

Generative AI and the Nature of Work

Manuel Hoffmann^{1,2} Sam Boysel¹ Frank Nagle¹
Sida Peng³ Kevin Xu⁴

¹Harvard Business School, Harvard University

²University of California, Irvine (Incoming)

³Microsoft Corporation

⁴GitHub Inc.



**Harvard
Business
School**

Laboratory for
Innovation Science
at Harvard



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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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 - 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

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



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

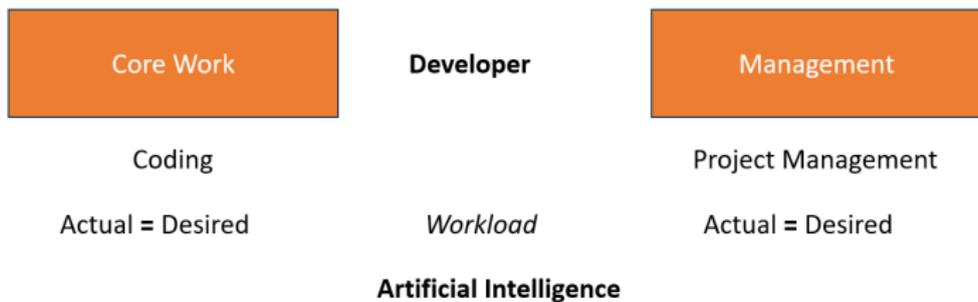


Can generative AI re-align actual work with desired work?



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

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

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

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

Simple Model: GenAI reduces cost of core work

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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 (σ 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

- \Rightarrow 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)
- \Rightarrow 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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Moderator: Ability

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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

- ⇒ Individual writes a piece of code and uploads it to an open source repository (project folder), and becomes the "maintainer" of that project

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

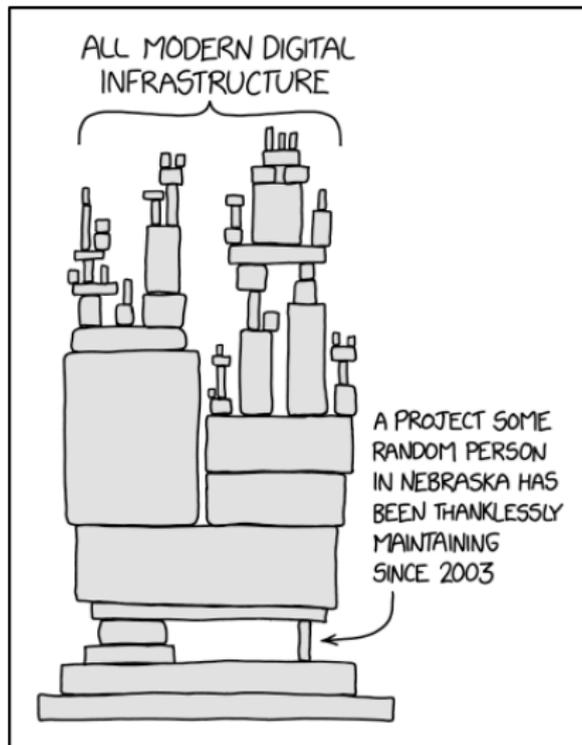
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- ⇒ Maintainer can address those issues (or not) and accept/merge pull requests (or not)
- ⇒ Maintainer can add additional maintainers to the project

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

Code Issues Pull requests 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	217baef · 2 days ago	2,544 Commits
github	Ci: Don't require po4a on Solaris	2 weeks ago	
build-aux	Fix versionsh compatibility with Solaris	2 weeks ago	
cmake	Add SPDX license identifier into 0BSD 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 7 Pull requests 2 Actions Security Insights

Commits

master

All users

All time

Commits on Jul 13, 2024

liblzma: Tweak a comment

Larhz committed 3 days ago ✓ 8 / 8

7c292d6



Commits on Jul 11, 2024

CMake: Bump maximum policy version to 3.30

Larhz committed 5 days ago ✓ 8 / 8

6408eda



CMake: Require CMake 3.20 or later

Larhz committed 5 days ago

9231c30



Commits on Jul 9, 2024

Update THANKS

Larhz committed last week ✓ 8 / 8

028185d



Commits on Jul 6, 2024

xz: Remove the TODO comment about --recursive

Larhz committed last week ✓ 8 / 8

ba9cfaf



The GitHub Platform: Project Management



tukaani-project / xz

<> 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
<input type="radio"/>	<input checked="" type="radio"/>						
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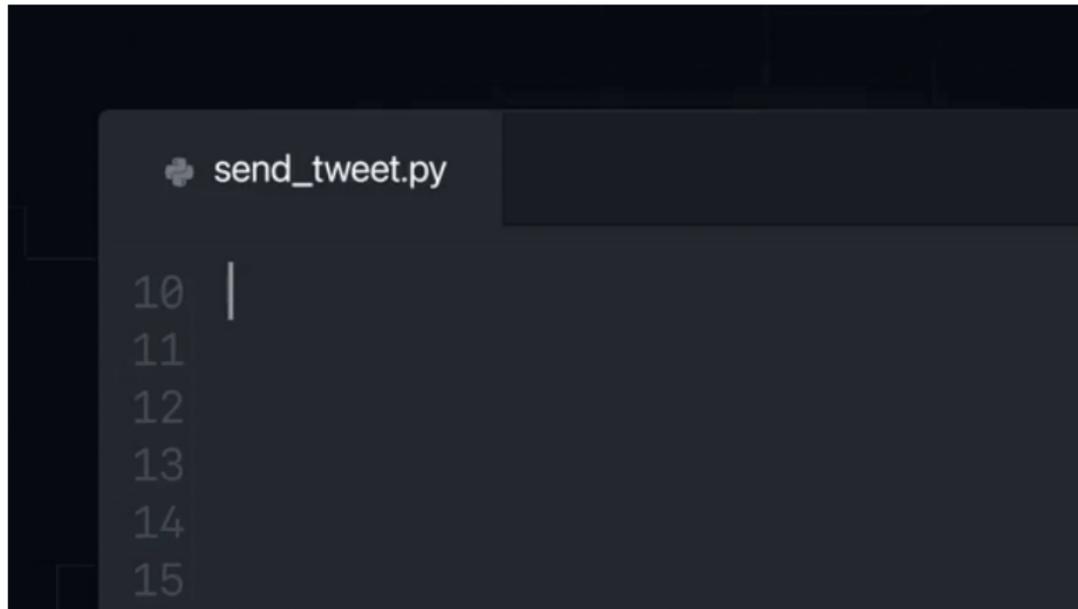
- tsan also needs sanitizer nerf for crc64**
#122 opened 2 weeks ago by nate-thrivedave 3
- no_sanitize_address isn't required**
#112 opened on Apr 19 by nigeltao 7
- Enable sponsorship on your repo**
#105 opened on Apr 10 by kaapee 6
- [Feature Request]: Is there a real-world benchmark for xz?**
#83 opened on Feb 24 by svenha 6
- Where can I download Latest compiled binaries ?**
#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.

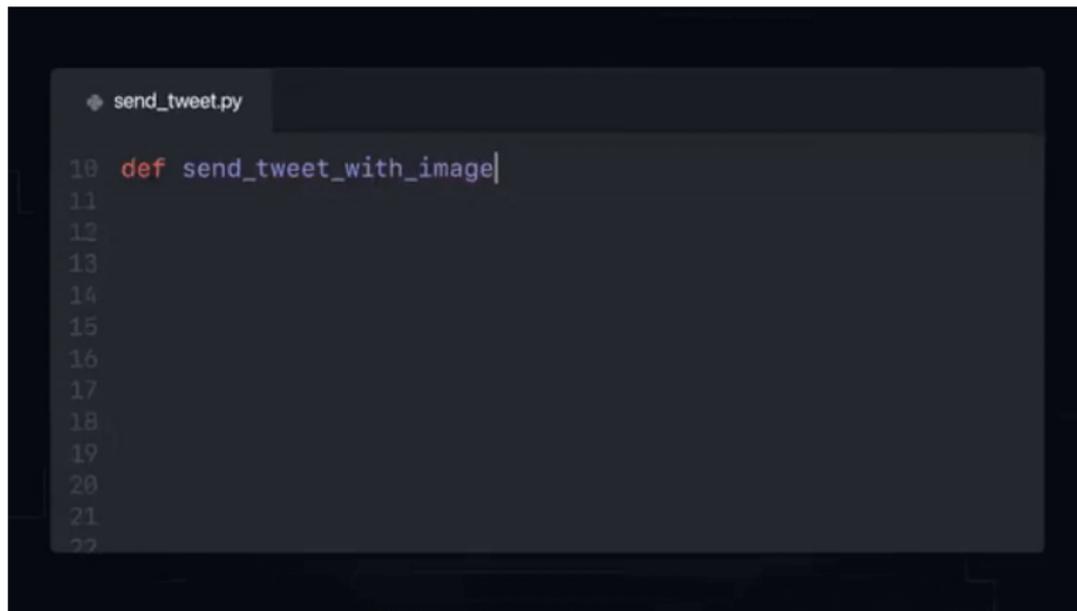
- ⇒ **AI built by** OpenAI and Microsoft/GitHub
- ⇒ **Based on** models underlying ChatGPT
 - Here: Generative Pre-trained Transformer 3 series (GPT-3)
- ⇒ **LLM**. Next Word Prediction (Text Completion).
 - Next Code Prediction (Code Completion)
 - Programmers obtain code-snippets while coding

GitHub Copilot: Artificial Intelligence in Action



```
send_tweet.py  
  
10 |  
11  
12  
13  
14  
15
```

GitHub Copilot: Artificial Intelligence in Action



The image shows a screenshot of a code editor window with a dark background. The file name 'send_tweet.py' is visible in the top left corner. The code is a Python function definition for 'send_tweet_with_image'. The function signature is 'def send_tweet_with_image' followed by a vertical bar. The lines are numbered from 10 to 22. The code is as follows:

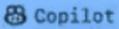
```
10 def send_tweet_with_image|
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22
```

Details

GitHub Copilot: Artificial Intelligence in Action

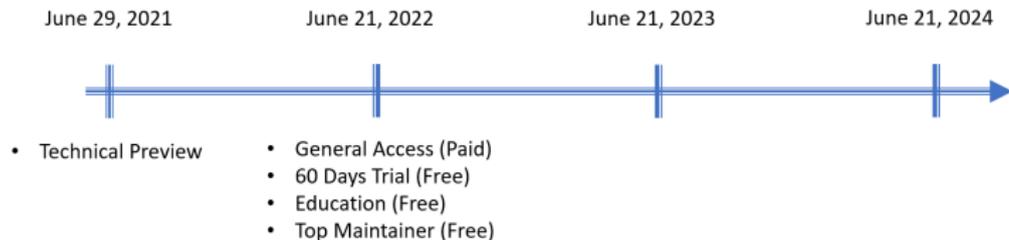
```
◆ send_tweet.py

10 def send_tweet_with_image(message, image):
11     """Send a tweet with an image attached"""
12     # Twitter authentication
13     auth = tweepy.OAuthHandler(CONSUMER_KEY, CONSUMER_SECRET)
14     auth.set_access_token(ACCESS_TOKEN, ACCESS_TOKEN_SECRET)
15     api = tweepy.API(auth)
16
17     # Send the tweet with the image
18     api.update_with_media(image, status=message)
19
20
21
22
```

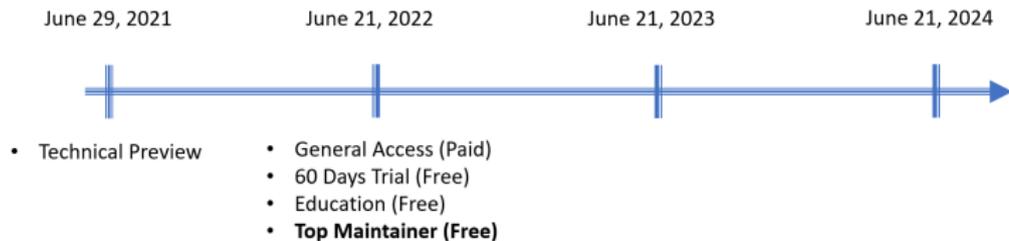


Details

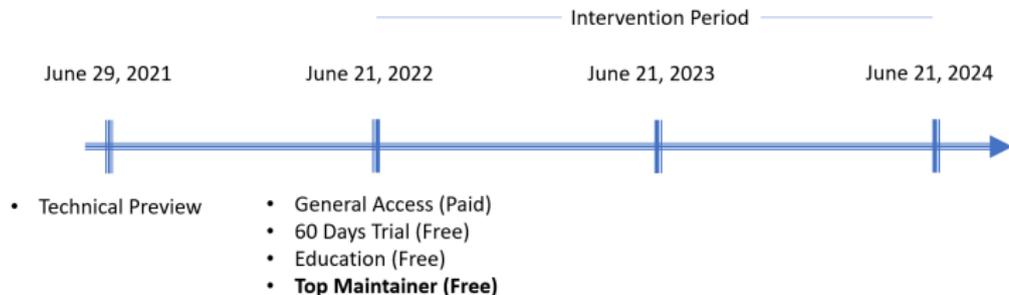
GitHub Copilot AI deployment timeline



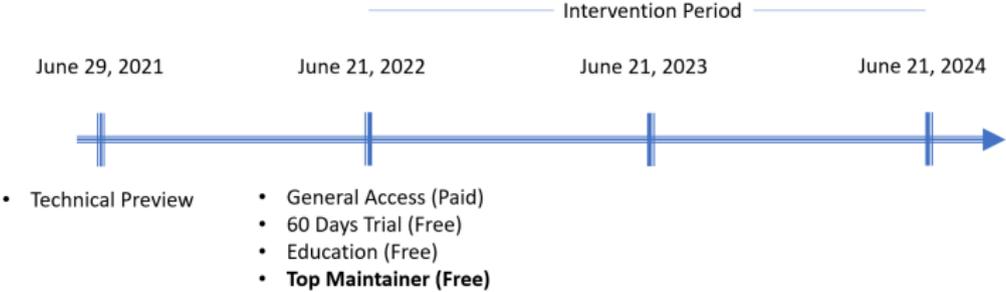
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GitHub Copilot AI deployment timeline



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 

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

 1 

0 replies

Write a reply

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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.

 3  2

0 replies

Write a reply

Category

 Copilot

Labels

 Copilot  Product Feedback

6 participants



Notifications

 Subscribe

You're not receiving notifications from this thread.

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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

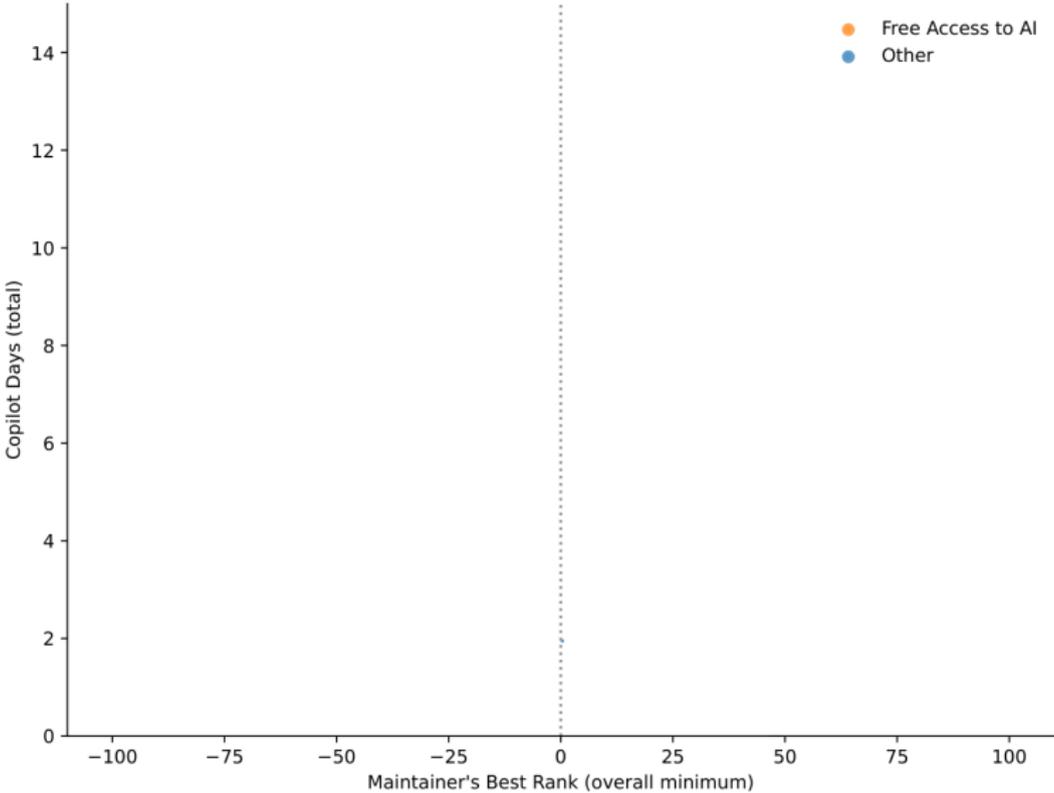
- Over 187k maintainers with 6 mill. observations
- Final sample: 6,885 maintainers with 269,546 obs.

Restrictions

Descriptive statistics of top maintainers

	Mean	SD	Min	Max
AI Treatment				
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
Work and Social Activities				
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

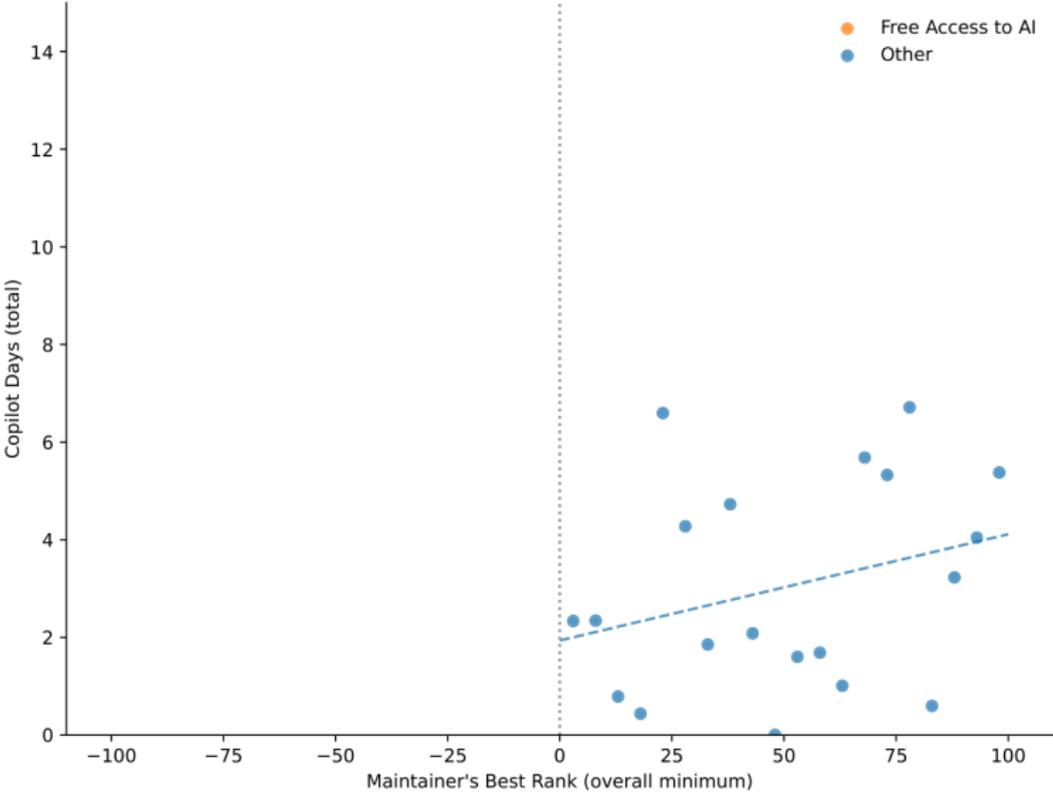
Copilot AI usage increases for free access rankings



Table

Dynamics

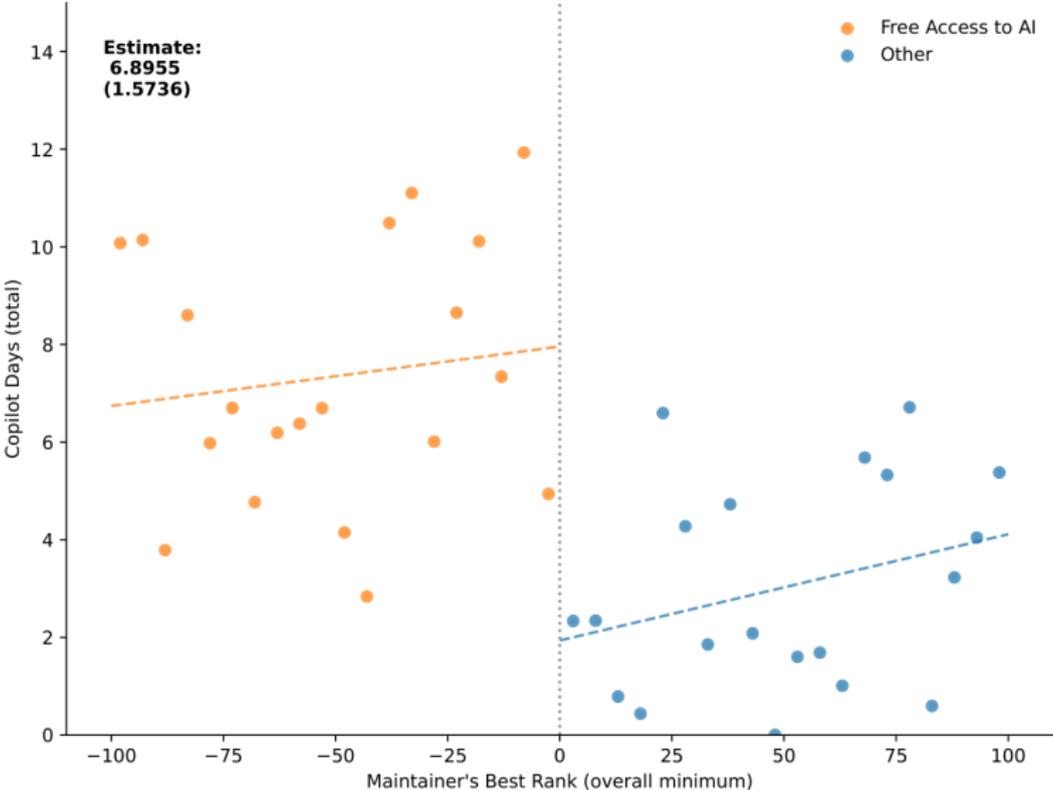
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Table

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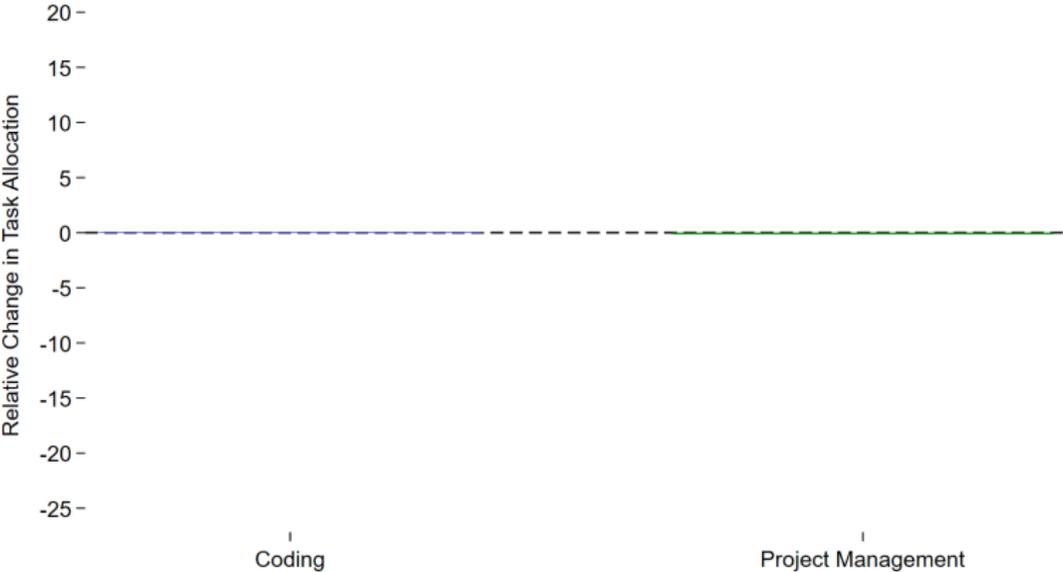
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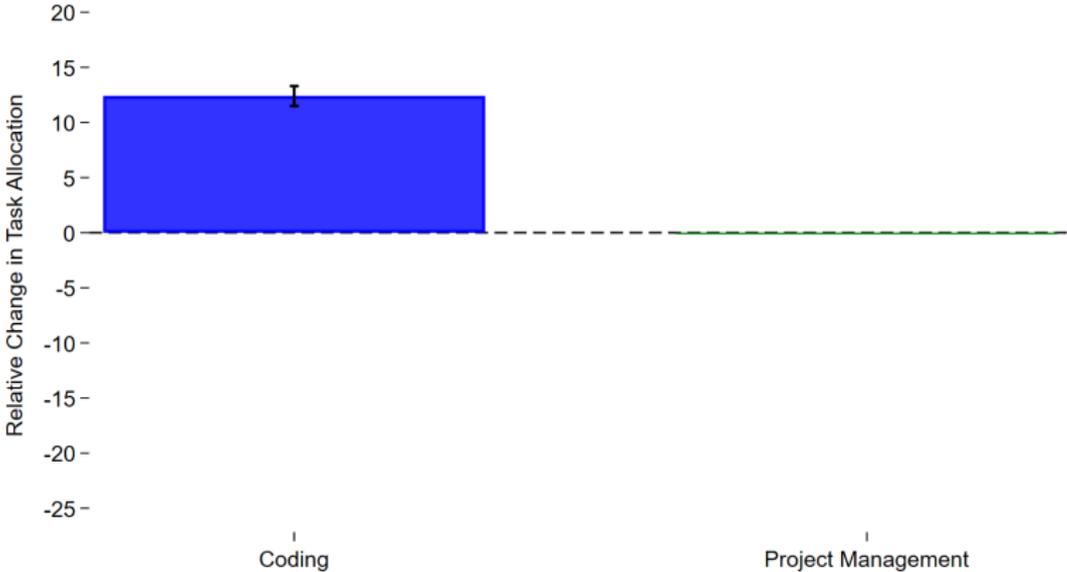
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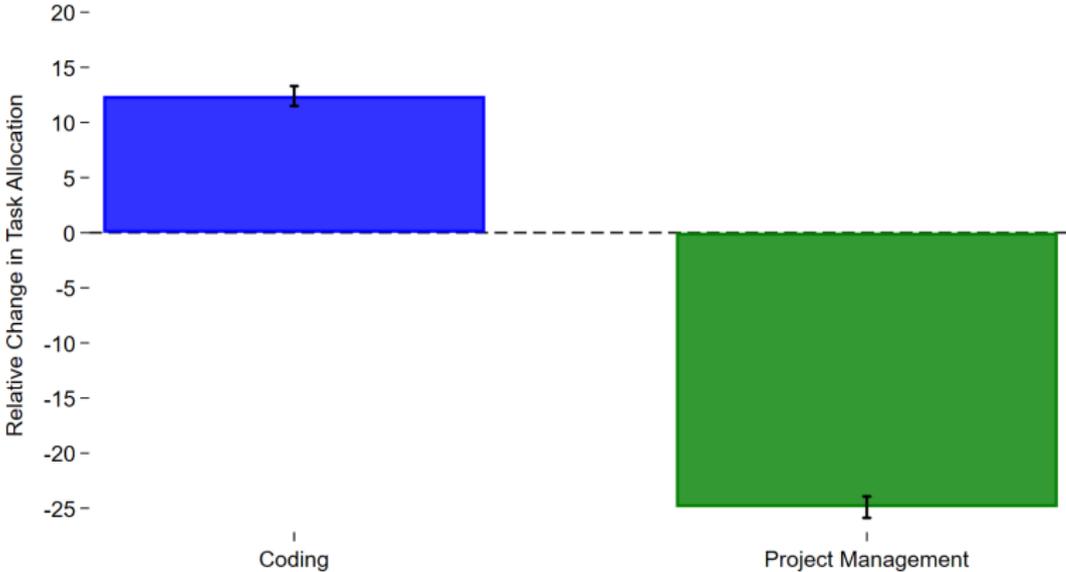
The impact of the Copilot AI on task allocation



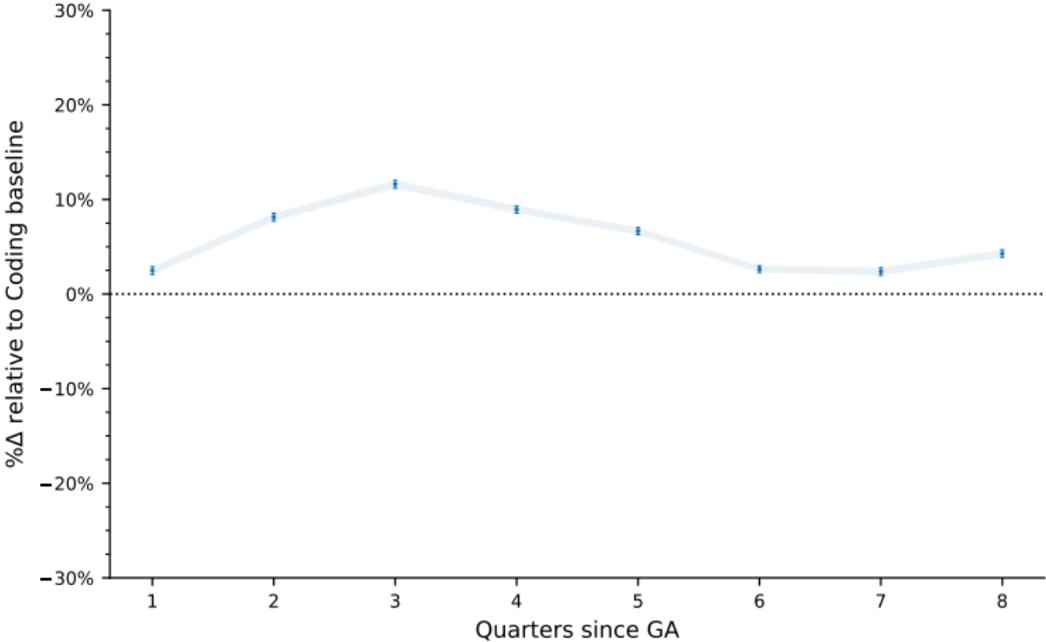
Copilot AI increases coding



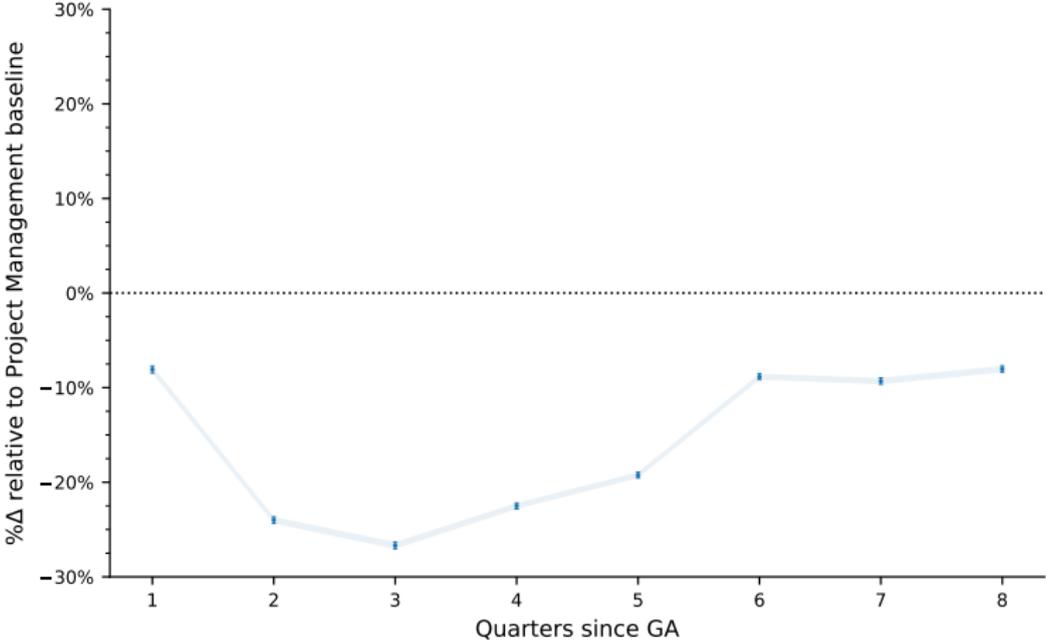
Copilot AI reduces project management



Dynamic effects of free-access AI on coding



Dynamic effects of free-access AI on project management

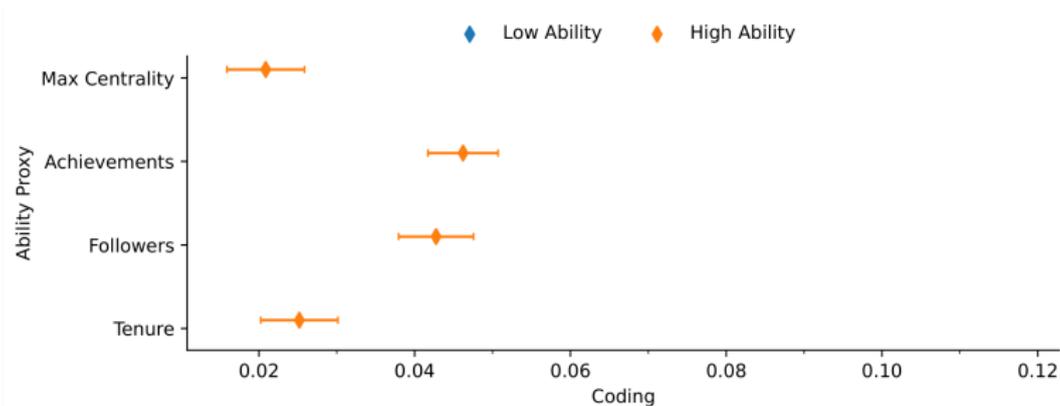


What are the mechanisms?

⇒ **Main Intuition.**

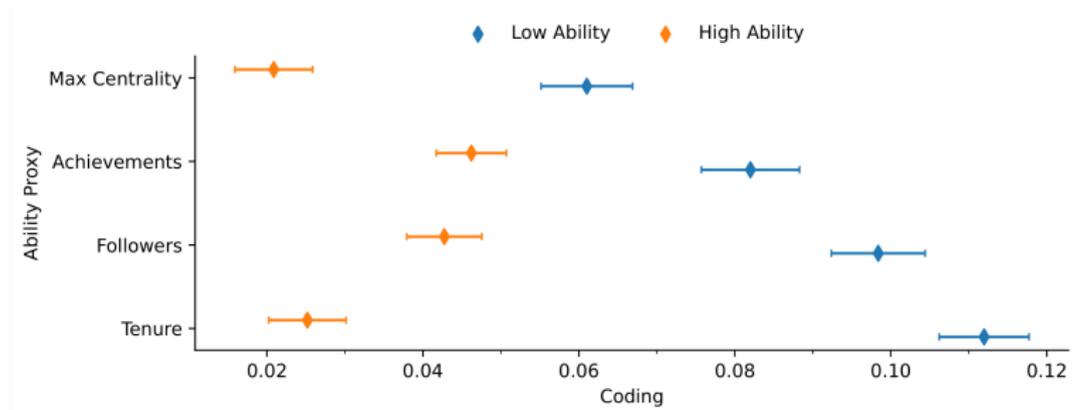
- Copilot reduces the cost of core work
- You can solve problems by yourself
- You do not need others to solve problems

Low ability developers code more



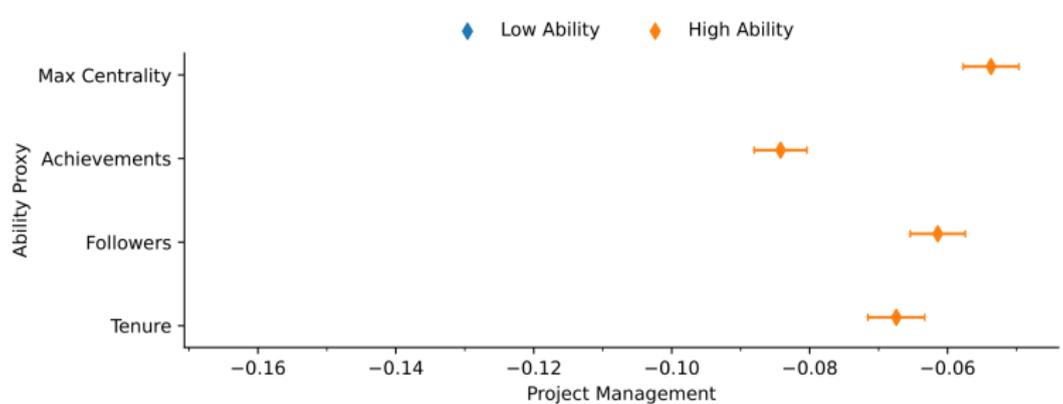
Distributional effects

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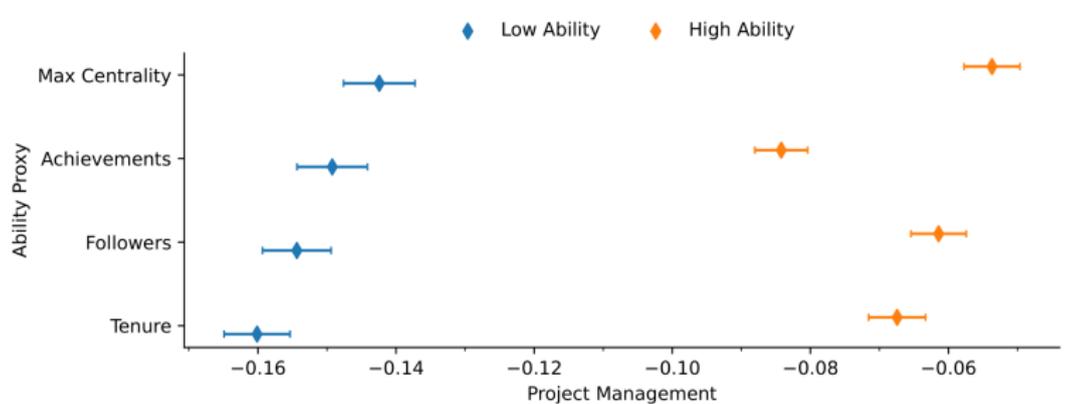
Distributional effects

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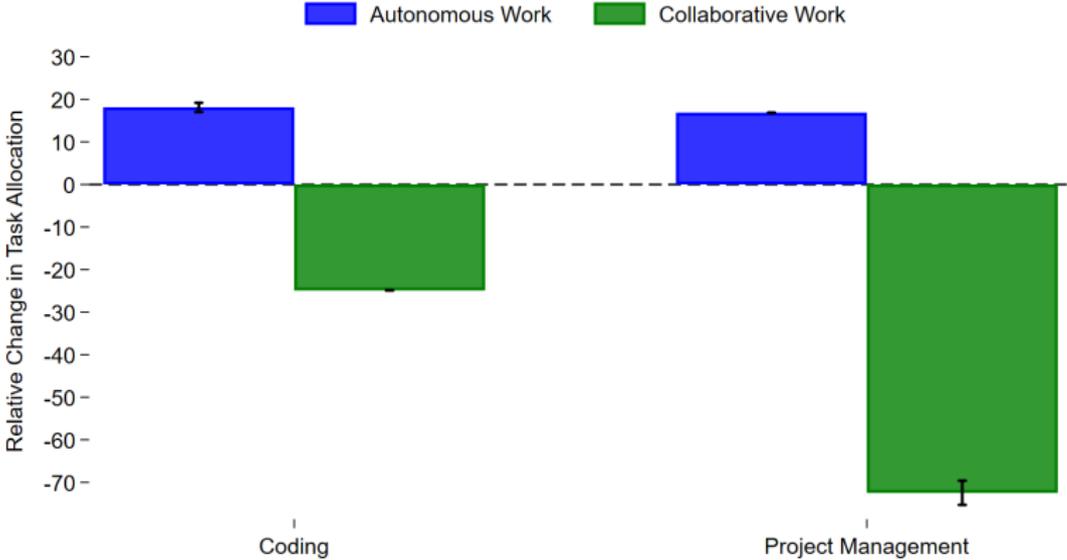
Low ability developers reduce project management more



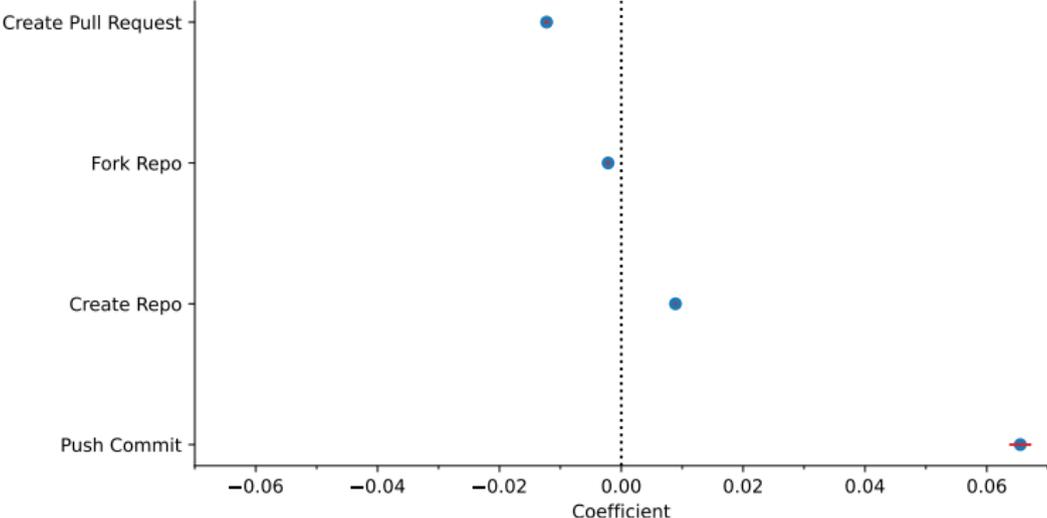
- Indicative of learning for low from high ability developers (AI training data)

Distributional effects

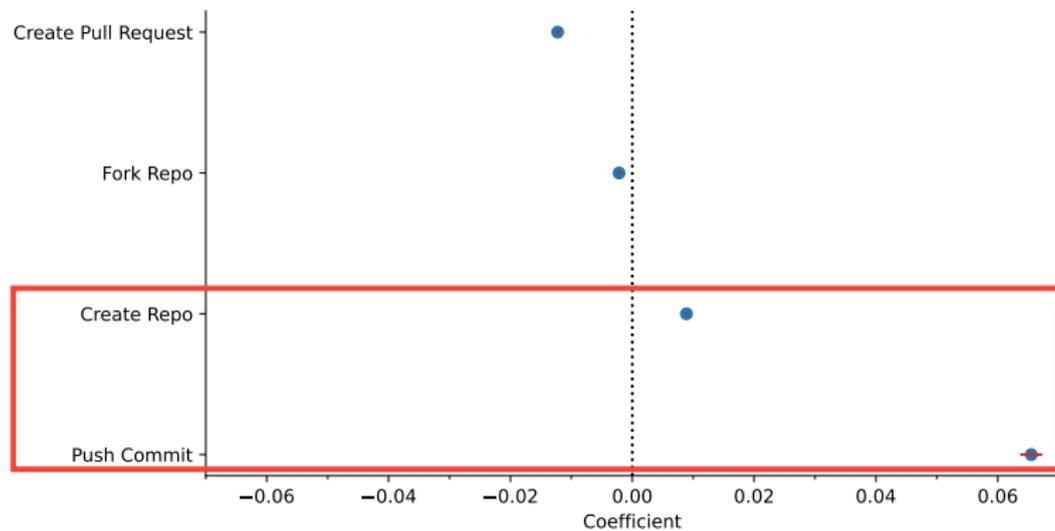
Copilot increases autonomous work



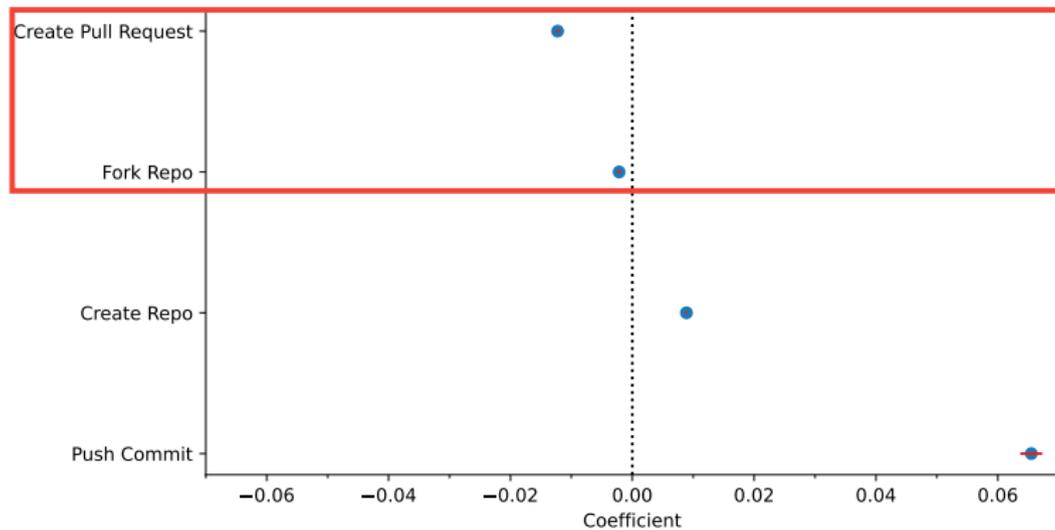
Granular coding effects



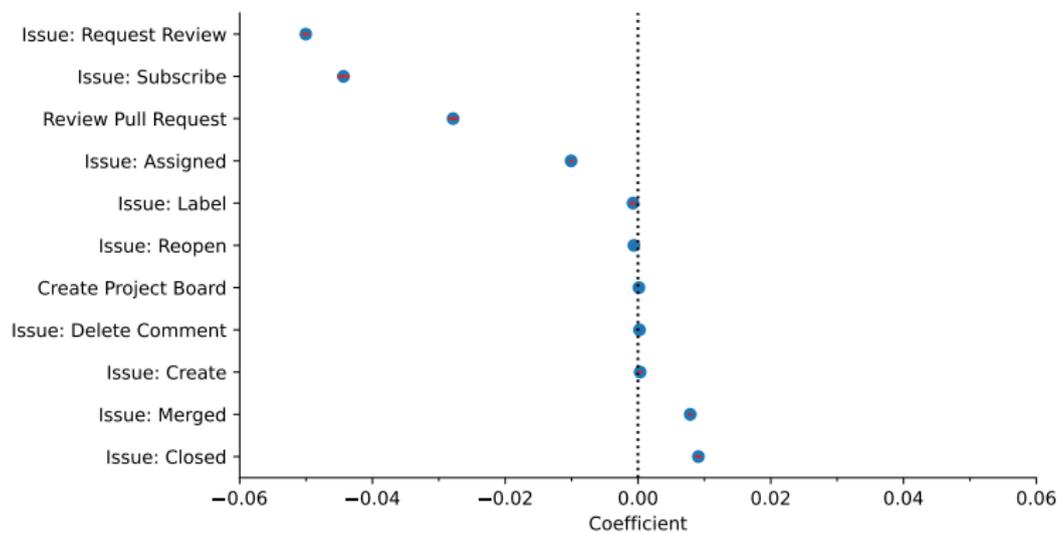
Granular coding effects for autonomous work



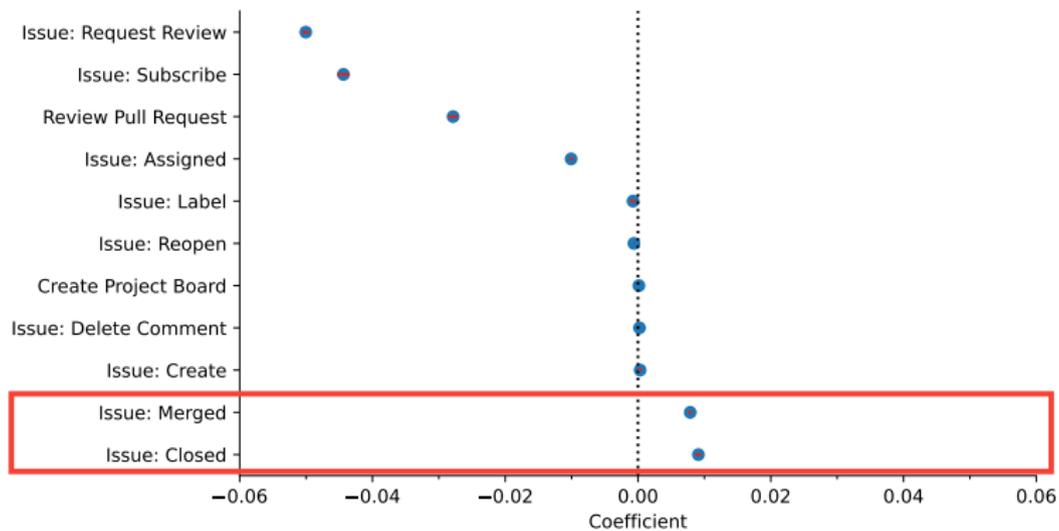
Granular coding effects for collaborative work



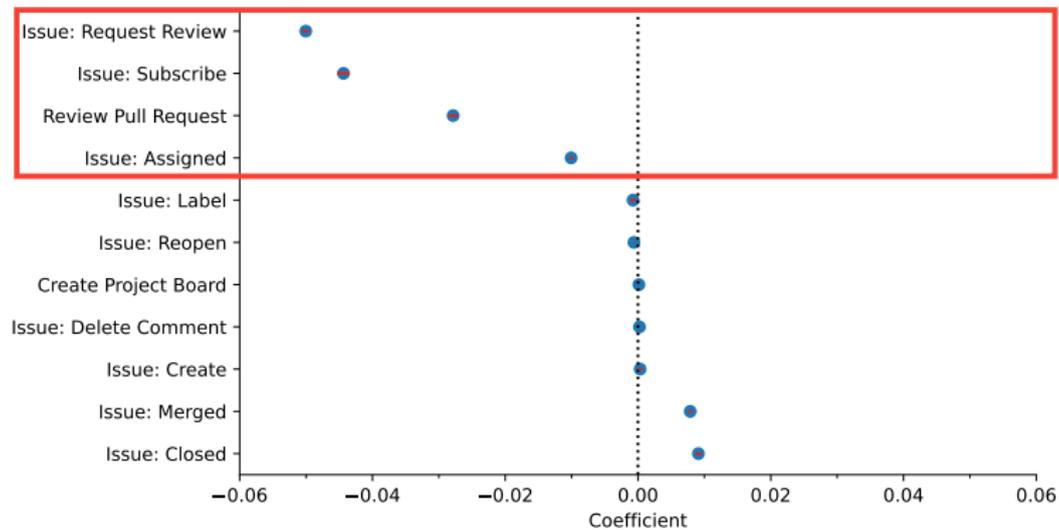
Granular project management effects



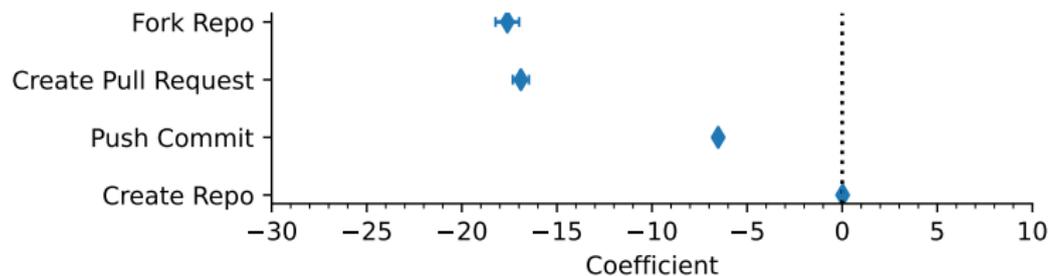
Granular project management effects for autonomous work



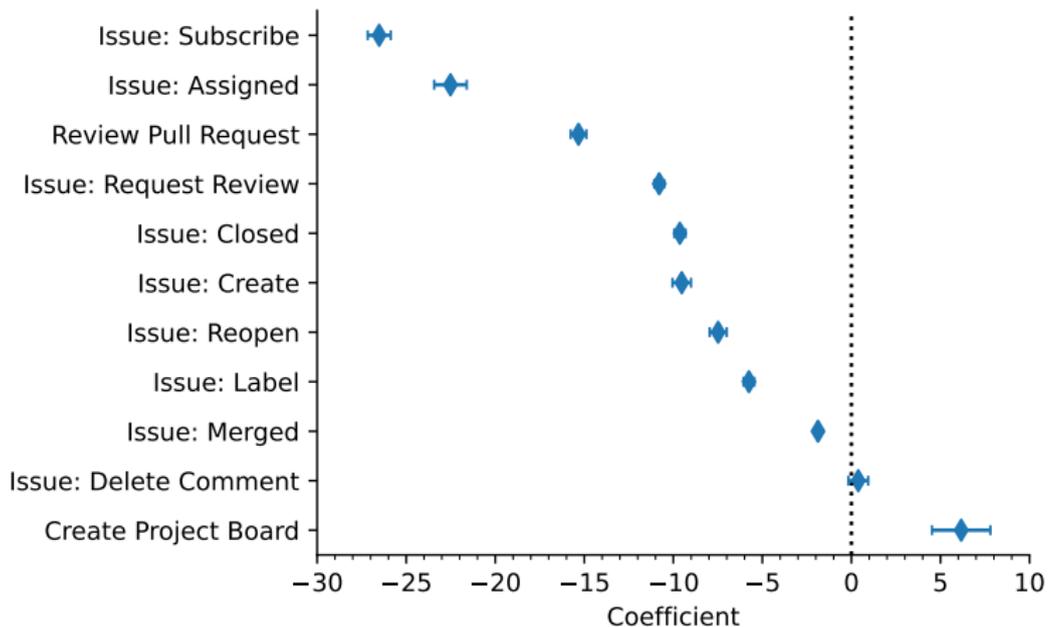
Granular project management effects for collaborative work



Collaborators drop for coding



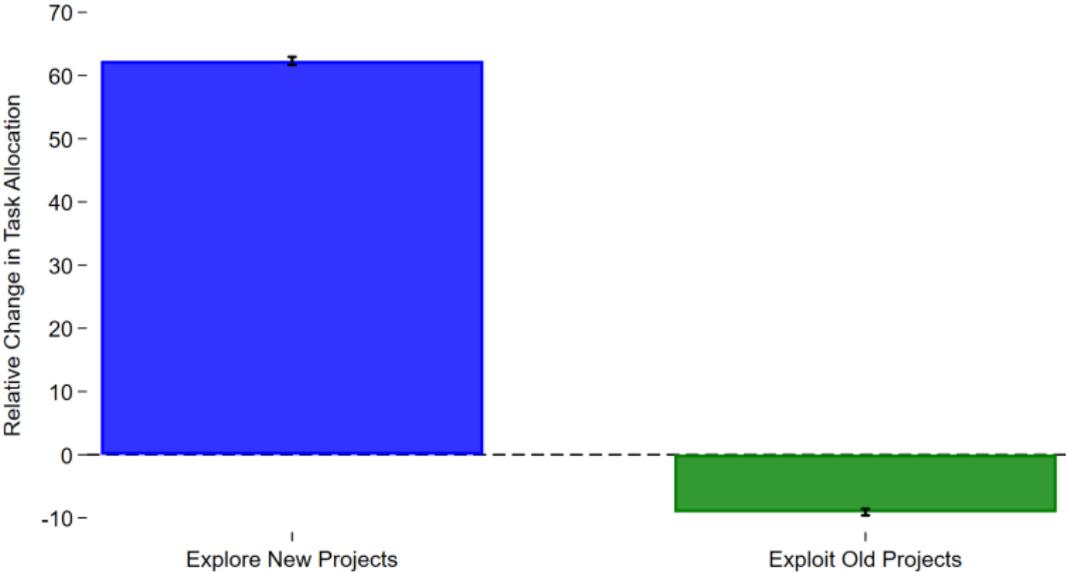
Collaborators drop for project management



⇒ 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	
$\mathbb{1}(\text{Eligible})$	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	
$\mathbb{1}(\text{Eligible})$	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!

⇒ Manuel Hoffmann

⇒ mhoffmann@hbs.edu

