

Economic impacts of AI-augmented R&D

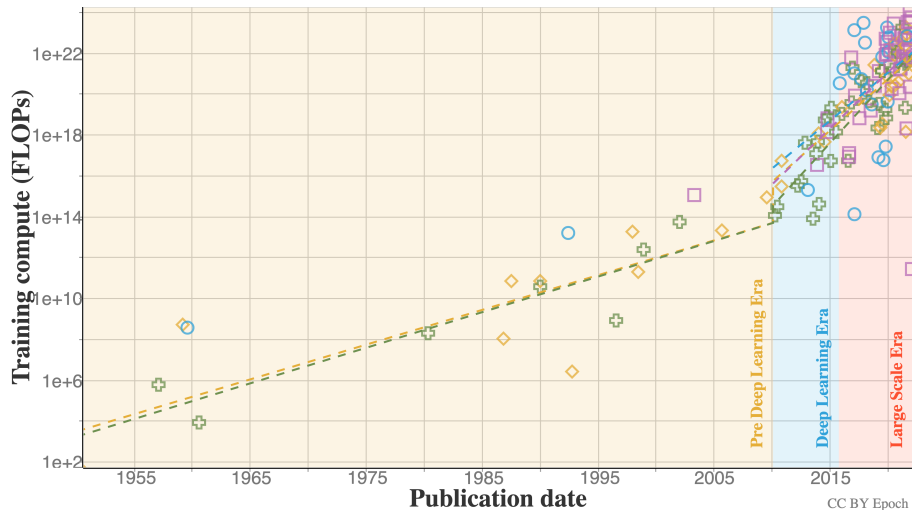
[arXiv:2212.08198](https://arxiv.org/abs/2212.08198)

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Fourth AI and Strategy Consortium, January 22-23, 2023

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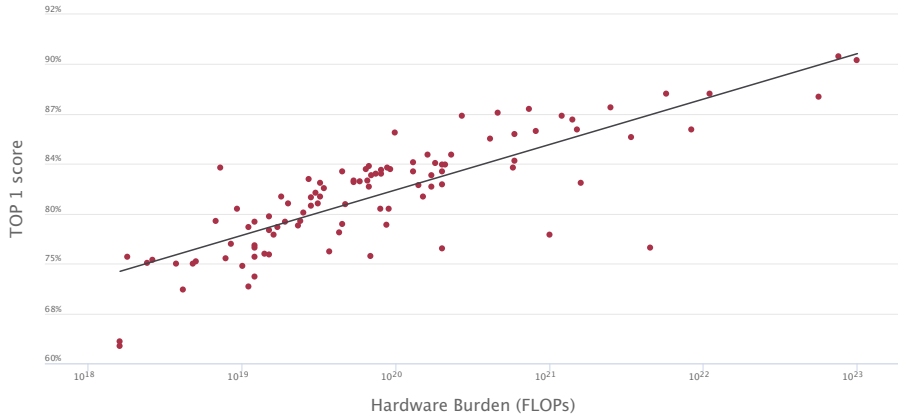
Motivation



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Sevialla, Heim, Ho, Besiroglu, Hobbhahn, and Villalobos, 2022

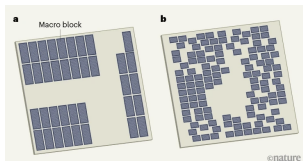
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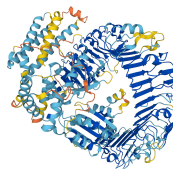
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Thompson, Greenewald, Lee, and Manso, 2020

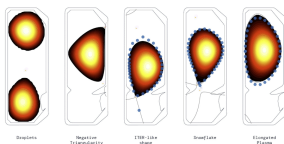
Motivation: AI's inroad into science and technology



(a) Reinforcement learning for chip floorplanning (Mirhoseini et al. 2021)



(b) AlphaFold (Jumper et al. 2021)



(c) Controlling the nuclear fusion plasma in a tokamak (Degraeve et al. 2022)

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How might AI change productivity and growth?

Output (Solow–Swan):

$$\underbrace{Y}_{\text{Output}} = \underbrace{A^\theta}_{\text{Stock of ideas}} \times \underbrace{K^\beta}_{\text{Capital}} \times \underbrace{L^\gamma}_{\text{Labor}}$$

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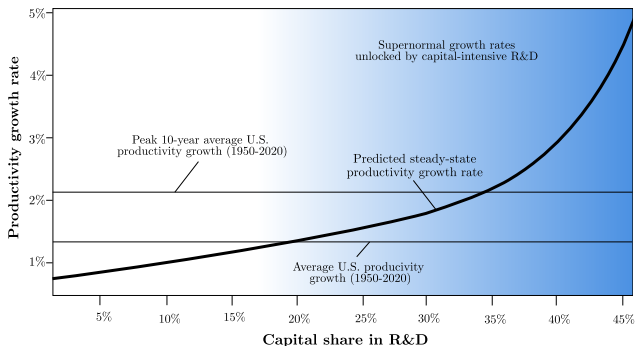
$$\underbrace{\dot{A}}_{\text{Change in stock of ideas}} = L^\gamma \times A^\theta$$

Building on Howitt and Aghion 1998; Howitt 1999, we introduce capital into idea-production:

$$\dot{A} = L^\gamma \times K^\beta \times A^\theta$$

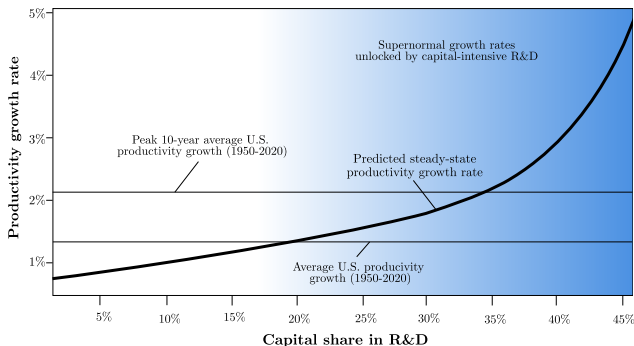
What does theory predict?

Steady-state productivity is increasing in the capital-share of R&D

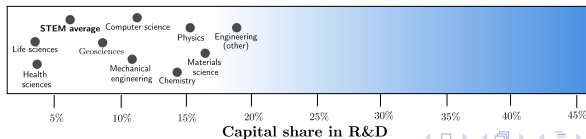


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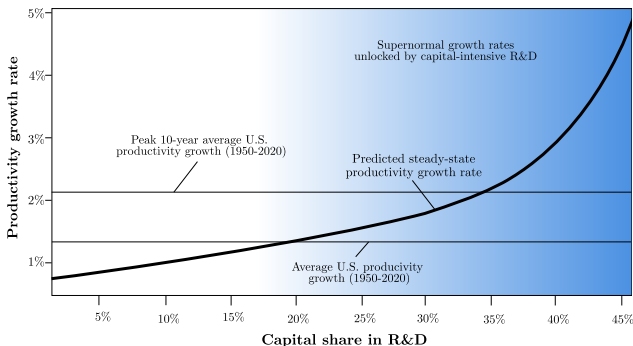


U.S. R&D is highly labor-intensive

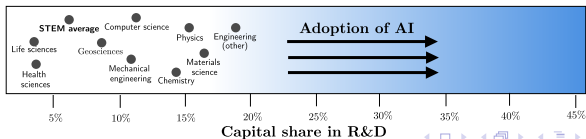


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Steady-state productivity is increasing in the capital-share of R&D



The adoption of AI might change this



Background: Machine Learning

- In classical statistical learning theory, there generally is a trade-off between bias and variance
- Not with current AI: DNNs evade bias-variance trade-off through “overparameterization”

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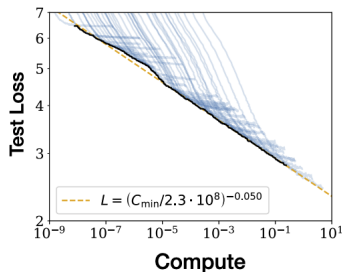
“The only thing that matters in the long run is the leveraging of computation.” — Sutton (2019)

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“The only thing that matters in the long run is the leveraging of computation.” — Sutton (2019)

- Scaling laws indicate predictable and regular returns to compute



Scaling laws from Kaplan et al. 2020

Our data

We want estimate the 'idea production function' for deep learning

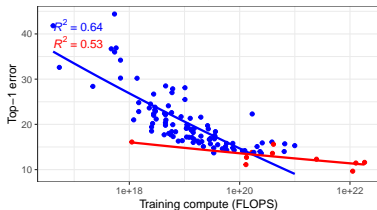
- ~ 150 computer vision from papers published between 2012 and 2022
- Estimates of compute inputs and estimates of the quality of human capital

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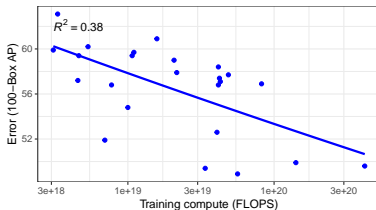
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A Image classification on ImageNet



B Object Detection on MS COCO-2017



Compute usage and performance
With extra training data (red), without (blue)

Human capital

- **Standard approach:** look at information about bibliometric indicators for researchers

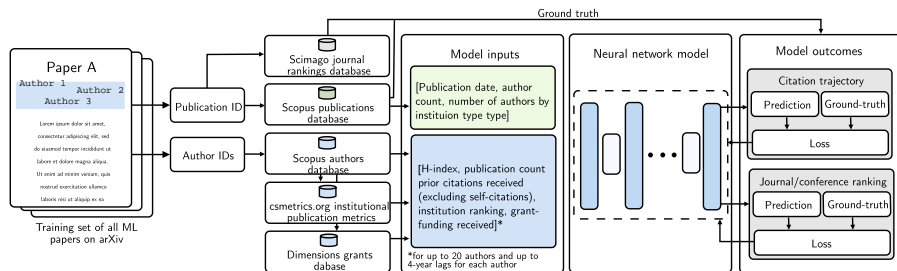
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Our training setup

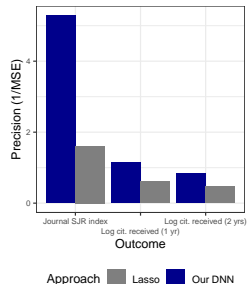
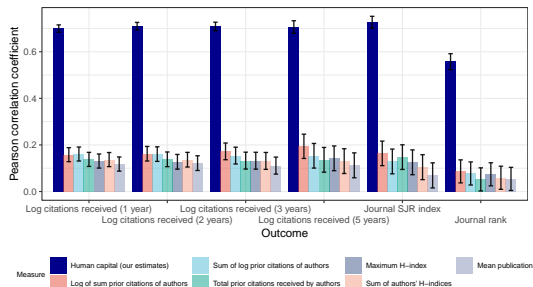


Human capital

Our estimates are highly predictive of publication-related outcomes

Human capital

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(g) Our human capital estimates predicts key outcomes much better than commonly used indicators

(h) Our estimates surpass individual lasso regs on test-set

Our estimates

Idea production:

$$\dot{A} = L^{\gamma} \times K^{\beta} \times A^{\theta}$$

Our estimates

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More generally, we consider CES production:

$$\dot{A} = \left[\gamma L^{\frac{\sigma-1}{\sigma}} + \beta K^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \times A^{\theta}$$

In a competitive R&D sector, we derive the optimal capital share:

$$\underbrace{f}_{\text{Capital share in R\&D}} = \frac{\beta K^{\frac{\sigma-1}{\sigma}}}{\beta K^{\frac{\sigma-1}{\sigma}} + \gamma L^{\frac{\sigma-1}{\sigma}}}.$$

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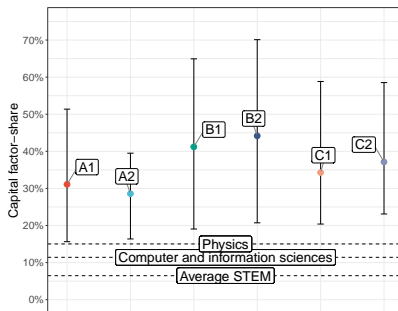
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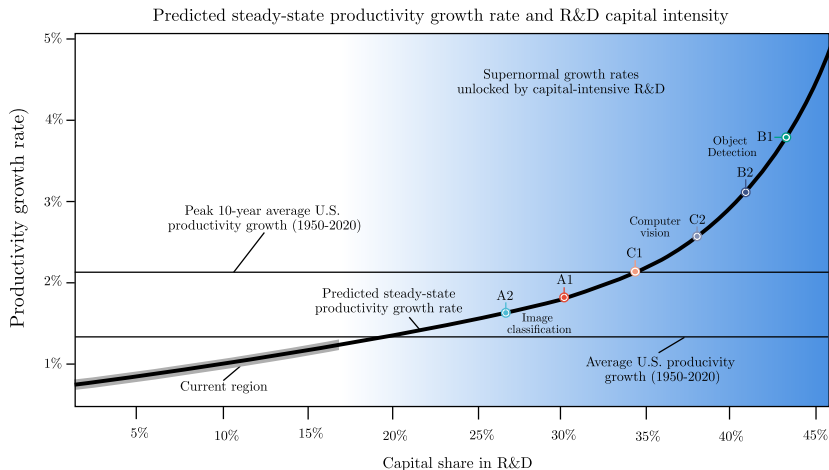
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R&D capital shares for AI are high:



Capital shares for deep learning in computer vision

What do our results imply?



Widespread adoption of deep learning could raise productivity growth to between 2% and 2.5% merely by changing factor shares

Thanks!

Feedback would be much appreciated. Get in touch at tamay@mit.edu



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