

# Generative AI and the Nature of Work

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<sup>4</sup>GitHub Inc.



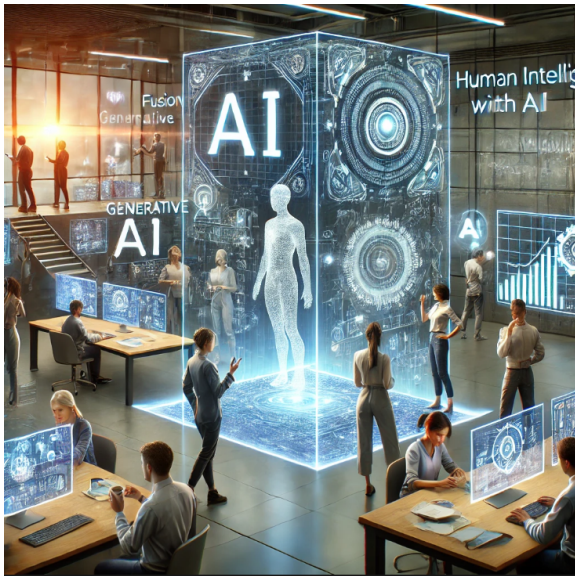
**Harvard  
Business  
School**

Laboratory for  
Innovation Science  
at Harvard



Conference on the Transformative Power of Generative AI  
European Central Bank, Frankfurt April 2, 2025

# The future of work with generative AI?



DALL-E rendering of "Generative AI and the Nature of Work"

Research

# Research Question

**Broadly:** How does AI change the nature of work?

**Narrowly:** Does AI change task allocation for open source software (OSS) production?

# Overview

**RQ:** How does AI adoption change the nature of work?

**Context:** Weekly activity for 2 years of OSS maintainers

**Natural experiment:** A discontinuity in GitHub's Copilot program to offer a free coding GenAI to “top maintainers”

## Main results

- ⇒ Task reallocation: Core Work ↑ Project Management ↓
- ⇒ Impact stronger for those with lower ability
- ⇒ Two primary mechanisms:
  - Autonomous work ↑, collaborative work ↓
  - Exploration ↑ Exploitation ↓

# Contribution

- ⇒ **GenAI in many areas:** Chat GPT for writing (Noy and Zhang 2023), customer support (Brynjolfsson et al. 2023), consulting (Dell'Acqua et al. 2023), startup assistance (Otis et al. 2024)
- ⇒ **GenAI in open source:** GitHub Copilot programming assistance
  - Observational studies (Dohmke et al. 2023)
  - Experimental productivity study (Peng et al. 2023)

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- ⇒ **GenAI in open source:** GitHub Copilot programming assistance
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  - Experimental productivity study (Peng et al. 2023)
- ⇒ **Our contribution**
  - Beyond productivity effects: nature of work
  - GenAI impact on private provision of public goods (OSS)
  - Long-term causal evidence of genAI from a real-world scenario

# Can generative AI re-align actual work with desired work?



Core Work

Management

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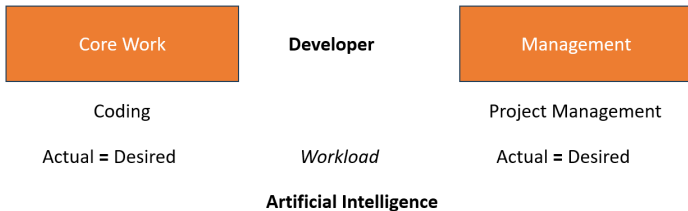


# Can generative AI re-align actual work with desired work?



FOSS Contributor Survey (Nagle et al. 2020)

# Can generative AI re-align actual work with desired work?



## ⇒ Research Question:

What is the impact of generative AI on the nature of work?

- How does AI change core work vs project management?
- How does AI change patterns of collaboration and innovation?

## Simple Model: GenAI reduces cost of core work

$$\underset{c, m}{\text{maximize}} \quad u_{\theta}(c, m)$$

$$\text{subject to} \quad p_c c + p_m m \leq \omega$$

$$u(c, m) = \left( \beta_c^{1/\sigma} c^{\frac{\sigma-1}{\sigma}} + \beta_m^{1/\sigma} m^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

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Shock: Generative AI **reduces**  $p_c$ . (Acemoglu et al. 2024)

# Main hypotheses for AI assisting with core work

$$c^* = \frac{\omega p_c^{-\sigma}}{p_c^{1-\sigma} + \frac{\beta_m}{\beta_c}}$$
$$m^* = \frac{\omega}{\frac{\beta_c}{\beta_m} p_c^{1-\sigma} + 1}$$

**Hypothesis 1a:**  $\uparrow$  core work

$\Rightarrow$  When IT reduces costs of a task, workers do more of it (Autor et al. 2003; Bloom et al 2014; Orlikowski 2007; Zammuto et al 2007)

**Hypothesis 1b:**  $\downarrow \uparrow$  project management ( $\sigma$  dependent)

$\Rightarrow$  Management is a less routine task, so automation won't always impact it (Autor et al. 2003; Mintzberg 1994)

# What drives the effects of generative AI adoption?

Mechanism 1: Autonomous Work vs Collaborative Work

Extend model Nested CES

- Two types of core/managerial work instead of one: autonomous vs. collaborative
- Some context-specific assumptions (high collaborative frictions, common in distributed work)



# What drives the effects of generative AI adoption?

## Mechanism 1: Autonomous Work vs Collaborative Work

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**Hypothesis 2:** Autonomous work  $\uparrow$ , collaborative work  $\downarrow$  for both core and managerial work

⇒ Tech that streamlines communication and decision-making reduce collaboration overhead, freeing workers to focus on their own work in isolation (Faraj, Jarvenpaa, and Majchrzak, 2011; Aral and Van Alstyne, 2011)

# What drives the effects of generative AI adoption?

Mechanism 2: Exploration vs Exploitation

## Extend model Nested CES

- Two types of core/managerial work instead of one: exploration vs. exploitation
- Some context-specific assumptions (ease of starting new work, common in distributed work)

# What drives the effects of generative AI adoption?

## Mechanism 2: Exploration vs Exploitation

### Extend model Nested CES

- Two types of core/managerial work instead of one: exploration vs. exploitation
- Some context-specific assumptions (ease of starting new work, common in distributed work)

**Hypothesis 3:** Exploration  $\uparrow$ , exploitation  $\downarrow$  for both core and managerial work

- ⇒ When the costs of experimentation decrease, individuals and organizations tend to shift their focus toward exploratory activities (Benner and Tushman, 2003; Levinthal and March, 1993)
- ⇒ IT investments automate routine tasks and facilitate rapid feedback, and thereby promote experimentation (Bresnahan, Brynjolfsson, and Hitt, 2002; Zammuto et al., 2007)

# What drives the effects of generative AI adoption?

Moderator: Ability

Extend model with two ability types:

$$\sigma = \{\sigma^H, \sigma^L\} \text{ s.t. } \sigma^H < \sigma^L$$

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**Hypotheses 4:** Main effect larger for low ability individuals

- ⇒ For lower-ability individuals, managerial tasks, which require multitasking, coordination, discretion, and interpersonal communication (Finkelstein and Hambrick, 1990; Hambrick and Finkelstein, 1987), can detract from their ability to focus on core work, thus making them substitutes for each other

# Key challenge in testing hypotheses

⇒ Identify a setting where

1. work patterns are observable and
2. an AI tool consequential to linchpin workers has been introduced (quasi) exogenously

⇒ Our setting addresses both issues:

- The introduction of GitHub Copilot for key developers in open source software projects

# Open Source Software Process in a Nutshell

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- ⇒ Other individuals can
  - report "issues" (bugs, feature requests, etc.)
  - provide actual suggested code requests (pull requests)

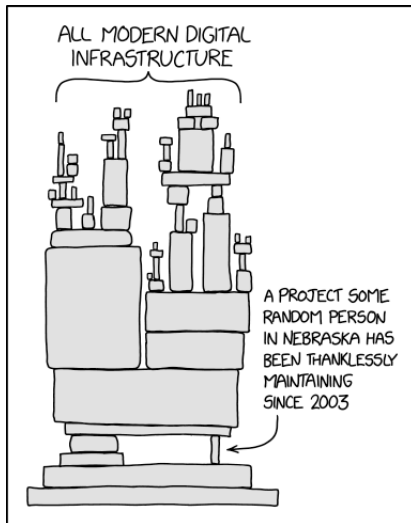
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- ⇒ Maintainer can address those issues (or not) and accept/merge pull requests (or not)
- ⇒ Maintainer can add additional maintainers to the project

# The linchpin problem in OSS



Source: XKCD PG

- ⇒ **GitHub:** the *de facto* hub for collaborative OSS development
  - allows for the private provision of public good
  - observable task allocation of coding and project management
  - introduction of an GenAI tool
  
- ⇒ **Natural experiment:** A discontinuity in GitHub's Copilot program to offer a free coding GenAI to “top maintainers”

# The GitHub Platform: Coding



tukaani-project / xz

Q Type to search

<> Code

Issues 0

Pull requests 3

Actions

Security

Insights

XZ Public

Watch 17 Fork 37 Star 485

master 15 Branches 54 Tags

Go to file

Add file

<> Code

Larhzu CMake: Prefer C11 with a fallback to C99 217Bad · 2 days ago 2,544 Commits

github	CI: Don't require po4a on Solaris	2 weeks ago
build-aux	Fix version.sh compatibility with Solaris	2 weeks ago
cmake	Add SPDX license identifier into BSD source code files.	4 months ago
debug	debug/translation.bash: Remove an outdated test command	last month
doc	Fix typos	last week
dos	DOS: Omit useless defines from config.h	2 months ago
doxygen	Doxygen: update-doxygen: Support out-of-tree builds	2 months ago
extra	Add SPDX license identifiers to GPL, LGPL, and FSFULLR files.	4 months ago
lib	Add SPDX license identifiers to GPL, LGPL, and FSFULLR files.	4 months ago
m4	Build: Update visibility.m4 from Gnulib	last month
po	Translations: Run "make -C po update-po"	2 weeks ago
po4a	Translations: Run po4a/update-po	2 weeks ago
src	xz: Fix white space	3 days ago

About

XZ Utils

tukaani.org/xz/

cli library compression

Readme

Unknown and 3 other licenses found

Security policy

Activity

Custom properties

485 stars

17 watching

37 forks

Report repository

Releases 13

XZ Utils 5.6.2 (stable) Latest

2 weeks ago

+ 12 releases

Contributors 22

# The GitHub Platform: Coding



tukaani-project / xz

Search Type  to search +

[Code](#) [Issues](#) [Pull requests](#) [Actions](#) [Security](#) [Insights](#)

## Commits

master

All users All time

Commits on Jul 13, 2024

liblzma: Tweak a comment

Larhu committed 3 days ago ✓ 8 / 8

7c292dd

Commits on Jul 11, 2024

CMake: Bump maximum policy version to 3.30

Larhu committed 5 days ago ✓ 8 / 8

6480eda

CMake: Require CMake 3.20 or later

Larhu committed 5 days ago

9231c39

Commits on Jul 9, 2024

Update THANKS

Larhu committed last week ✓ 8 / 8

828185d

Commits on Jul 6, 2024

xz: Remove the TODO comment about --recursive

Larhu committed last week ✓ 8 / 8

ba9cf81

# The GitHub Platform: Project Management



tukaani-project / xz

🔍 Type  to search

[Code](#) [Issues 8](#) [Pull requests 3](#) [Actions](#) [Security](#) [Insights](#)

Want to contribute to tukaani-project/xz? Dismiss  
If you have a bug or an idea, browse the open issues before opening a new one. You can also take a look at the [Open Source Guide](#).

**Response to backdoor incident**  
#103 by thesamesam was closed 2 weeks ago  
 Closed 41

**Filters**  **Labels 14** **Milestones 0** [New issue](#)

8 Open  39 Closed	Author	Label	Projects	Milestones	Assignee	Sort
<b>tsan also needs sanitizer nerf for crc64</b> #122 opened 2 weeks ago by nate-thirdwave  3						
<b>no_sanitize_address isn't required</b> #112 opened on Apr 19 by nigeltao  7						
<b>Enable sponsorship on your repo</b> #105 opened on Apr 10 by kaapee  6						
<b>[Feature Request]: Is there a real-world benchmark for xz?</b> #83 opened on Feb 24 by svenha  6						
<b>Where can I download Latest compiled binaries ?</b> #81 opened on Feb 18 by vectors  5						

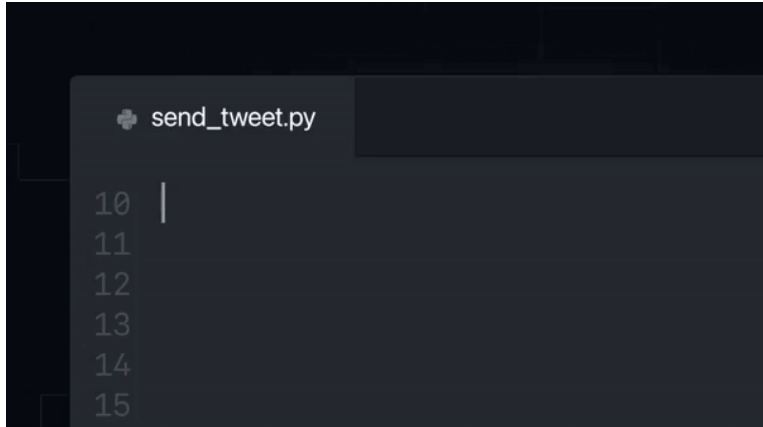


# GitHub Generative AI: Copilot

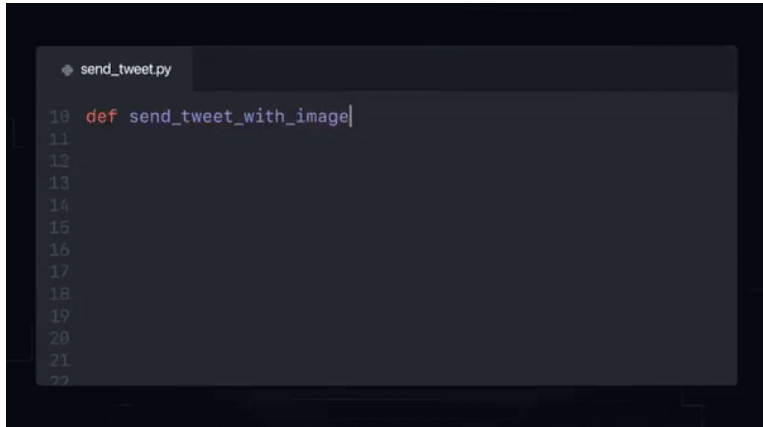
LLM to assist programmers to code faster, solve problems more quickly, and learn code that they previously did not know.

- ⇒ **AI built by** OpenAI and Microsoft/GitHub
- ⇒ **Based on** models underlying ChatGPT
  - Here: Generative Pre-trained Transformer 3 series (GPT-3)
- ⇒ **LLM**. Next Word Prediction (Text Completion).
  - Next Code Prediction (Code Completion)
  - Programmers obtain code-snippets while coding

# GitHub Copilot: Artificial Intelligence in Action



# GitHub Copilot: Artificial Intelligence in Action

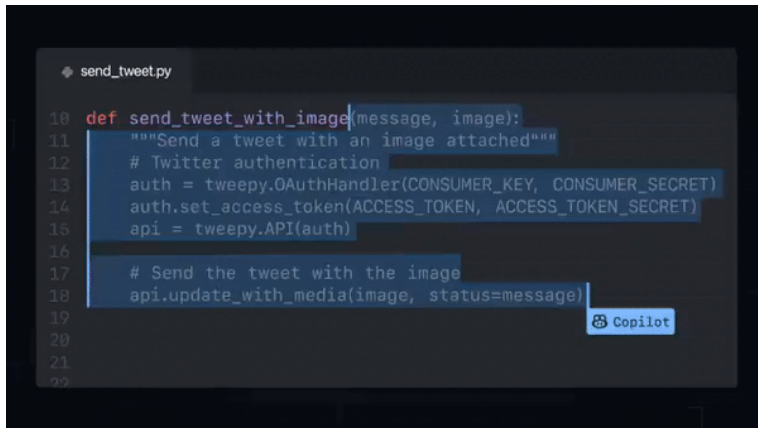


A screenshot of a code editor interface with a dark theme. The editor shows a file named `send_tweet.py`. The code content is as follows:

```
10 def send_tweet_with_image|
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```

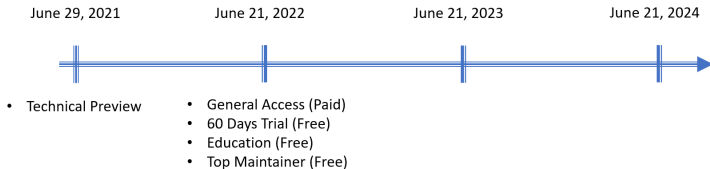
Details

# GitHub Copilot: Artificial Intelligence in Action

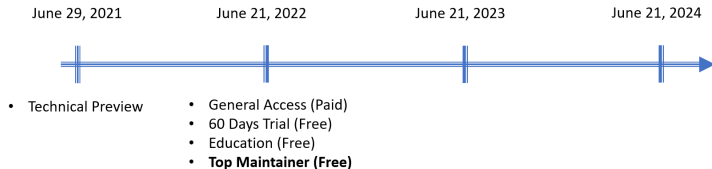


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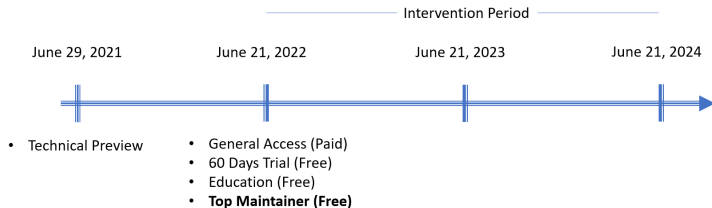
# GitHub Copilot AI deployment timeline



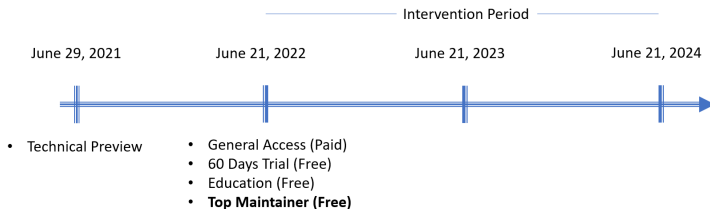
# GitHub Copilot AI deployment timeline



# GitHub Copilot AI deployment timeline



# GitHub Copilot AI deployment timeline



Main Outcomes: Coding & Project Management



# GitHub Copilot top maintainer natural experiment

- ⇒ **GitHub Goal:** Reward top open source maintainers
- ⇒ Provide *free access* to Copilot AI for top  $X$  maintainers
- ⇒ Internal ranking ( $R_i$ ) at project (repository) level

$$\text{Eligible} = \begin{cases} \text{AI Free Access for Top Maintainer} & \text{if } R_i < 0. \\ 0 & \text{if } R_i \geq 0. \end{cases}$$

- ⇒ Identical maintainer just above and below the threshold

# No manipulation of the top maintainer ranking

As a developer of what kind of open source project can continue to use the co-pilot for free? #19754

Unanswered

XiaoYingYo asked this question in Copilot



XiaoYingYo on Jun 30, 2022

...

As a developer of what kind of open source project can continue to use the co-pilot for free?  
Fork number of times?  
Star number of times?



5 comments

Oldest

Newest

Top



thomscoder on Jun 30, 2022

...

I do not think there is a full fledged list of projects.  
It's probably a combination of factors: stars, forks, contributors, used by etc..

I'd say a size of the impact the Organization would receive if you were to be "slowed down" by a 10\$/month fee



0 replies

Write a reply



D7EAD on Jun 30, 2022

...

Hi!

Github Copilot is available for free, as of right now, to verified students and "popular open source projects." What Github defines as a popular open source project is, sadly, not expressly stated.



0 replies

Write a reply

Category



Copilot

Labels



Copilot



Product Feedback

6 participants



Notifications



Subscribe

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↑ 5



5 comments

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↑ 1



0 replies

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↑ 3



2

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## No manipulation of the top maintainer ranking

GitHub Copilot is available for free as of right now, to verified students and "**popular open source projects.**" What GitHub defines as a popular open source project is, **sadly**, not expressly stated.

# Identification: regression discontinuity design

## Baseline Model

$$Y_{it} = \alpha_0 + \alpha_1 \mathbb{1}Eligible_{it} + \alpha_2 R_{it} + \alpha_3 Eligible_{it} \times R_{it} + \epsilon_{it}$$

s.t.

$Y = \{Copilot, Activity\}$  (First stage, ITT)

$k = \{i, p\}$  (Individual, Project)

## Identifying Assumption

Outcomes change at the threshold due to AI only

# Open and Proprietary GitHub Data

⇒ Maintainers ( $i$ ) observed over time ( $t$ )

- Task Allocation

$$Y_{it} = \frac{(\text{cumulative activity } x)_{it}}{(\text{total cumulative activity})_{it}}$$

where  $x \in \{\text{coding, project management}\}$

- Copilot usage
- Top maintainer ranking

⇒ Balanced maintainer-week panel

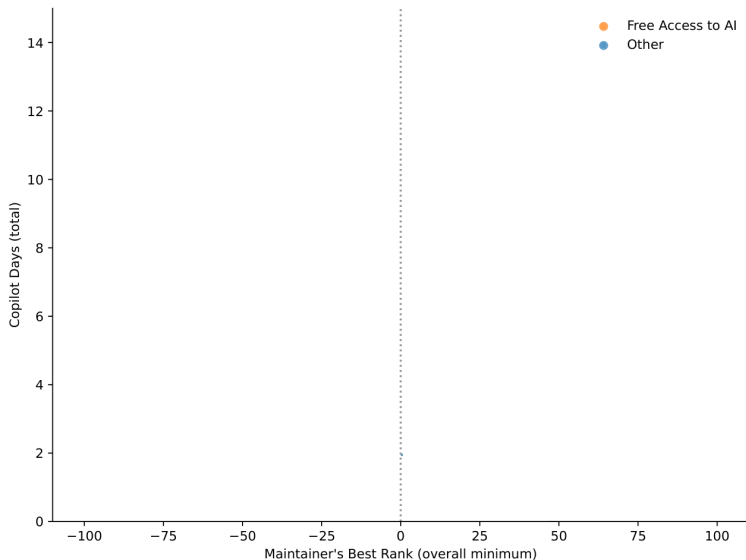
- Over 187k maintainers with 6 mill. observations
- Final sample: 6,885 maintainers with 269,546 obs.

Restrictions

# Descriptive statistics of top maintainers

	Mean	SD	Min	Max
<b>AI Treatment</b>				
AI Total Days	9.95	32.06	0	365
AI Ever Used	0.19	0.39	0	1
AI Exposure Share	0.03	0.10	0	1
AI Days Used / Week	0.21	0.95	0	7
<b>Work and Social Activities</b>				
Coding	0.44	0.29	0	1
Project Management	0.24	0.22	0	1
Comments	0.09	0.12	0	1
Reactions	0.05	0.12	0	1

# Copilot AI usage increases for free access rankings

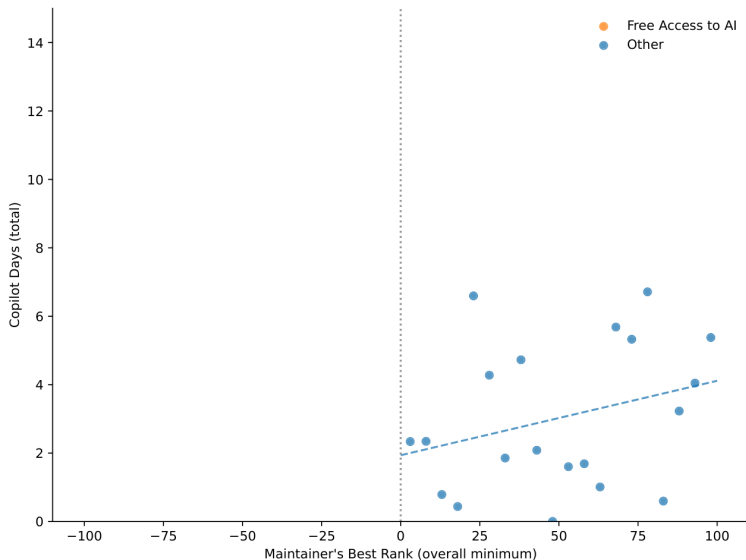


Table

Dynamics



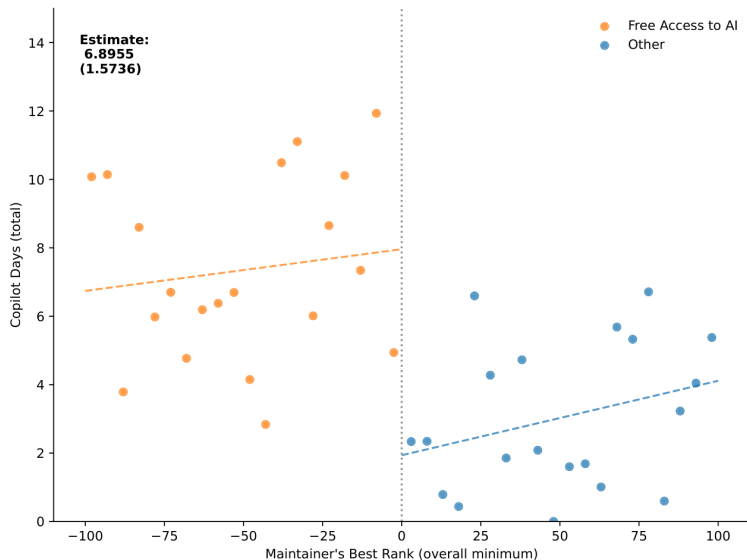
# Copilot AI usage increases for free access rankings



Table

Dynamics

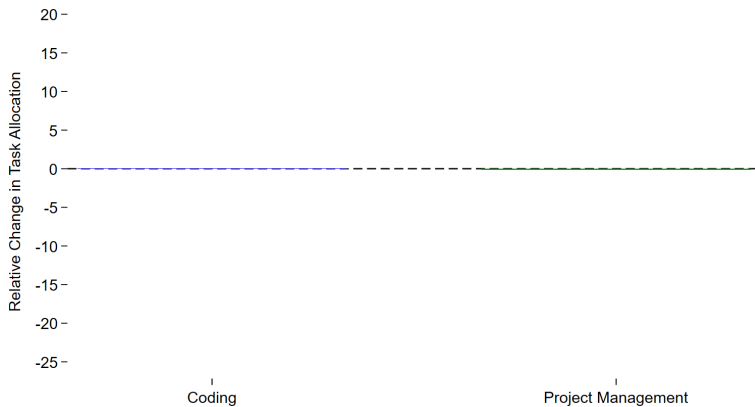
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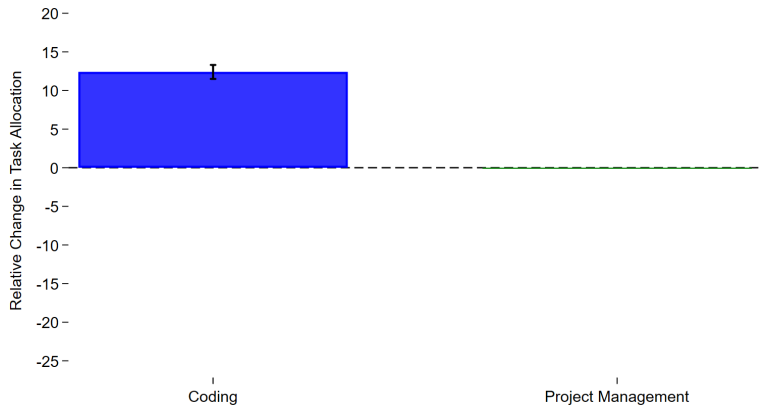
Table

Dynamics

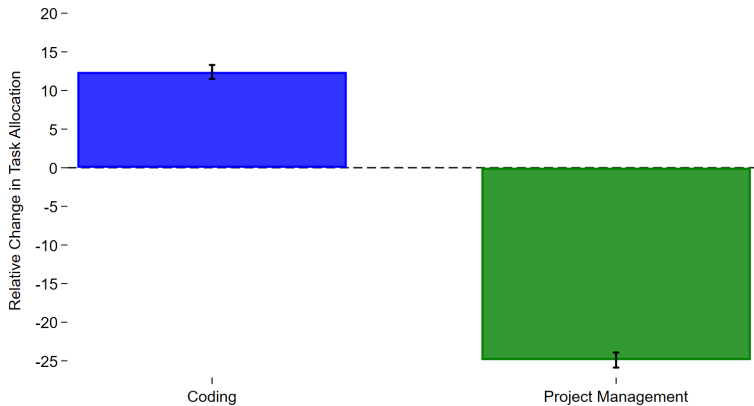
# The impact of the Copilot AI on task allocation



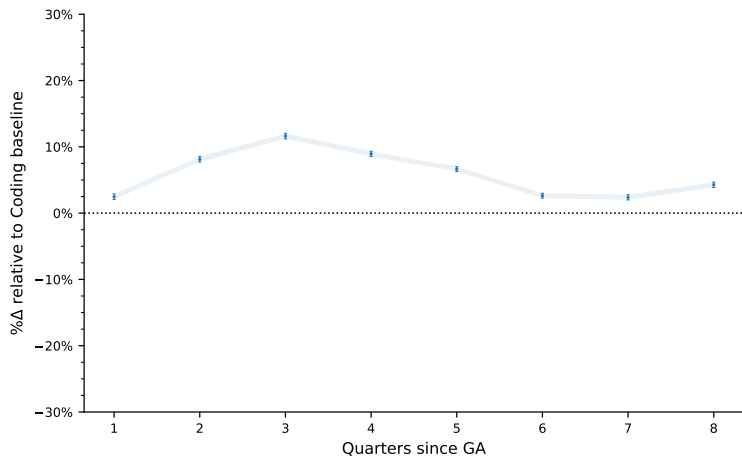
# Copilot AI increases coding



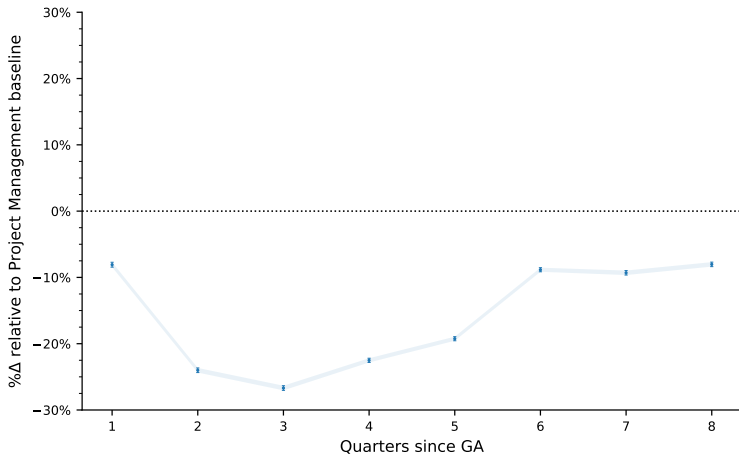
# Copilot AI reduces project management



# Dynamic effects of free-access AI on coding



# Dynamic effects of free-access AI on project management



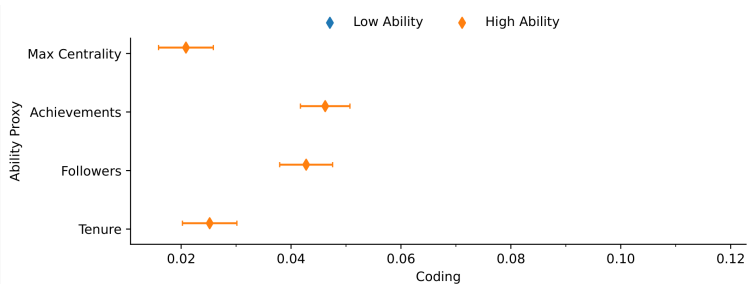
# What are the mechanisms?

## ⇒ **Main Intuition.**

- Copilot reduces the cost of core work
- You can solve problems by yourself
- You do not need others to solve problems

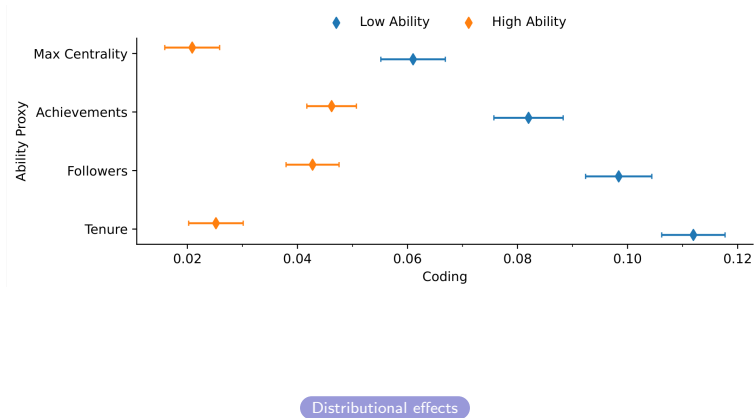


# Low ability developers code more

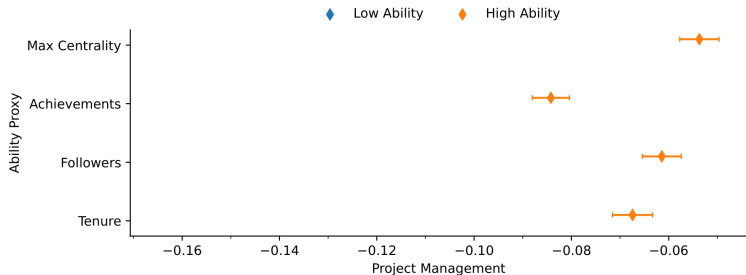


Distributional effects

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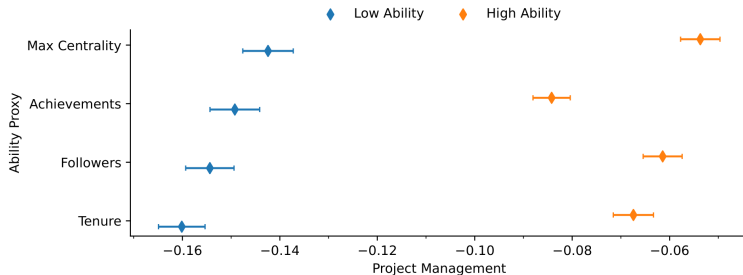


# Low ability developers reduce project management more



Distributional effects

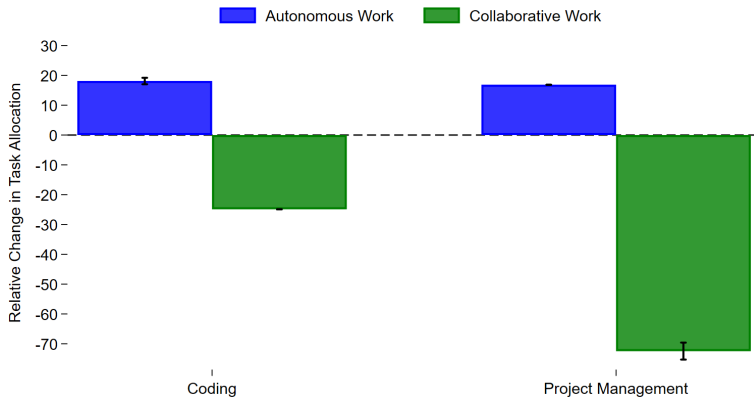
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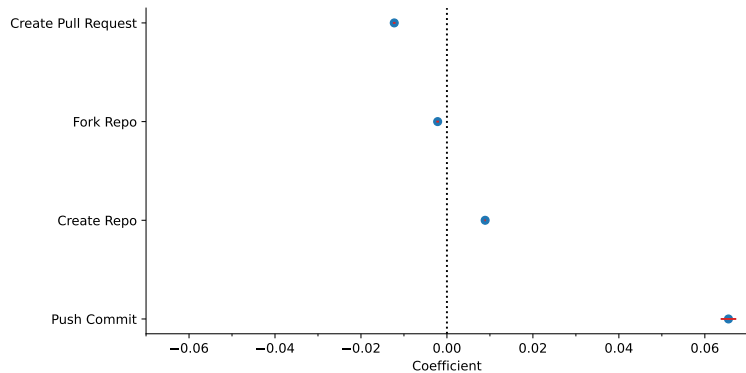
- Indicative of learning for low from high ability developers (AI training data)

Distributional effects

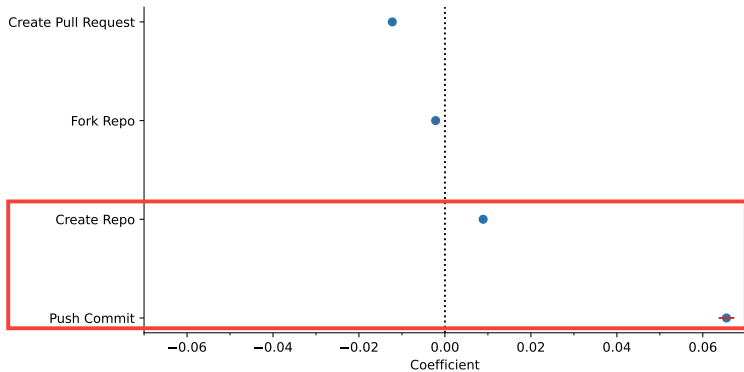
# Copilot increases autonomous work



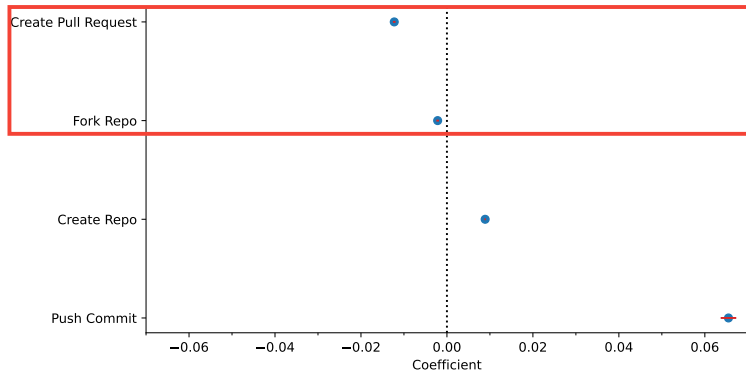
# Granular coding effects



# Granular coding effects for autonomous work

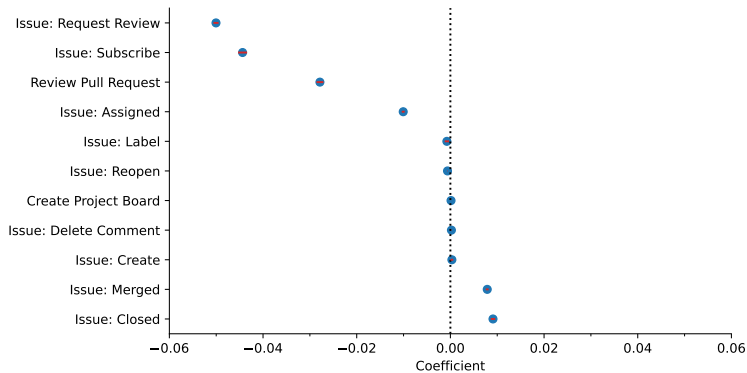


# Granular coding effects for collaborative work

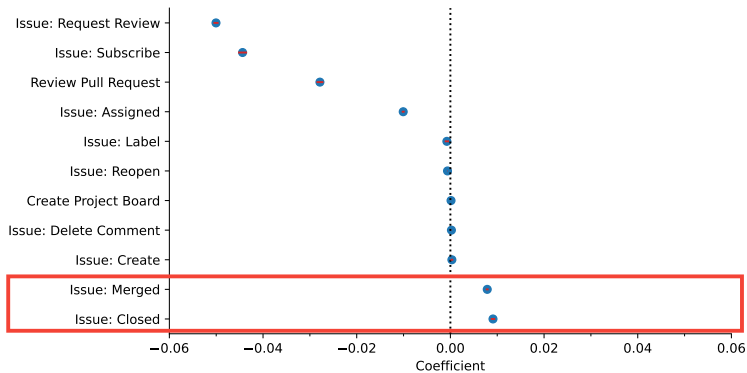




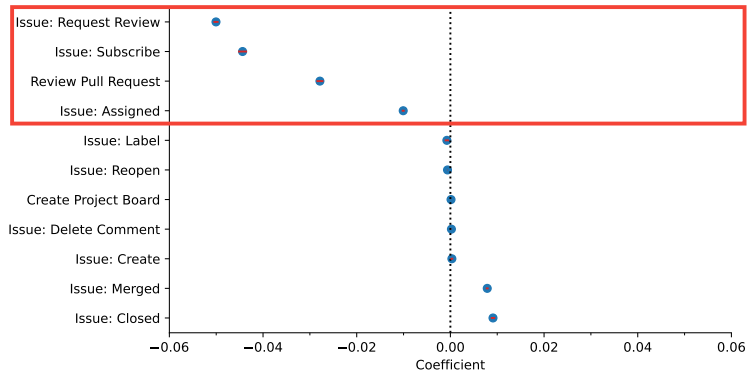
# Granular project management effects



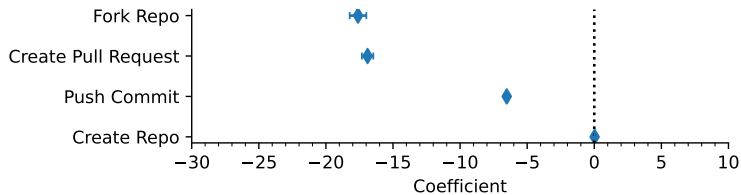
# Granular project management effects for autonomous work



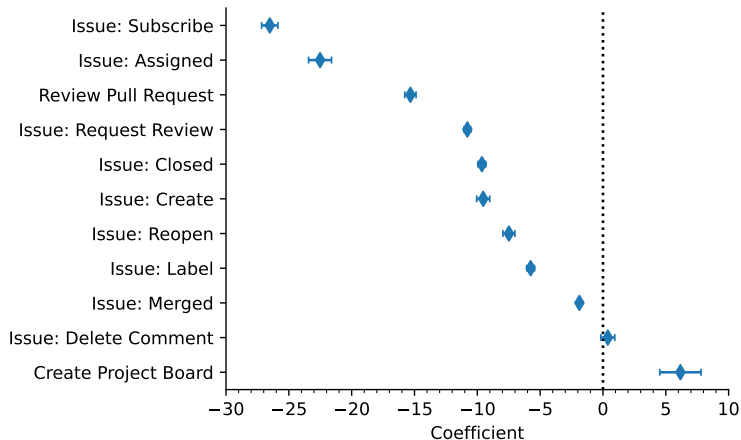
# Granular project management effects for collaborative work



# Collaborators drop for coding



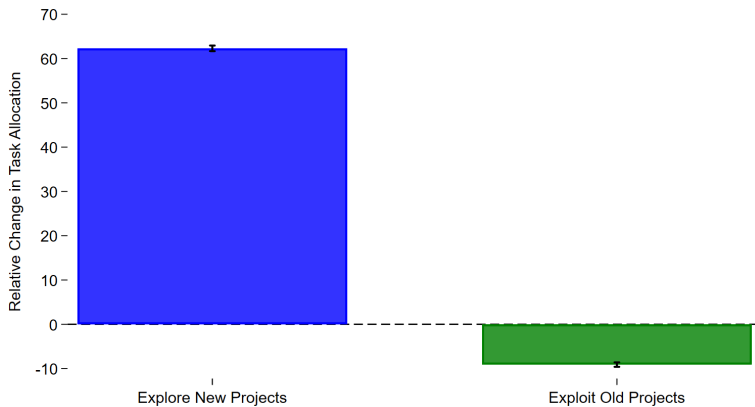
# Collaborators drop for project management



## ⇒ Further findings

- Bugfixes relative to feature requests drops Project Level
- Code quality does not seem to drop Individual level

# Copilot increases experimentation



## Exploration increases: new languages

	Programming Language Exposure	
$\mathbb{1}(\textit{Eligible})$	1.7526*** (0.075)	1.8135*** (0.077)
Baseline	9.2448*** (0.047)	8.3208*** (0.048)
Rel. TE (%)	18.95	21.79
N	181,798	170,433
Controls		✓

⇒ Language Exposure = cumulative count of distinct programming languages maintainer has interacted with

## Exploration increases: more valuable languages

	Salary-weighted Language Exposure	
$\mathbb{1}(\textit{Eligible})$	0.0137*** (0.000)	0.0140*** (0.000)
Baseline	11.691*** (0.000)	11.690*** (0.048)
TE (%)	1.379	1.410
TE (\$)	1,648	1,683
N	181,798	170,433
Controls		✓

- ⇒ Salary-weighted Language Exposure = cumulative mean of (log) median reported salary of Language Exposure
- ⇒ Stack-Overflow Developer Survey (2023)



# Back-of-the-envelope annual labor market potential

## ⇒ Individual

- Labor market potential: \$1,648
- Copilot price: \$120
- Net potential: \$1,528

## ⇒ Across 300k developers

- approx: **\$458 million.**

# Robustness

- ⇒ No manipulation. No Knowledge of Ranking [Ycombinator](#) [GitHub](#)
- ⇒ No manipulation. Empirical Evidence [Histogram](#) [McCrary Test](#)
- ⇒ No other intervention. Smoothness of covariates [Figures](#)
- ⇒ Stability. Polynomial (Degree 1 & 2) [Polynomial: Table](#)
- ⇒ Stability. Kernel (Uniform, triangle) [Kernel: Table](#)
- ⇒ Stability. Bandwidth (MSE, CER) [Bandwidth: Table](#)
  
- ⇒ Other [Residual](#) [Absolute](#) [Firm Affiliation](#)
- ⇒ Additional Identifications [Differences-in-discontinuities](#) [Propensity Score Matching](#)  
[Difference-in-difference for students](#)

# Conclusion

- ⇒ We place emphasis on **nature of work** instead of productivity
- ⇒ Generative AI changes work processes by
  - ↑ core work: coding, ↓ project management
  - ↑ autonomous work, ↓ collaborative work
  - ↑ exploration, ↓ exploitation
  - impact greater for lower ability individuals
- ⇒ Treatment effect remain after 2 years in real world setting
- ⇒ Labor market potential: Half a billion USD
- ⇒ Generative AI can
  - re-align actual work with desired work
  - positively impact the public good (i.e. open source software)
  - flatten organizational hierarchies

# Thank you!

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