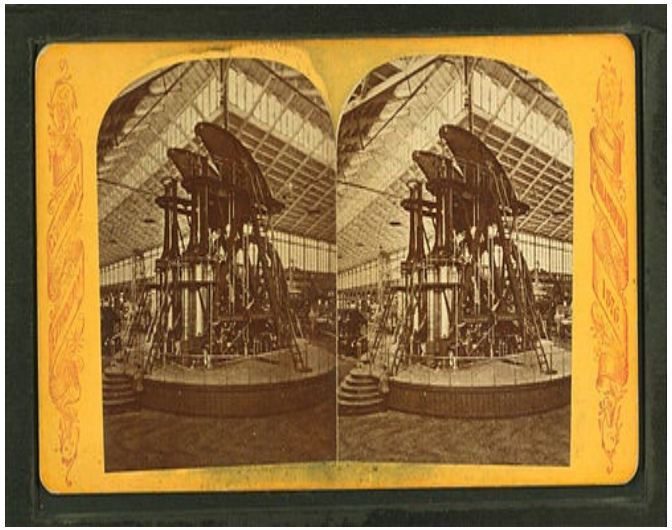
What if AI is a GPT?

- Definition:
- “characterized by the potential for pervasive use in a wide range of sectors and by their technological dynamism. As a GPT evolves and advances it spreads throughout the economy, bringing about and fostering generalized productivity gains.“ (Bresnahan, Trajtenberg, 1995)
- GPT in agriculture: Hybrid corn (Griliches, 1957)
  - Not a type of corn
  - A method of breeding corn suited to the local environment
  - “…the invention of a method of inventing”
- General examples: steam, electricity, semi-conductor
- Note: Acemoglu p.17 “I also do ***not*** discuss how AI can have revolut effects by changing the process of science” [our emphasis]

Steam: the AI of its time…



Watt Steam Engine, 1797



Corliss steam Engine, 1849: 30% less fuel, 30% more power

Albion Mills (steam-powered flour mill), London 1786

SS Savannah, the first steam-powered ship to cross the Atlantic Ocean—1819

Stephenson's Rocket, 1829

GPT and productivity growth: steam

Tangibles, type b

$$di^b = \sum \frac{P_L L}{P_I I^b} dl^{I^b} + \sum_{b \in K} \frac{P_{K_b} K_b^{I^b}}{P_I I^b} dk_b^{I^b} + da^{I^b}$$

- **Production**: steam engine producing sector

Consumption

$$dc = \sum_{s \in L} \frac{P_L L}{P_C C} dl^C + \sum_{b \in K} \frac{P_{K_b} K_b}{P_C C} dk_b^C + da^C$$

- **Use**: railways, coal mines

Labour productivity growth

$$d(v/l) = \sum_{b \in I} \frac{P_{I_b} I_b}{P_V V} da^{I^b} + \frac{P_C C}{P_V V} da^C$$

$$+ \frac{P_K K}{P_V V} \left(\sum_{b \in K} \frac{P_{K_b} K_b^{I^a}}{P_K K^I} d(k_b^{I^a} / l) + \sum_{b \in K} \frac{P_{K_b} K_b^C}{P_K K^C} d(k_b^C / l) \right)$$

$$d(v/l)' = \sum_{b \in Steam} \frac{P_{I_b} I_b}{P_V V} da^{I^b}$$

$$+ \frac{P_K K}{P_V V} \left(\sum_{b \in Steam} \frac{P_{K_b} K_b}{P_K K} d(k_b / l) \right)$$

- **Total d(v/l)**
  - TFP in production
  - **+**
  - Capital deepening
- **Steam impact**
  - TFP in steam production * size of steam production
  - +
  - Steam-capital deepening *share of steam capital payments

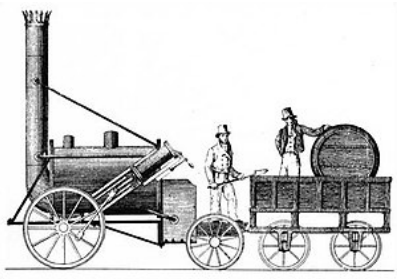
Why is the impact of GPTs so small when they are so productive?

$$d(v/l)' = \sum_{b \in Steam} \frac{P_{I_b} I_b}{P_V V} da^{I^b}$$

$$+ \frac{P_K K}{P_V V} \left(\sum_{b \in Steam} \frac{P_{K_b} K_b}{P_K K} d(k_b / l) \right)$$

Steam: 1760-1830
TFPG= 3%

ICT: 1973-95
TFPG = 22%



Steam: 1760-1830
Cap deepening= 4%

ICT: 1973-95
Cap deepening= 13%

Why is the impact of GPTs so small when they are so productive? **[Steam = 0.02%, ICT= 0.67%]**

Steam: 1760-1830
share= 1%

ICT: 1973-95
Share = 1.5%

Steam: 1760-1830
TFPG= 3%

ICT: 1973-95
TFPG = 22%

$$d(v/l)' = \sum_{b \in Steam} \frac{P_{I_b} I_b}{P_V V} da^{I^b}$$

$$+ \frac{P_K K}{P_V V} \left(\sum_{b \in Steam} \frac{P_{K_b} K_b}{P_K K} d(k_b / l) \right)$$

Steam: 1760-1830
share= 0.2%

ICT: 1973-95
Share = 4.2%

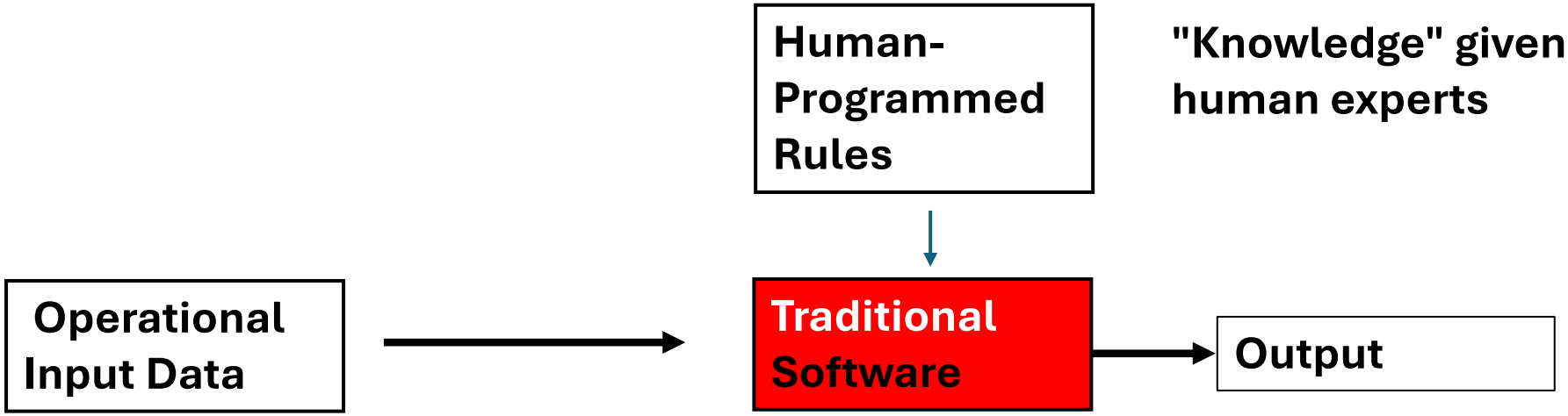
Steam: 1760-1830
Cap deepening= 4%

ICT: 1973-95
Cap deepening= 13%

What is AI?

- AI first generation “Handcrafted Knowledge AI” (Allen, 2020)
- Chess Deep Blue (1997 victory)
- Software was
  - Rules of chess moves
  - Strategy advice from chess masters

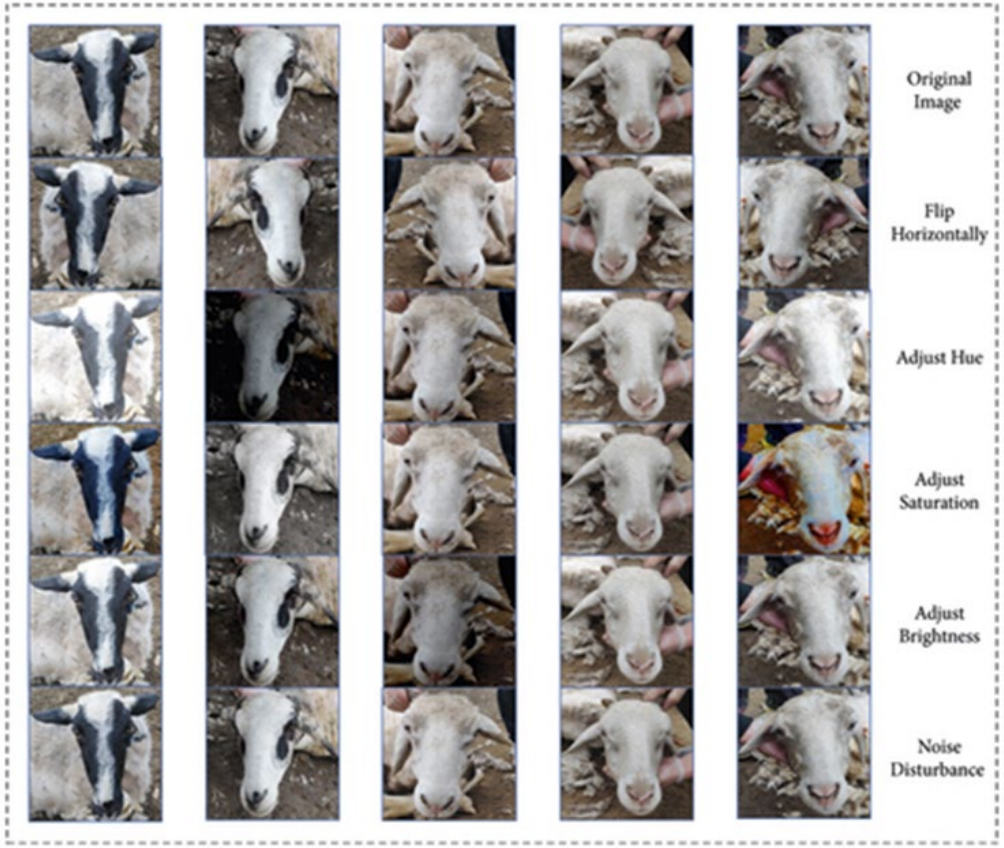
Source: Deep blue versus Gary Kasparov



Source: Allen, 2020

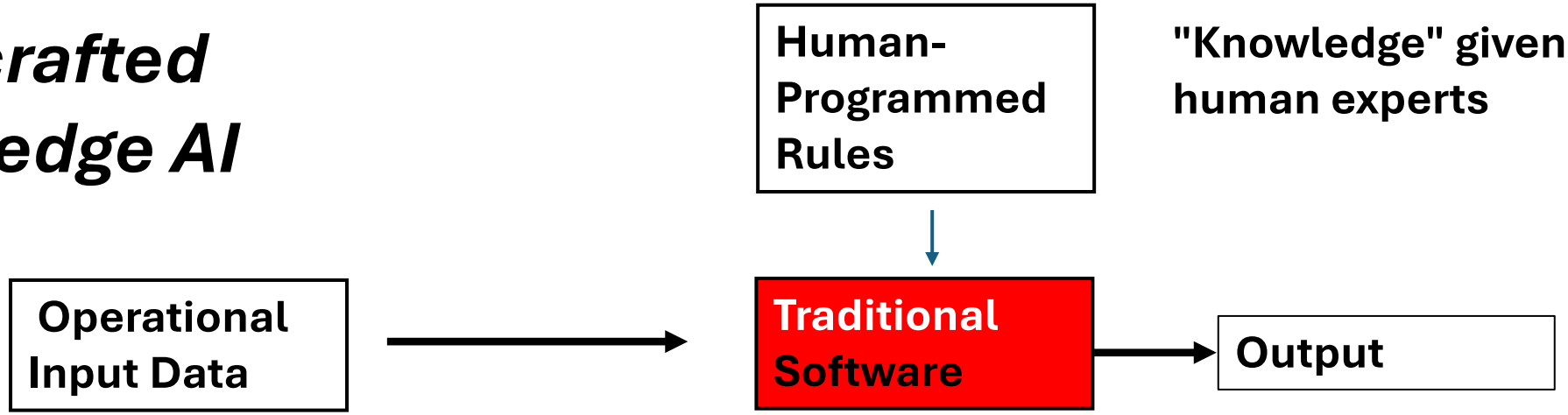
Machine Learning AI:
Do androids recognise eclectic sheep?

- Facial recognition: too hard for
  - Humans
  - For handmade software
- How does ML AI do it?
  - Use pictures (= unstructured data)
  - ML: Train software on subset of pictures (shapes, distances between features etc.)
  - Used trained software to recognise all pictures

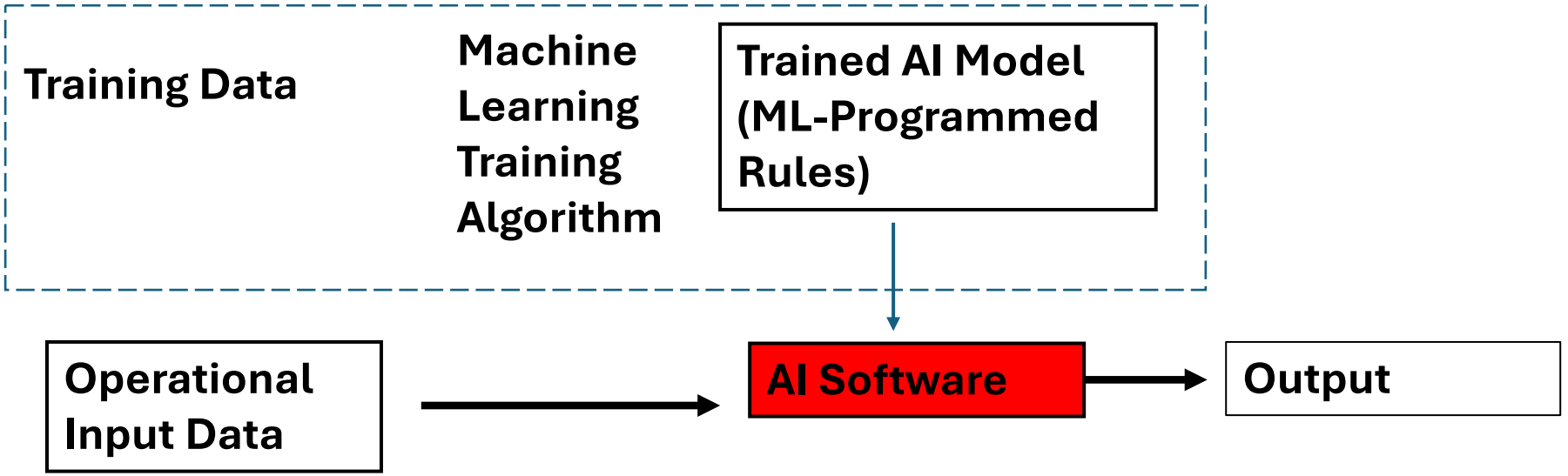


Xue, H, et al, 2021, Mathematical Problems in Engineering.

Handcrafted Knowledge AI



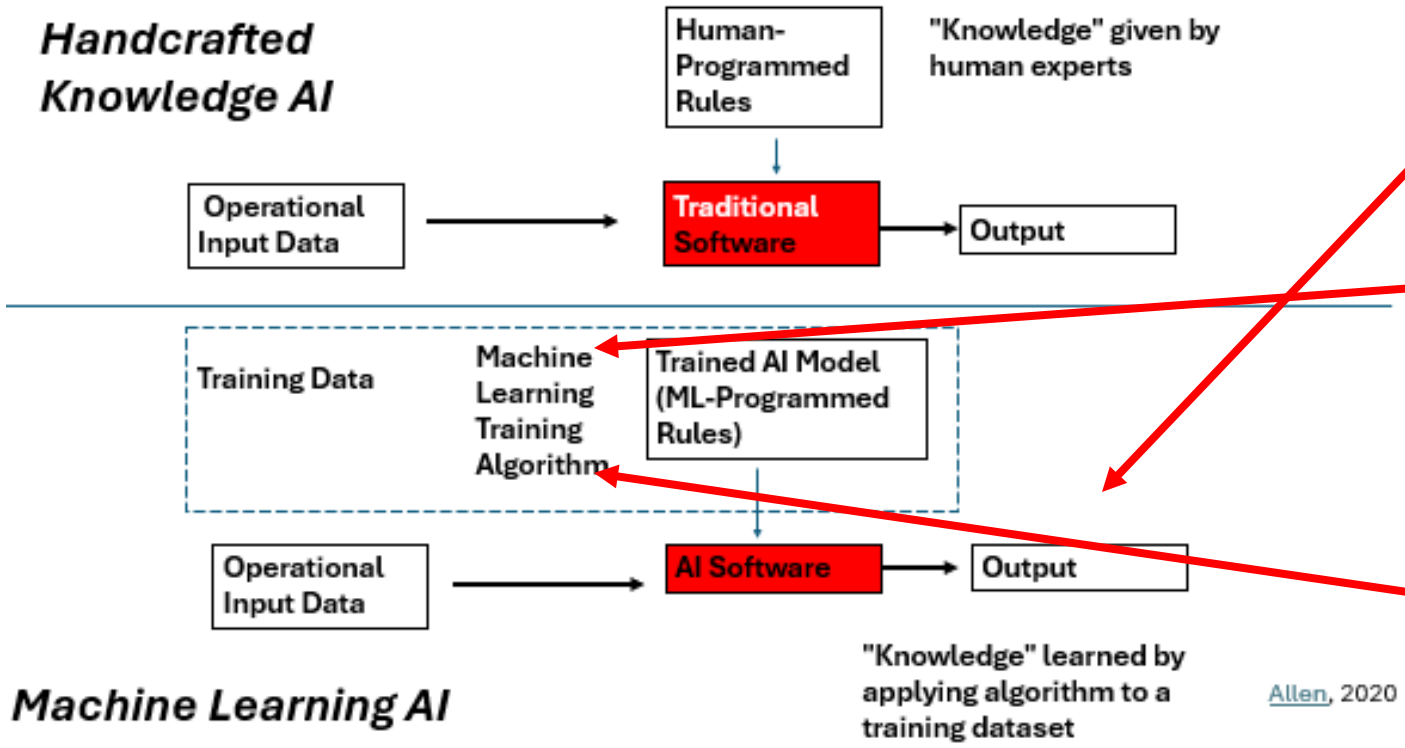
Machine Learning AI



"Knowledge" learned by applying algorithm to a training dataset

Allen, 2020

Digression: what is ChatGPT?



Allen, 2020

- Generative
  - generates responses and new content
- Pre-trained
  - Trained on data
- Transformer
  - Type of neural network ML method

Where is software in GDP?

- Investment types
- Tangible:
  - Buildings
  - Vehicles
  - Computer
  - Non-computer plant and machinery
- Intangible
  - Software and databases
  - R&D
  - Artistic originals

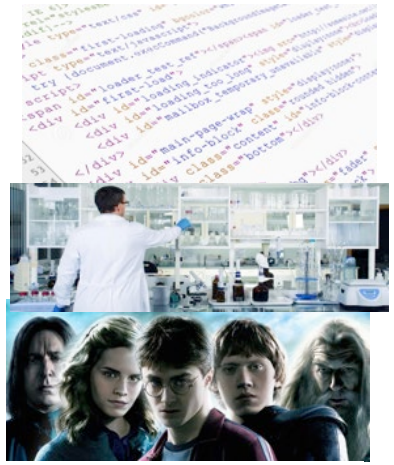
What do these task exposures measure?

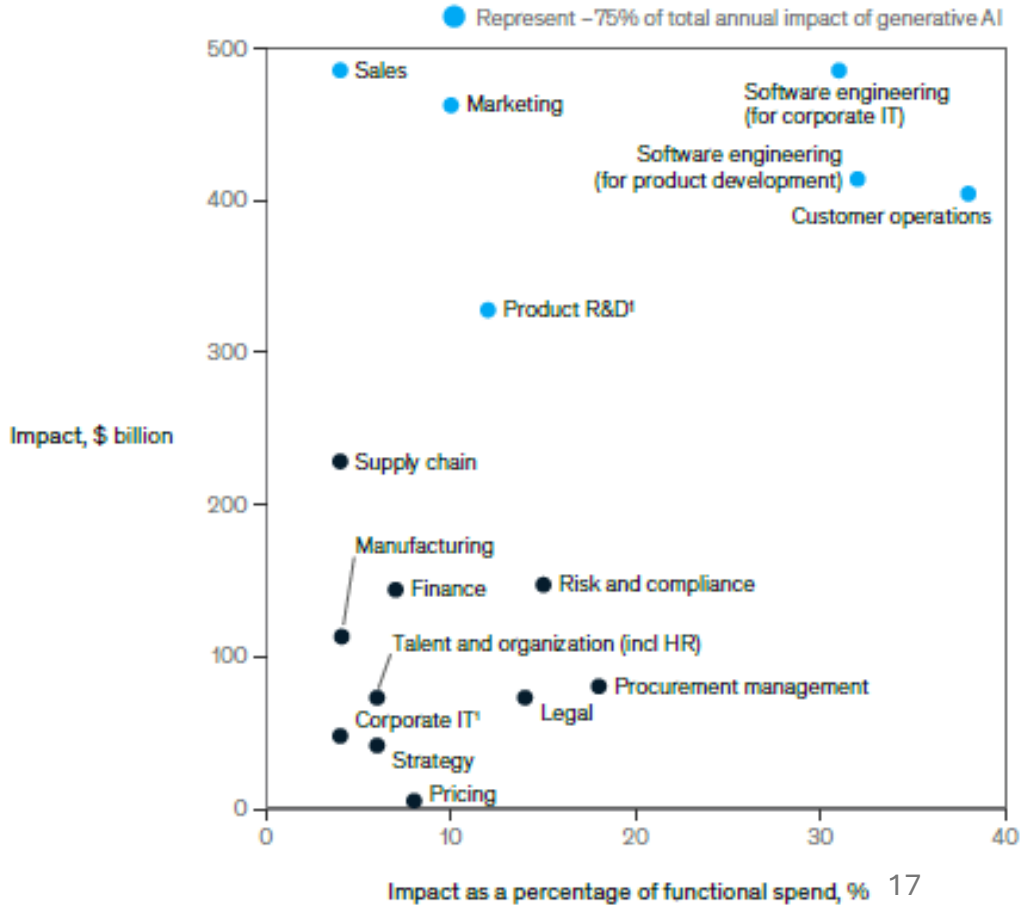
- Eloundou, et al, 2024, Supplementary material, Table 3.1.1.
- Direct exposure (E1) if:
  - *using LLM* …can decrease the time required to complete the [activity] or task by at least 50% [our italics]
- LLM+ Exposed (E2) if:
  - *additional software could be developed* on top of the LLM that could reduce the time it takes… (including) image generation systems [our italics]

- E2 seems like the equivalent of steam capital deepening
- = Software capital deepening

How do we interpret AI?

- Narrow: just software
  - Production: TFPG in software writing
  - Use: Software capital deepening
- But maybe AI is Broader…
  - AI uses data, so TFPG and deepening in data
  - AI helps with R&D and creativity
  - McKinsey: AI affects many intangible business functions





GPT analysis with intangibles

Intang, type a

$$dn^a = \sum \frac{P_L L^{N^a}}{P_N N^a} dl^{N^a} + \sum_{b \in K} \frac{P_{K_b} K_b^{N^a}}{P_N N^a} dk_b^{N^a} + da^{N^a}$$

- Production of intangible capital

Tan, type b

$$di^b = \sum \frac{P_L L^{I^b}}{P_I I^b} dl^{I^b} + \sum_{b \in K} \frac{P_{K_b} K_b^{I^b}}{P_I N^b} dk_b^{I^b} + da^{I^b}$$

- Production of tangible capital

Consumption

$$dc = \sum \frac{P_L L^C}{P_C C} dl^C + \sum_{b \in K} \frac{P_{K_b} K_b^C}{P_C C} dk_b^C + \sum_{a \in N} \frac{P_{R_a} R_a^C}{P_C C} dr_a^C + da^C$$

- Use of tangible and intangible

AI contribution to labour productivity growth, AI=software/data and robots

$$d(v/l)' = \sum_{a \in AI, SOFT/DATA} \frac{P_{N_a} N_a}{P_V V} da^{N^a} + \sum_{b \in AI, ROBOTS} \frac{P_{I_b} I_b}{P_V V} da^{I^b}$$

$$+ \frac{P_K K}{P_V V} \left(\sum_{b \in AI, ROBOTS} \frac{P_{K_b} K_b}{P_K K} d(k_b / l) \right)$$

$$+ \frac{P_R R}{P_V V} \left(\sum_{a \in AI, SOFT/DATA} \frac{P_{R_a} R_a^C}{P_R R} d(r_a^C / l) \right)$$

- TFPG in AI software/data and robots
- AI robot capital deepening
- AI software/data capital deepening

AI contribution to lab prod growth, AI=software/data, or broader

$$d(v/l)' = \sum_{a \in AI, SOFT/DATA} \frac{P_{N_a} N_a}{P_V V} da^{N^a}$$

$$+ \frac{P_R R}{P_V V} \left(\sum_{a \in AI, SOFT/DATA} \frac{P_{R_a} R_a^C}{P_R R} d(r_a^C / l) \right)$$

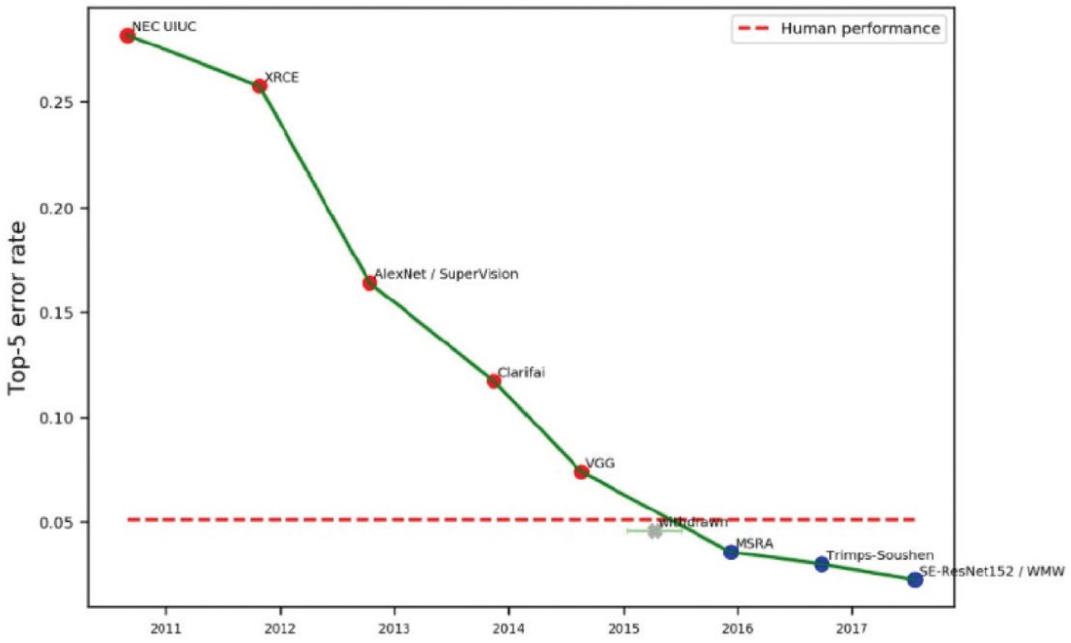
- **Production:** TFPG in AI software/data
- (Broader: TFPG in intangible business functions)

- **Use:** AI software/data capital deepening
- (Broader: capital deepening in intangible assets)

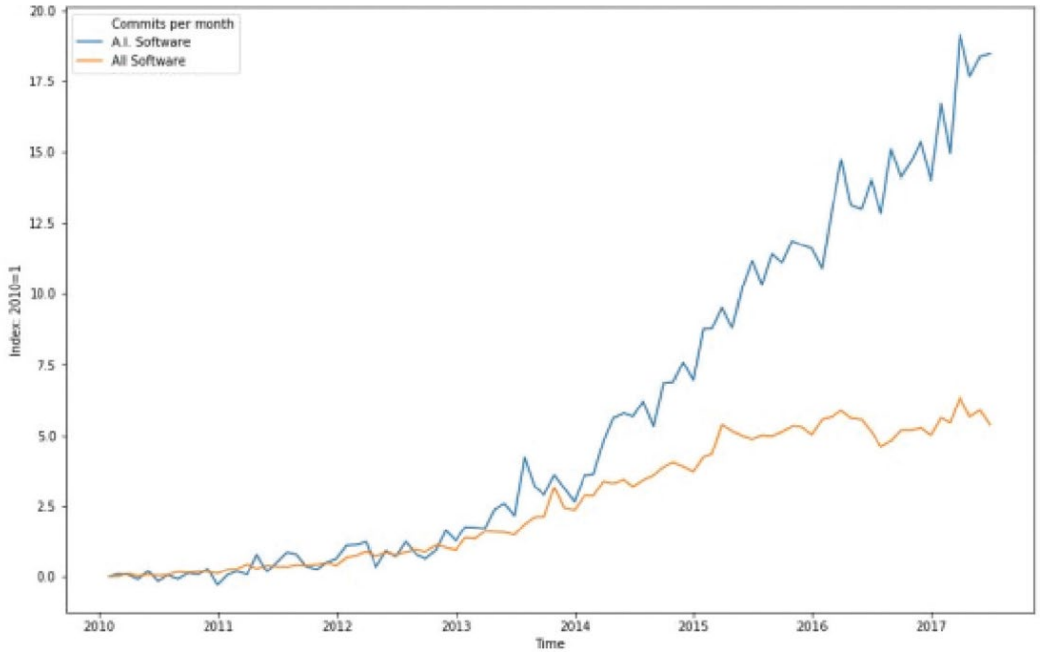
Illustration: software, pre-2015 and 2015-19

Big data era, but before Gen AI (2022+)

Image recognition



AI use in Open Source software



Source: Corrado, Haskel, Jona-Lasinio, OxRep 2021

J62-63, IT & other info services

$$d(v/l)' = \sum_{a \in J6263} \frac{P_{N_a} N_a}{P_V V} da^{N^a}$$

$$+$$

$$\frac{P_R R}{P_V V}\left(\sum_{a \in SOFT/DATA} \frac{P_{R_a} R_a^C}{P_R R} d(r_a^C / l) \right)$$

2010-14:
TFPG= 2.7%, Share =0.04, **Contrib = 0.11**

2015-19:
TFPG= 3.2%, Share =0.05, **Contrib = 0.15**

2010-14:
Kdeep= 5.2%, Share =0.03, **Contrib = 0.17**

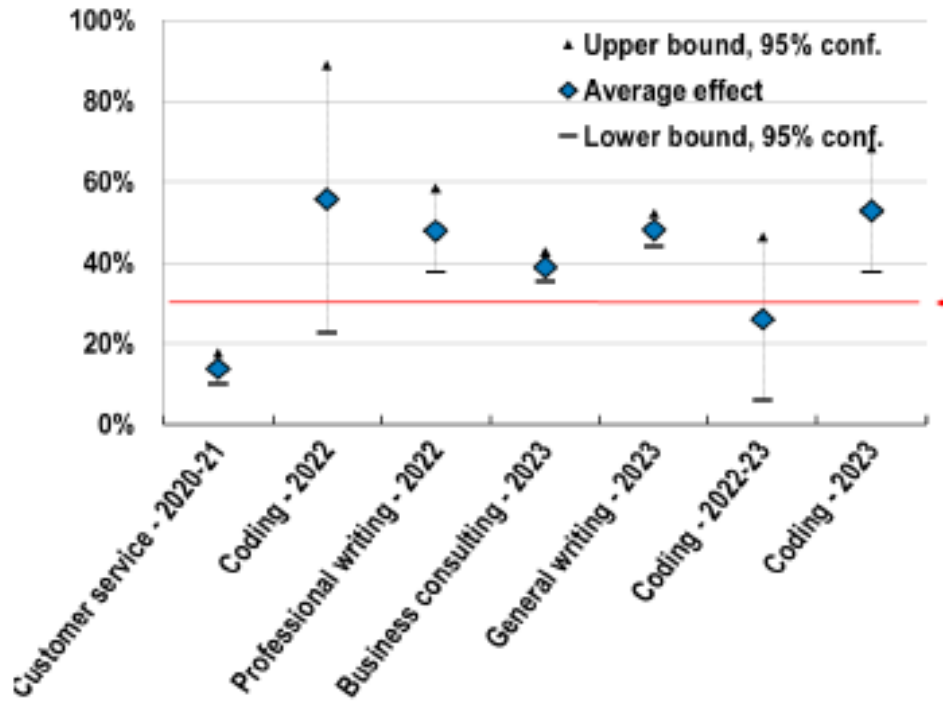
2015-19:
Kdeep= 6.7%, Share =0.04, **Contrib = 0.25**

Gains from IT/other info svcs: summary

- USA data pre/post 2015-19
  - TFP gain = 0.5%
  - K deep gain = 1.5%
  - Total gain = 0.04+0.08=0.12%pa
- Future TFP gains?
  - Micro studies; OECD average = 30% productivity gain from GenAI !
    - Not clear if TFP
    - Just the adopting firms
    - How long to take?
    - note across many business functions

Figure 3. Micro-level performance gains from AI for workers in specific tasks

Estimates of the impact of Generative AI from recent micro-level studies



Source: Filippucci, Gal, and Schief 2024

Broader

$$d(v/l)' = \sum_{a \in AI} \frac{P_{N_a} N_a}{P_V V} da^{N^a}$$

$$+$$

$$\frac{P_R R}{P_V V}\left(\sum_{a \in AI} \frac{P_{R_a} R_a^C}{P_R R} d(r_a^C / l) \right)$$

2015-19:
IT&info: TFPG= 3.2%, Share =0.05,
Contrib = 0.15
Intang: TFPG = ?, Share = 0.14+(X-M)

2015-19:
IT&info: Kdeep= 6.7%, Share =0.04,
Contrib = 0.25
Intang: Kdeep = 4.0%, Share = 0.25,
Contrib= 1.01

Steady state, two sector model

$$d(v/l)' = \sum_{a \in AI} \frac{P_{N_a} N_a}{P_V V}(da^{N^a} - da^C)$$

$$+ \frac{\frac{P_R R}{P_V V}(da^{N^a} - da^C)}{\frac{P_L L}{P_V V}}$$

2015-19:
IT&info: 0.05 + (X-M)
Intang: 0.14 + (X-M)

IT&info share: 0.04
Intang share: 0.25,
Lab share = 0.55 (share ratios: 0.07, 0.45)

Low share: 2% TFP advantage = 0.1+0.14=0.24pa

High share: 5% advantage = 0.7+2.25=2.95%pa

10% share, 2% advantage = 0.56%pa

Summary

- Investigation: AI as an innovation in innovation => TFP gain in production of intangibles
- Gains from steam and ICT at start were small because asset base was small
- Expect gains to be higher **because asset base is higher**
  - Steam income share <0.01 for 60 years
  - Software income share = 0.04 now
  - Intangible income share = 0.25 now
- Rough estimate of Big Data gains to LPG 2015-19 = 0.12pppa
- TFPG gains
  - 2%: short run TFPG rise = 0.1-0.2pppa, long run LPG=0.3-0.6pppa
  - 5%: short run TFPG rise = 0.3-0.5pppa, long run LPG =0.7-1.4pppa
- Provisional conservative estimate of near-term LPG gains = twice Big Data gains= 0.24ppa