Generative AI and the Nature of Work

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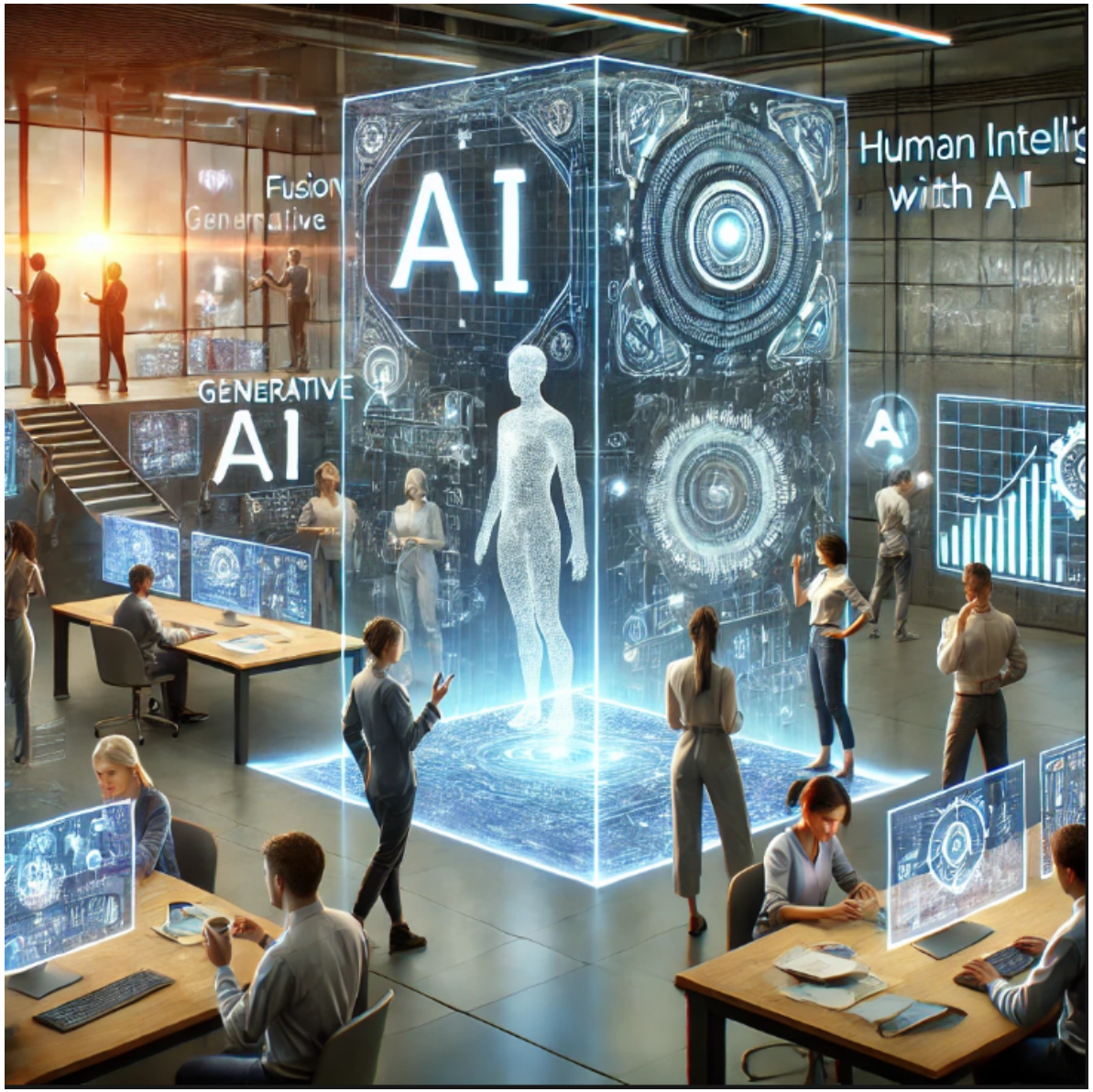
Harvard Business School

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

$\Rightarrow$ Task reallocation: Core Work $\uparrow$ Project Management $\downarrow$

$\Rightarrow$ Impact stronger for those with lower ability

$\Rightarrow$ Two primary mechanisms:

- Autonomous work $\uparrow$, collaborative work $\downarrow$
- Exploration $\uparrow$ Exploitation $\downarrow$

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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⇒ **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?

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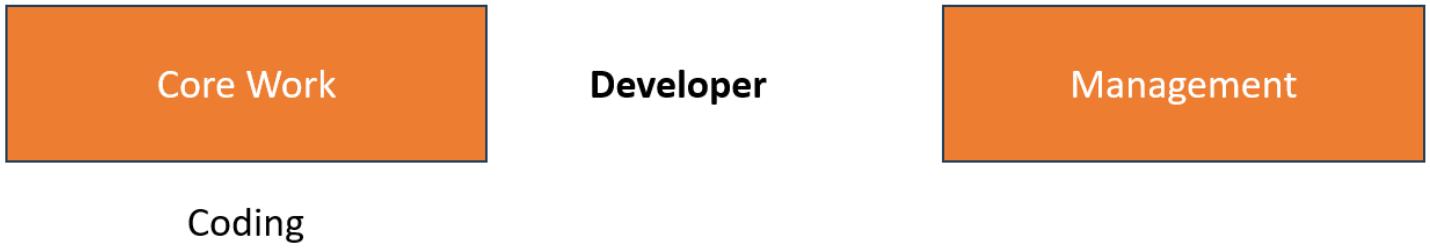

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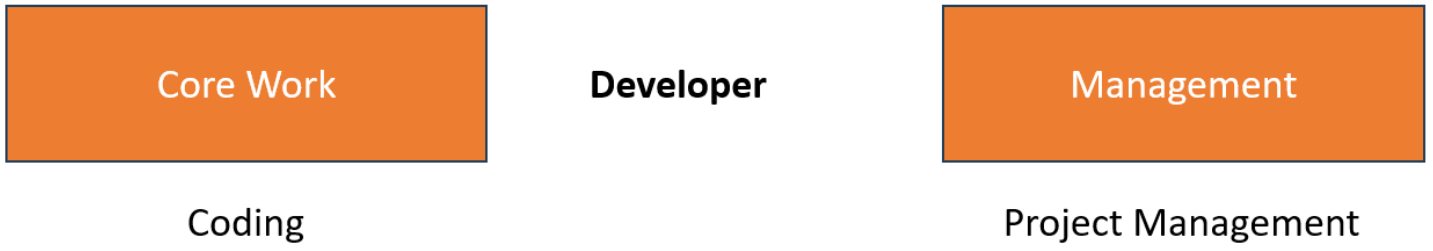

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FOSS Contributor Survey (Nagle et al. 2020)

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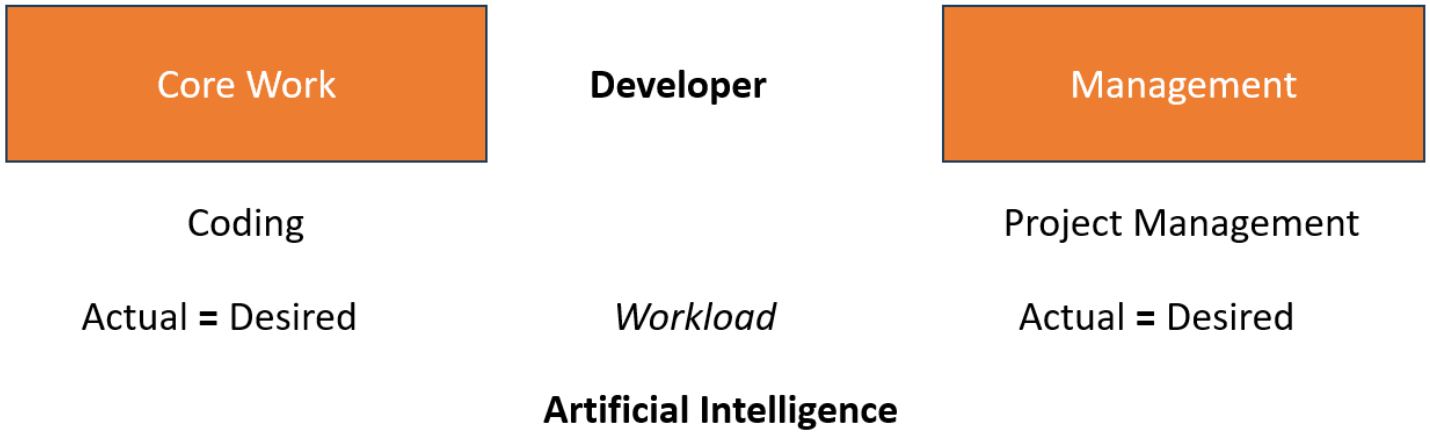

⇒ **Research Question**:

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

$$\begin{aligned} \underset{c,\, m}{\text{maximize}} \quad & u_\theta(c, m) \\ \text{subject to} \quad & p_c c + p_m m \leq \omega \end{aligned}$$

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

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

Main hypotheses for AI assisting with core work

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

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

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?

Extend model Nested CES

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

$\Rightarrow$ 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?

Extend model Nested CES

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Hypothesis 3: Exploration ↑, exploitation ↓ 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

$\Rightarrow$ 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

$\Rightarrow$ Identify a setting where

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

$\Rightarrow$ 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

$\Rightarrow$ 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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- report "issues" (bugs, feature requests, etc.)
- provide actual suggested code requests (pull requests)

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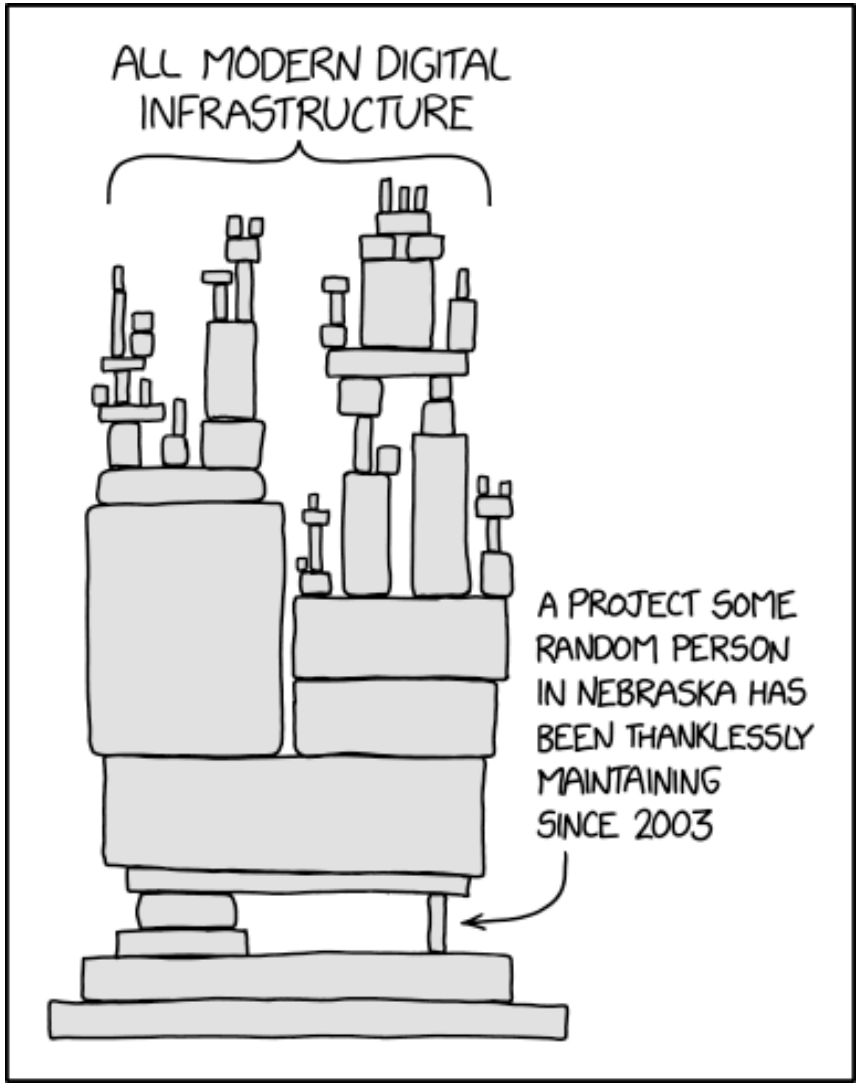
- report "issues" (bugs, feature requests, etc.)
- provide actual suggested code requests (pull requests)

⇒ 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



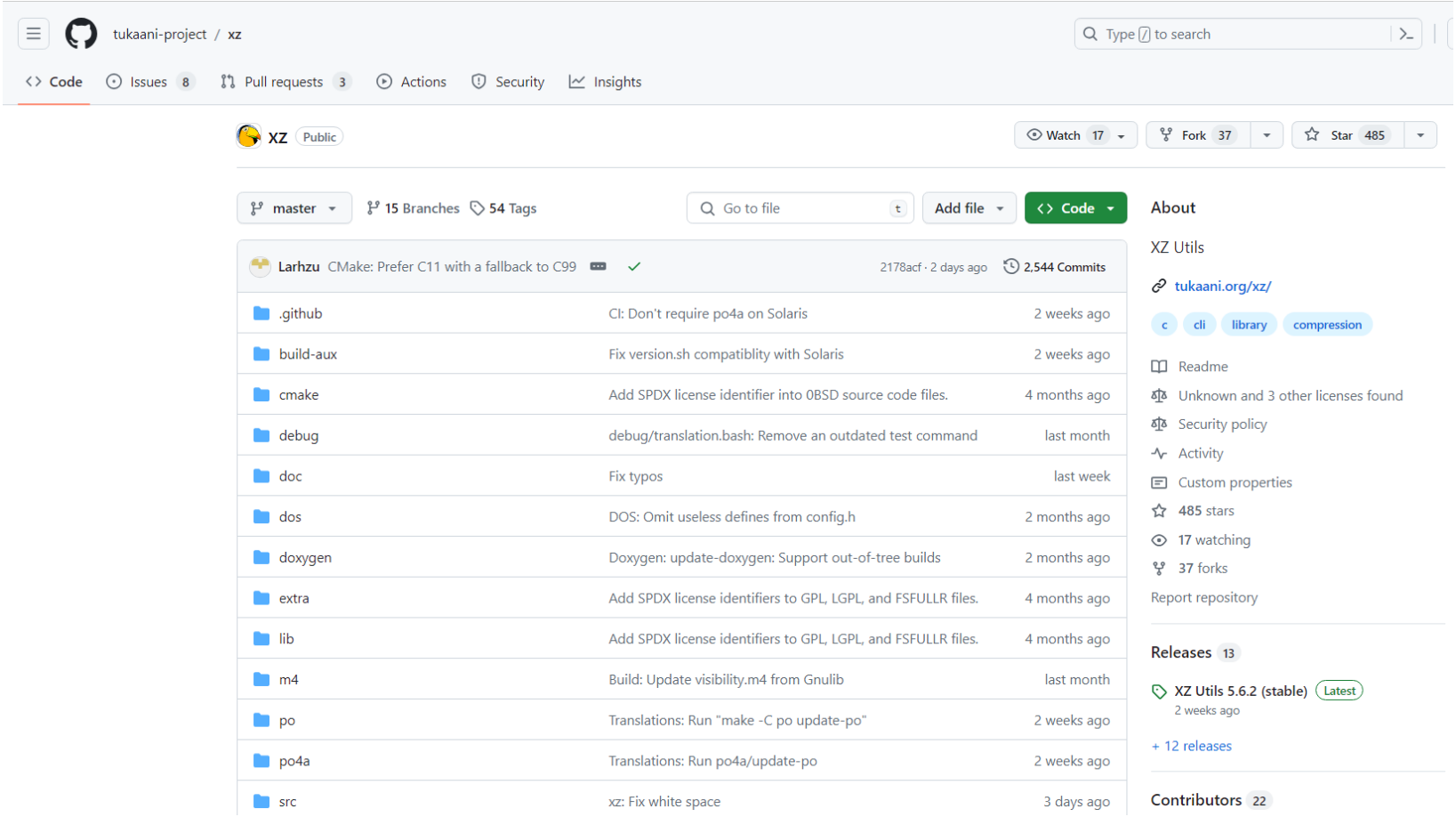
Source: XKCD PG

The GitHub Platform

⇒ **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



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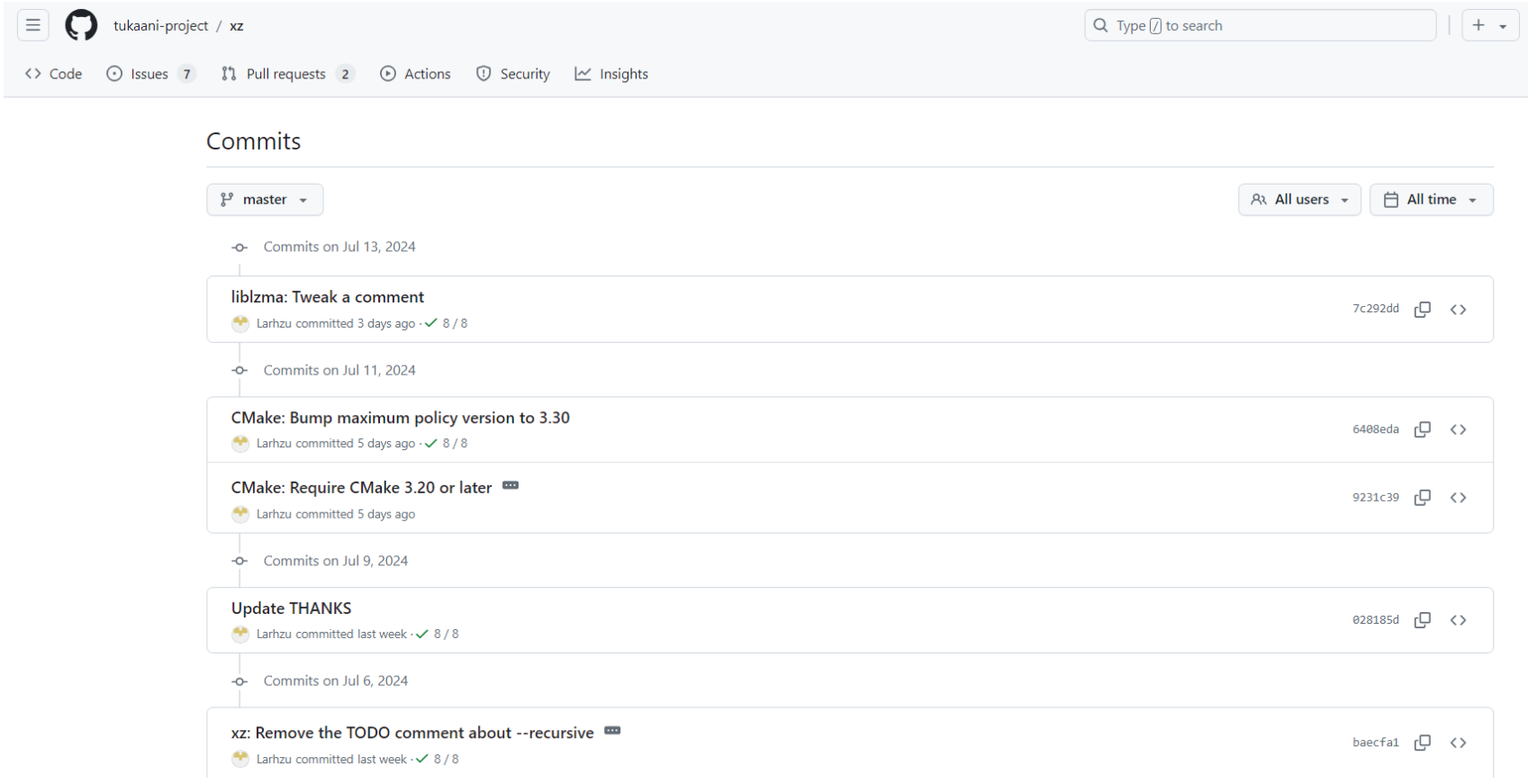
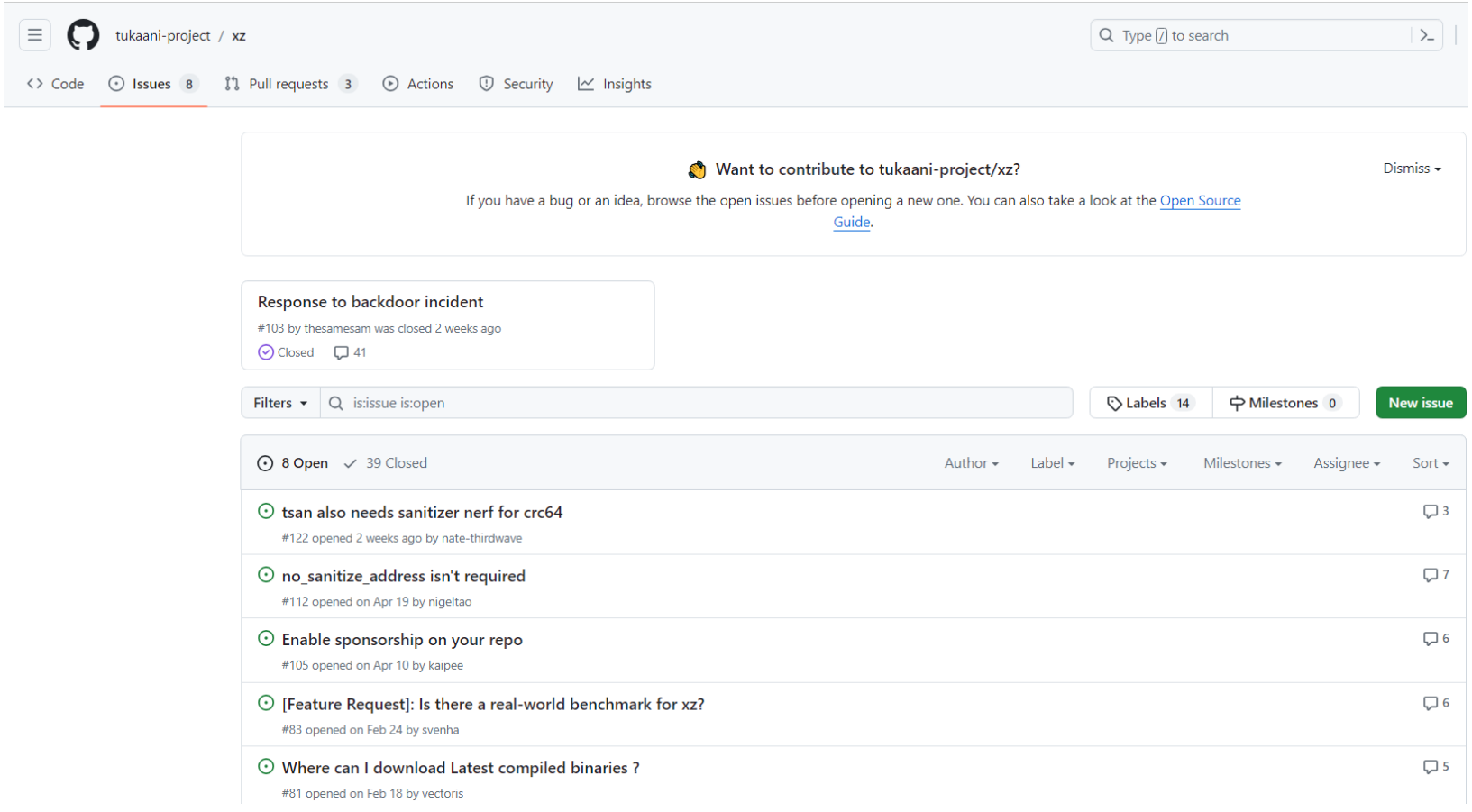


The GitHub Platform: Project Management

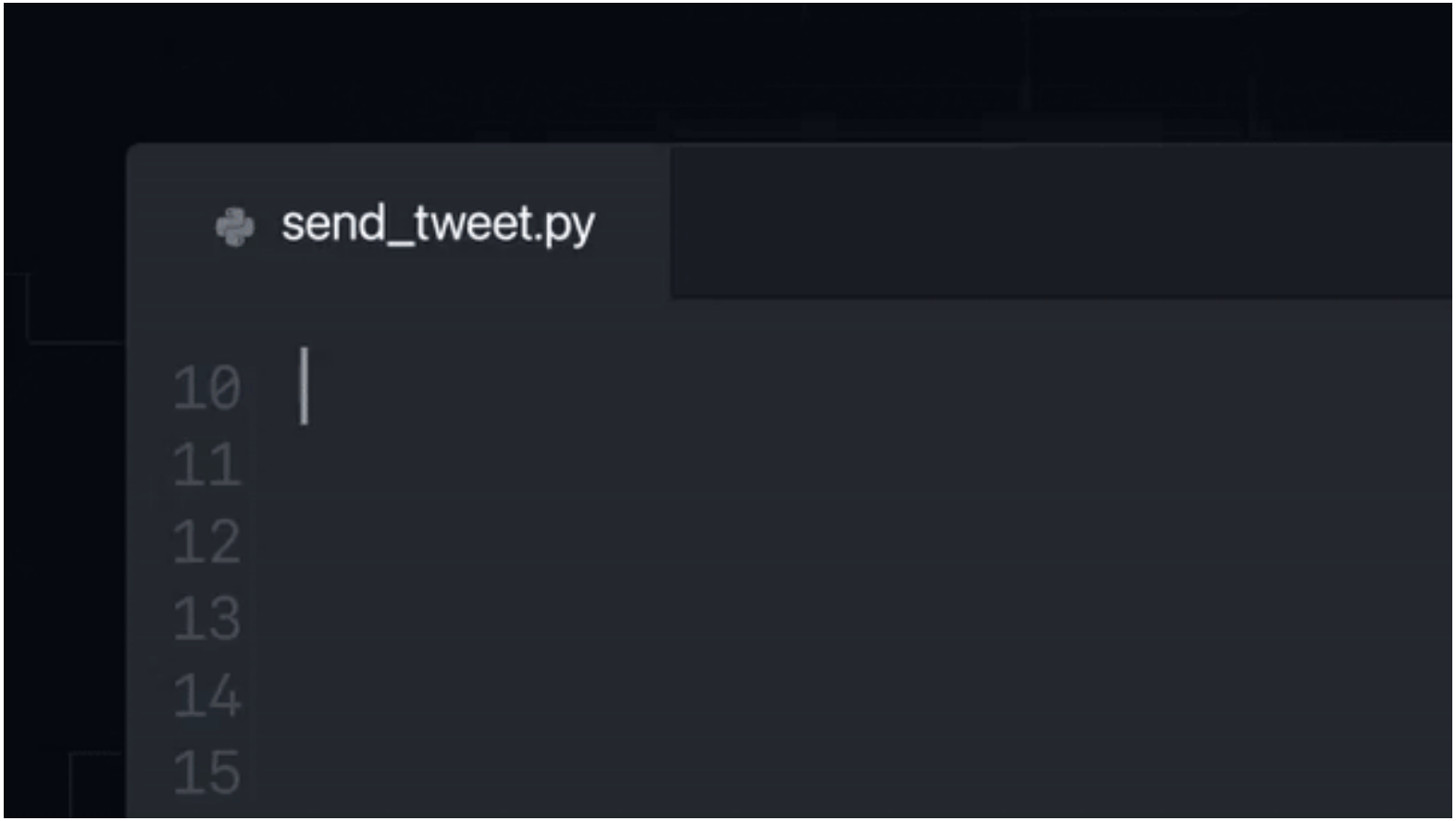


GitHub Generative AI: Copilot

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

Details

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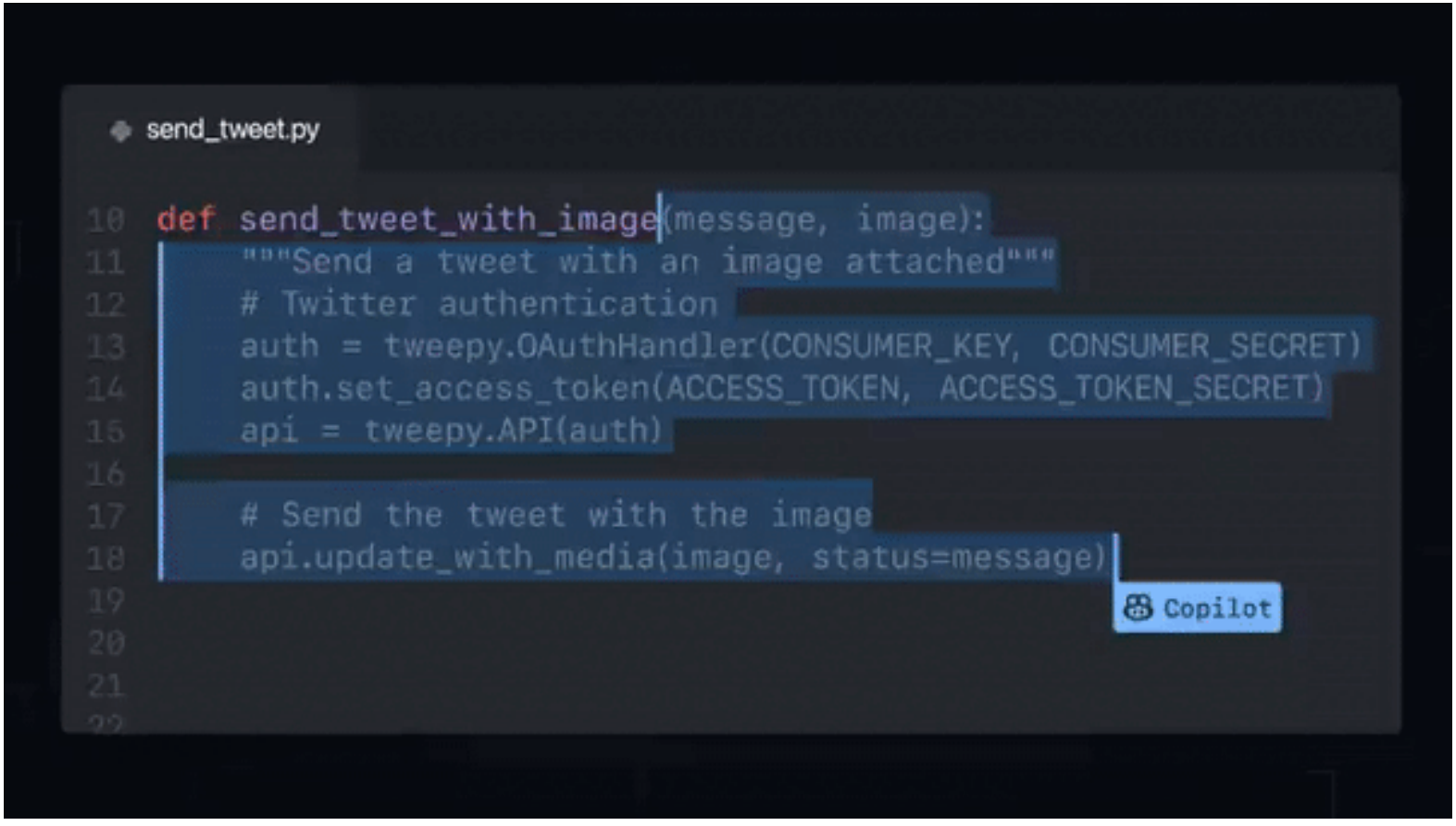

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GitHub Copilot AI deployment timeline

- Technical Preview

- General Access (Paid)
- 60 Days Trial (Free)
- Education (Free)
- Top Maintainer (Free)

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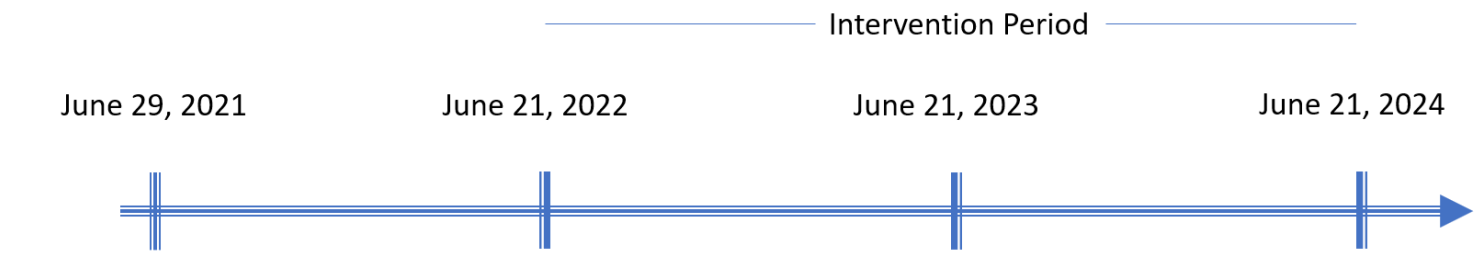

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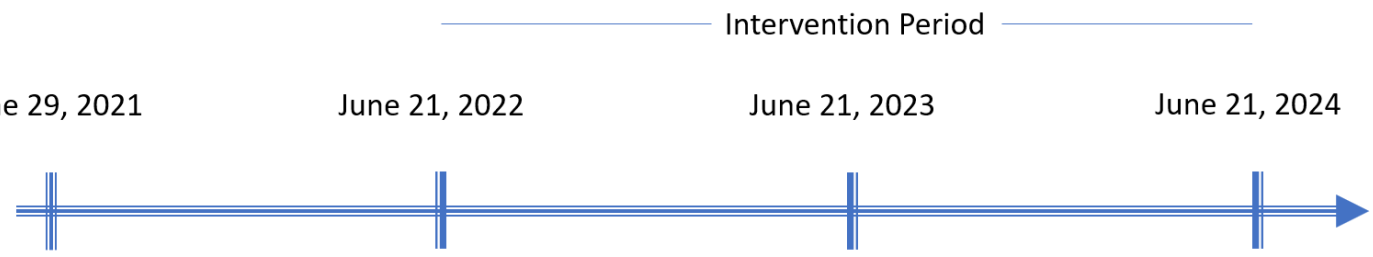

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Main Outcomes: Coding & Project Management

GitHub Copilot top maintainer natural experiment

$\Rightarrow$ **GitHub Goal**: Reward top open source maintainers

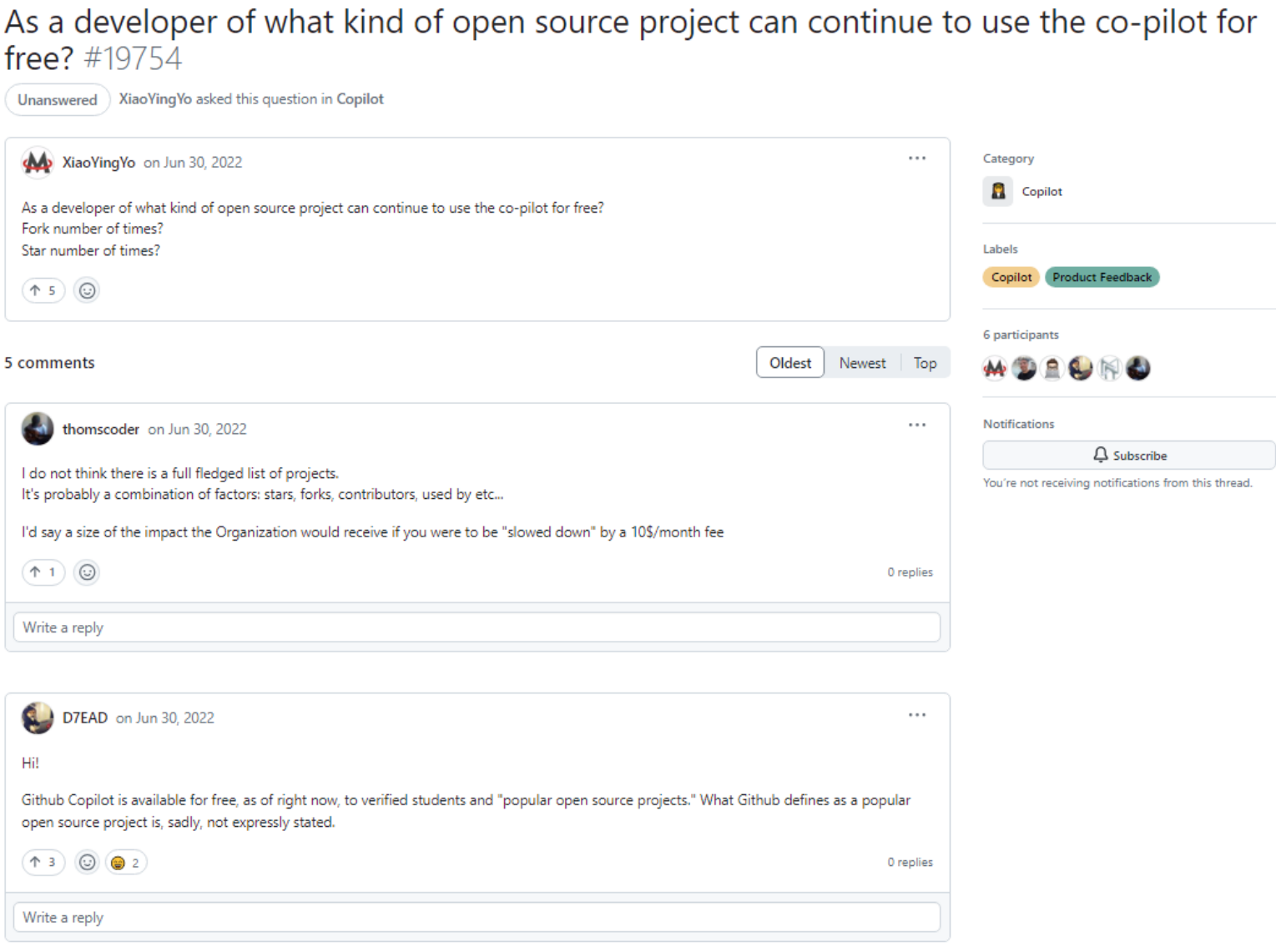
$\Rightarrow$ Provide *free access* to Copilot AI for top X maintainers

$\Rightarrow$ Internal ranking (R_i) at project (repository) level

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

$\Rightarrow$ 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

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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.

$$\mathrm{Y} = \{Copilot, Activity\} \text{ (First stage, ITT)}$$
$$\mathrm{k} = \{i, p\} \text{ (Individual, Project)}$$

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

Individual Outcomes

Copilot AI usage increases for free access rankings

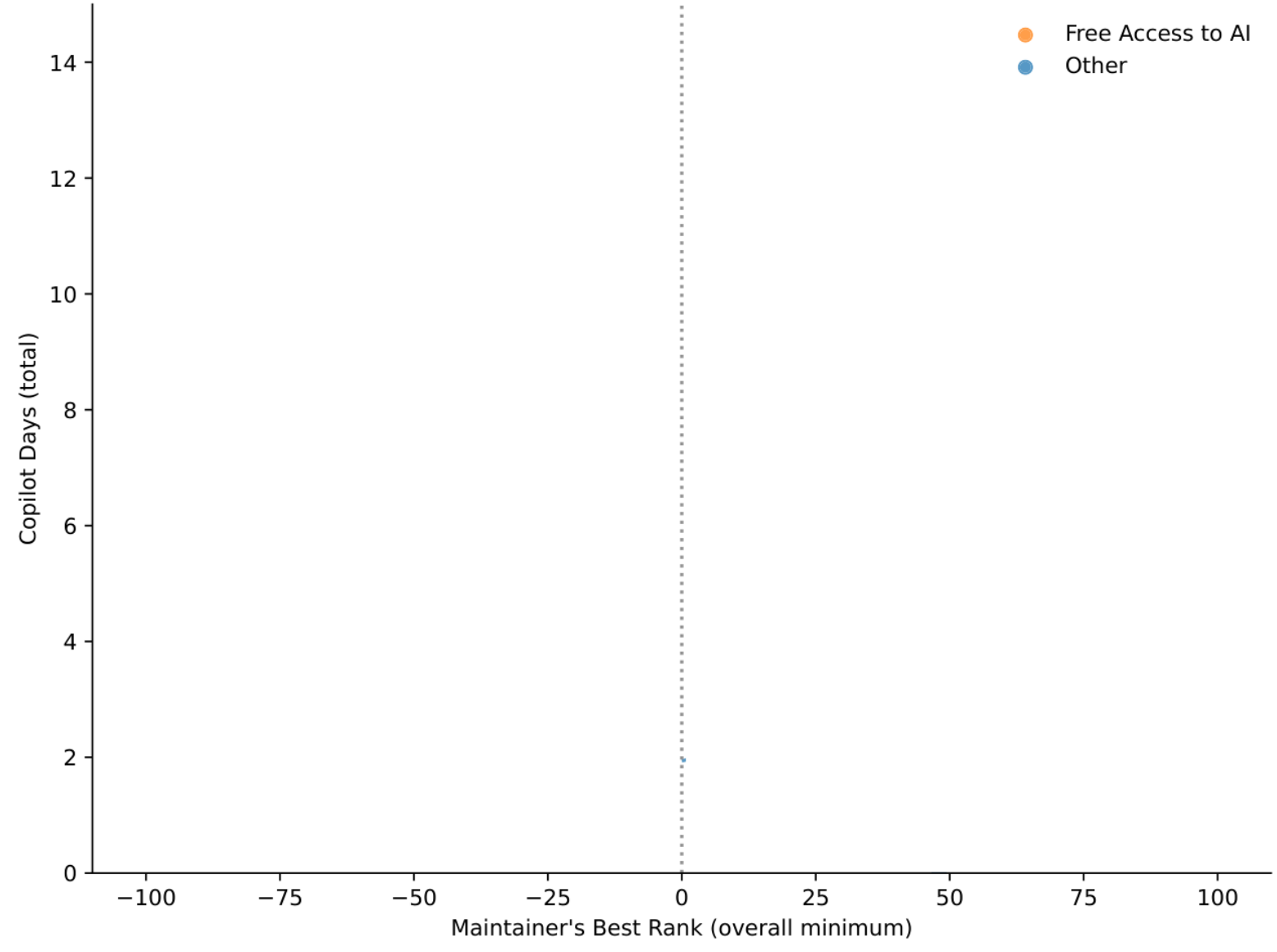
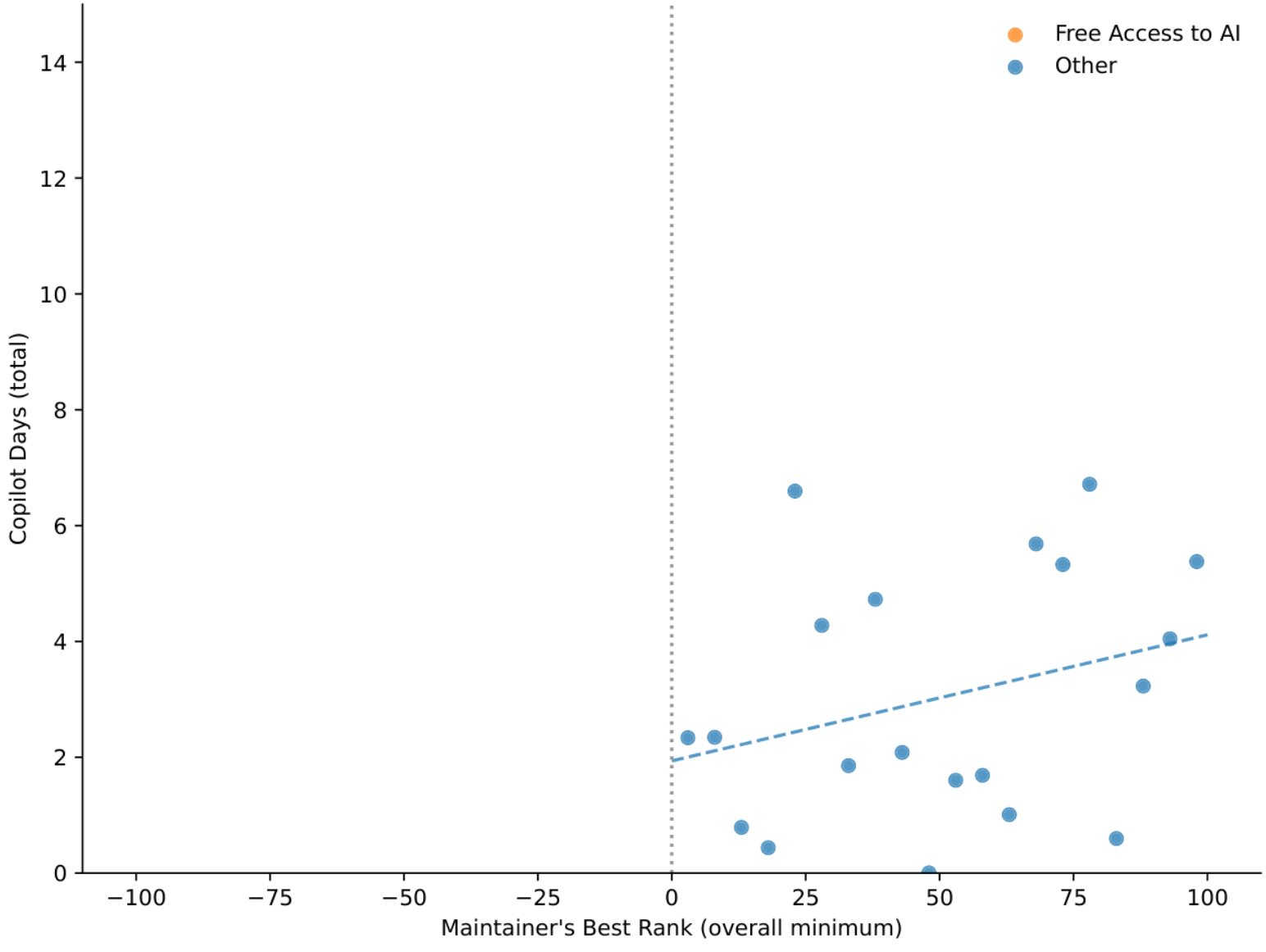


Table Dynamics

Copilot AI usage increases for free access rankings



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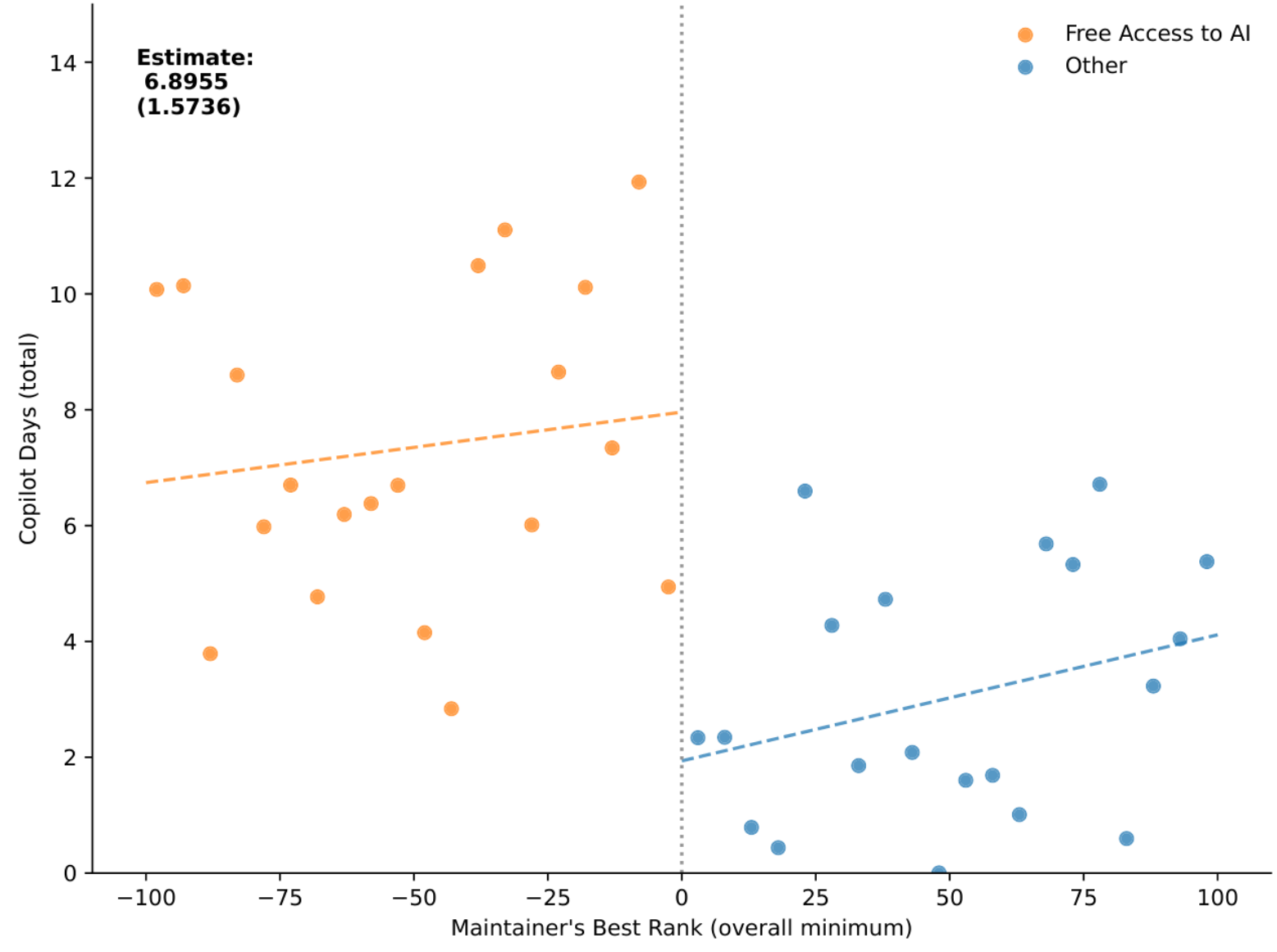
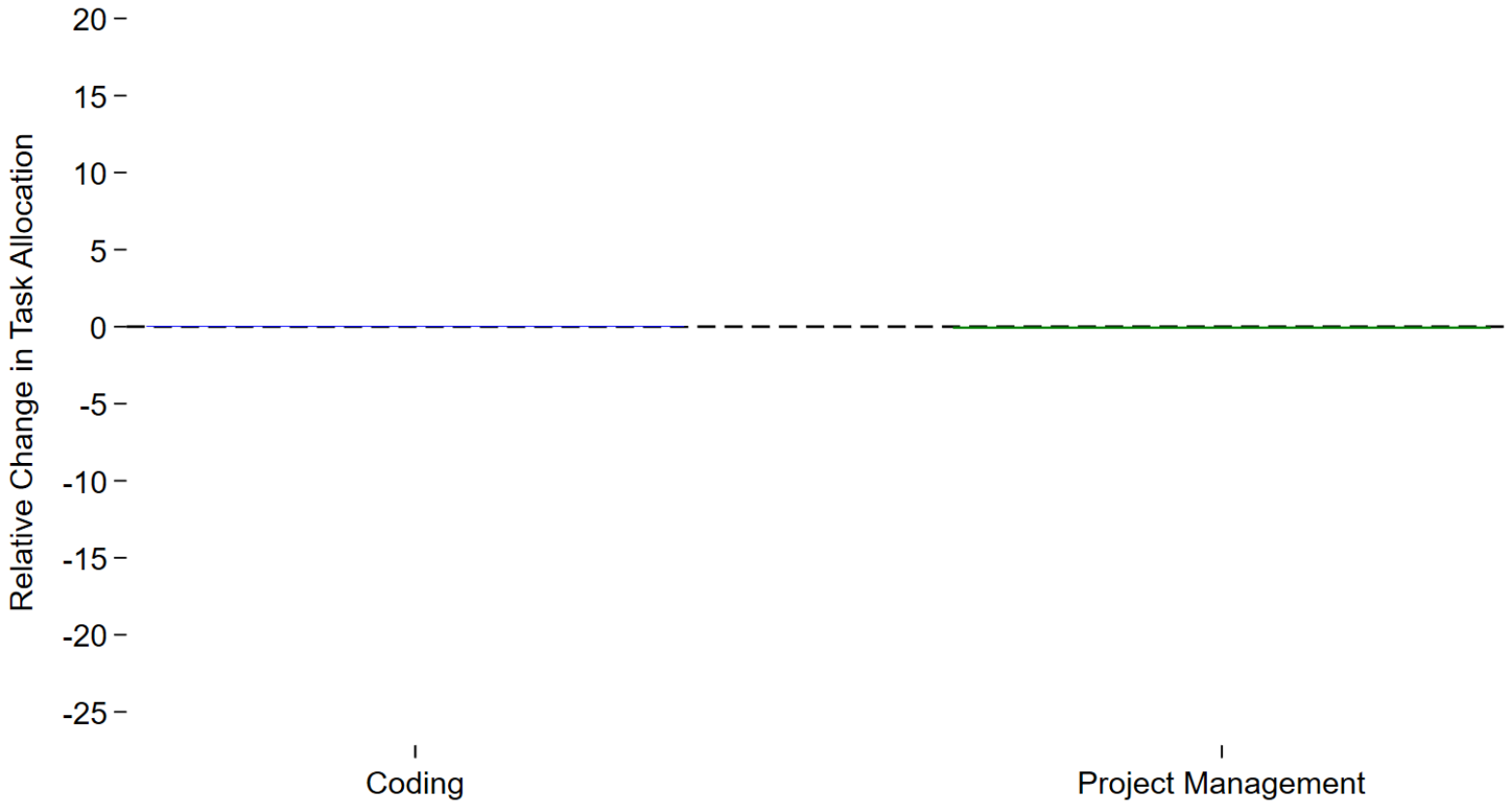
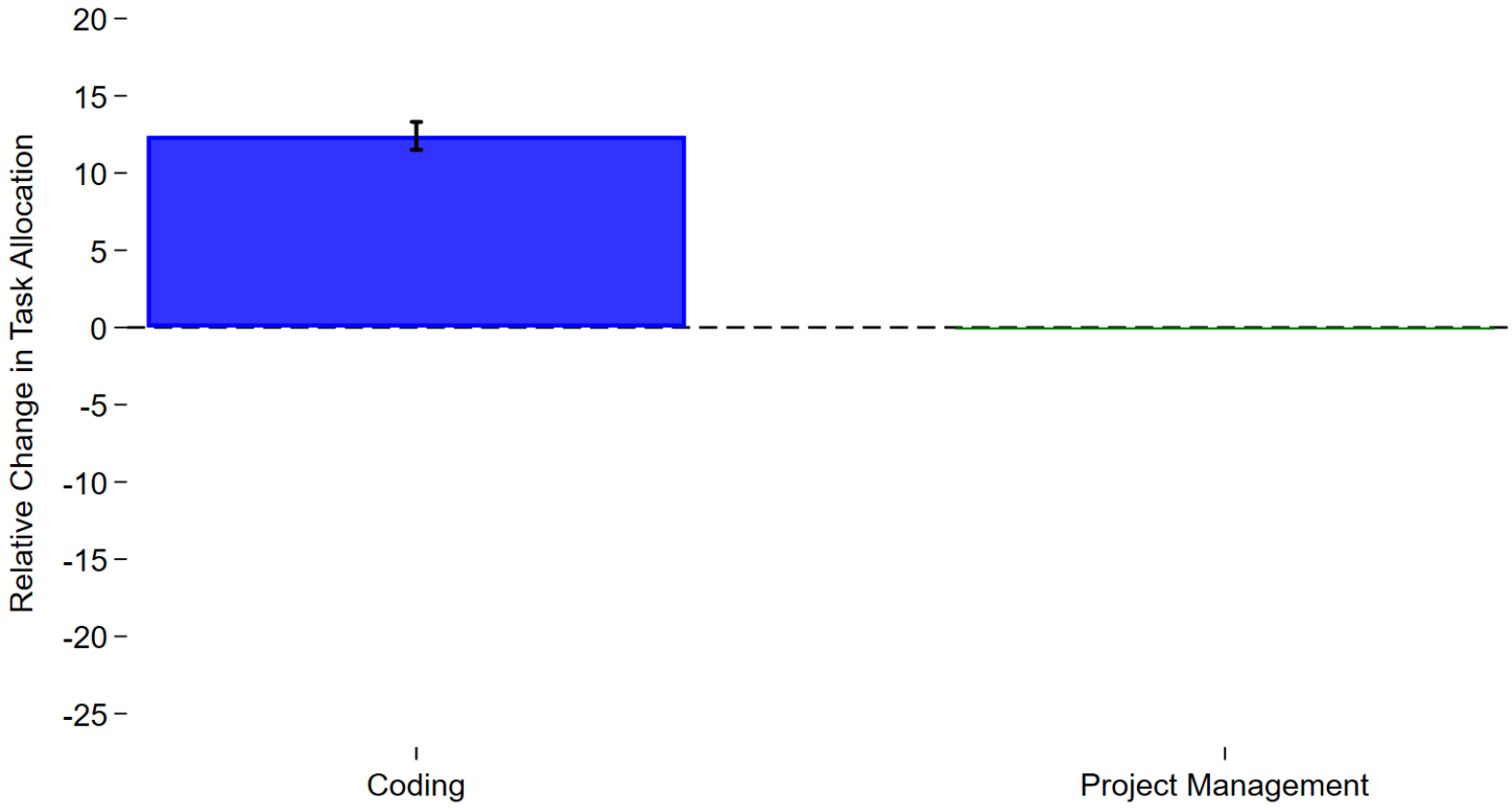


Table Dynamics

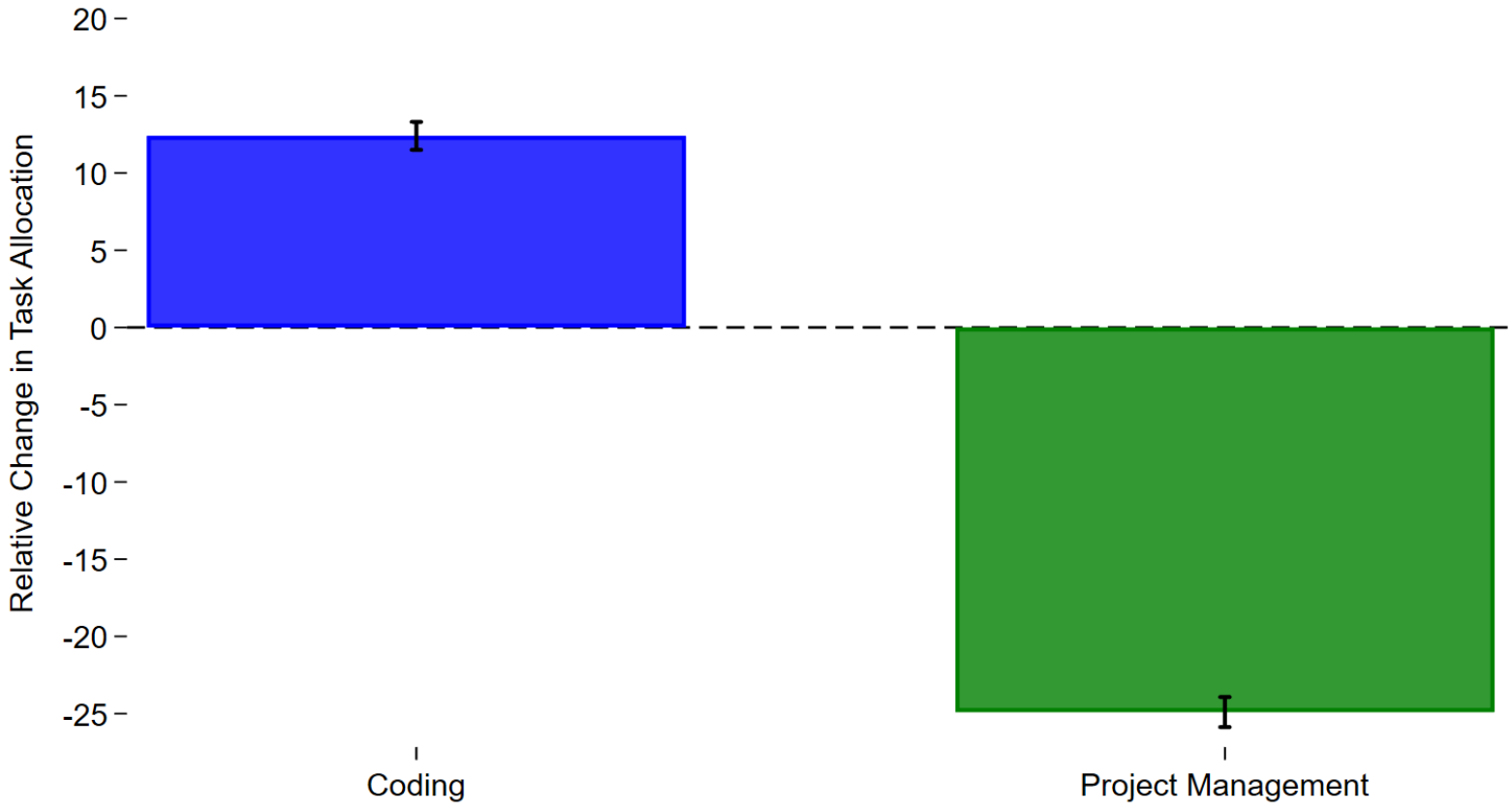
The impact of the Copilot AI on task allocation



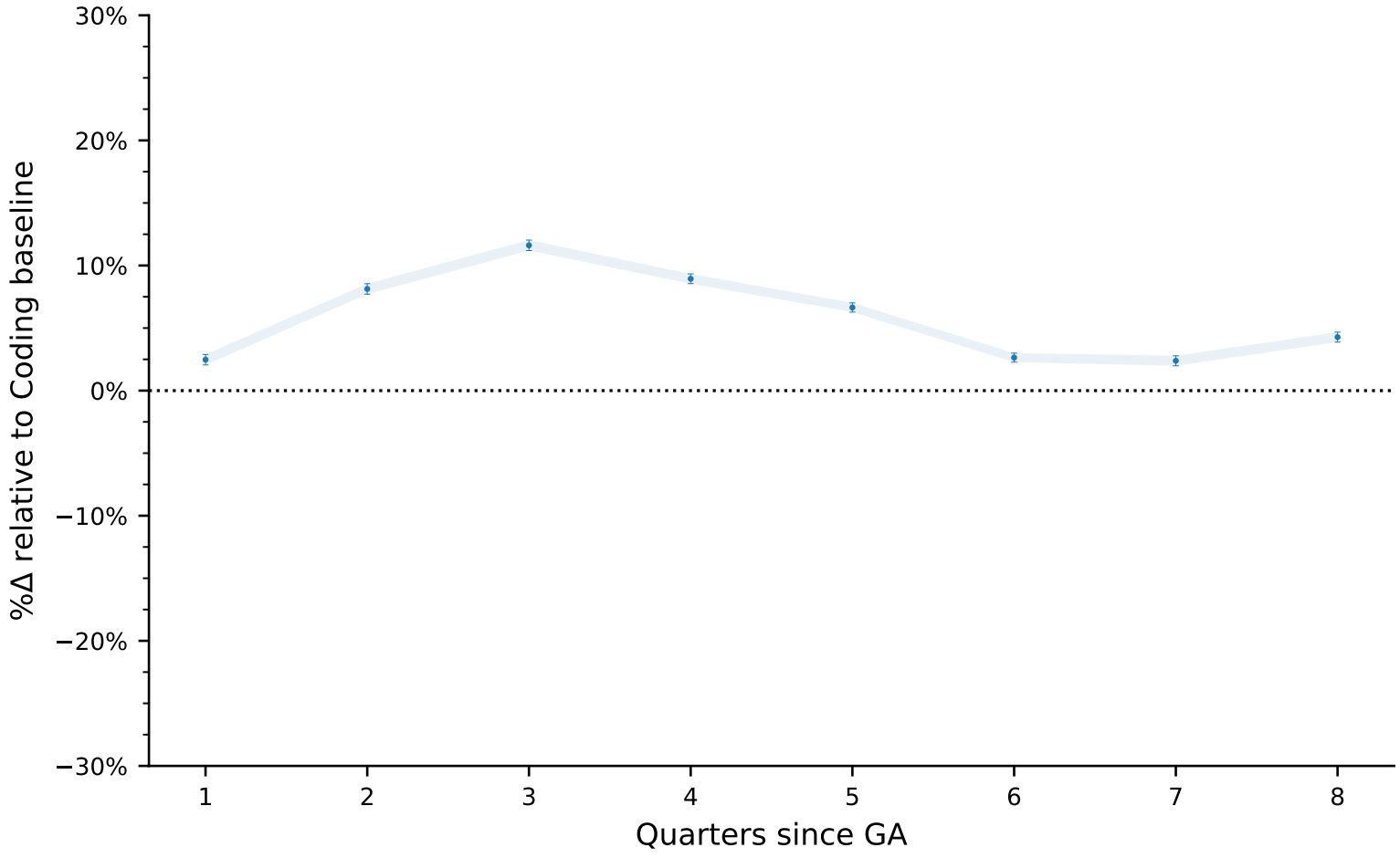
Copilot AI increases coding



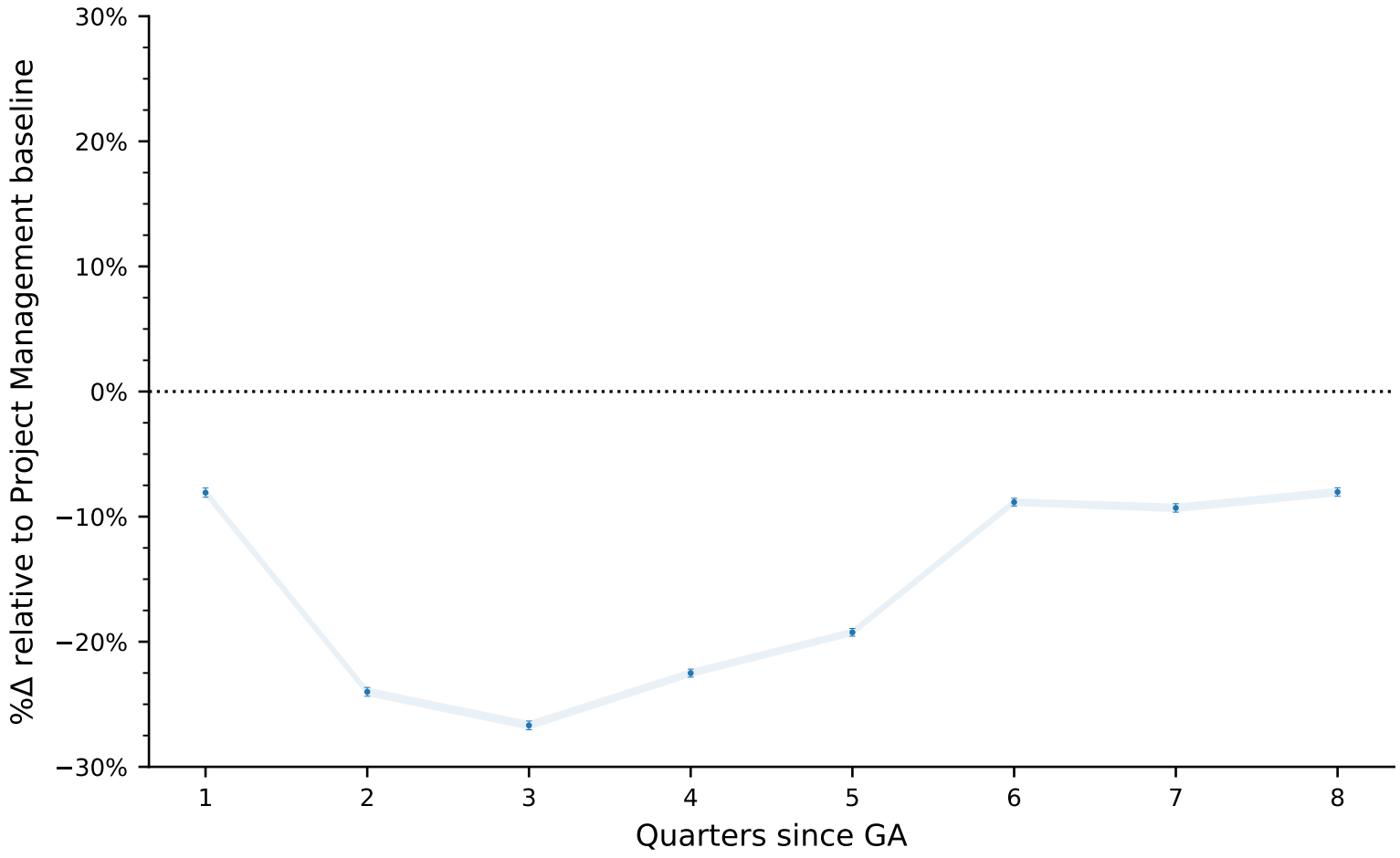
Copilot AI reduces project management



Dynamic effects of free-access AI on coding



Dynamic effects of free-access AI on project management

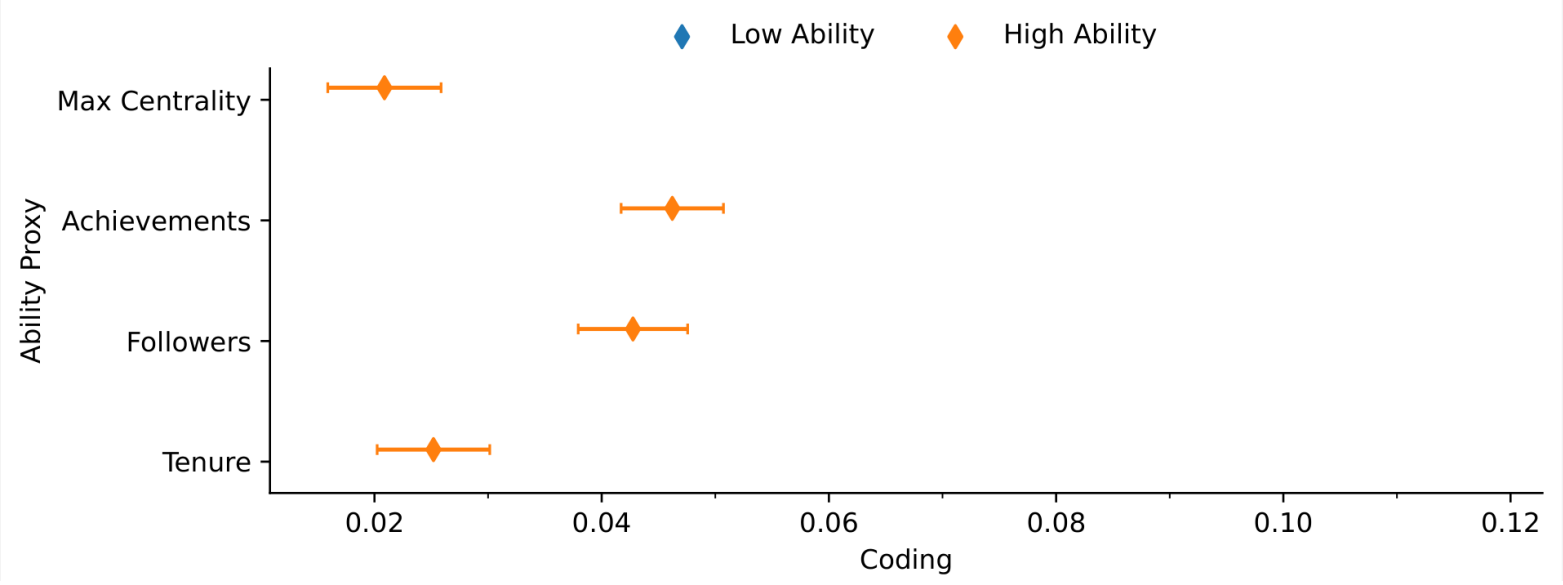


What are the mechanisms?

$\Rightarrow$ **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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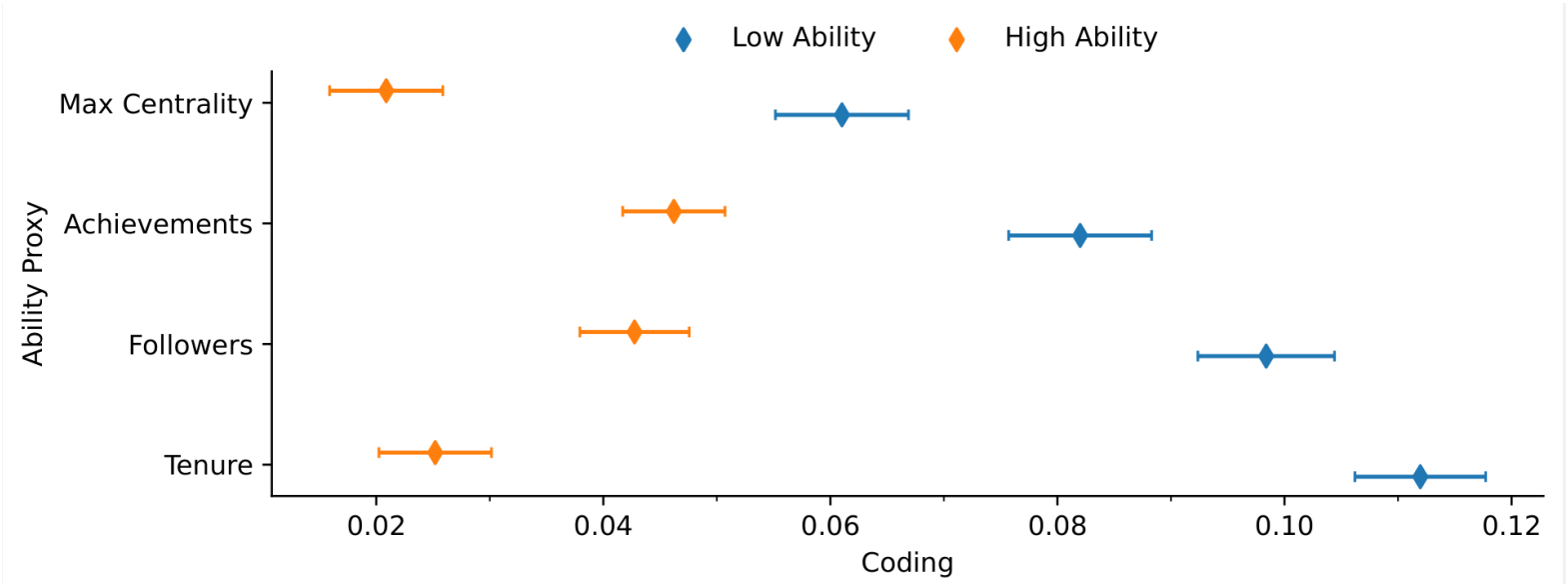

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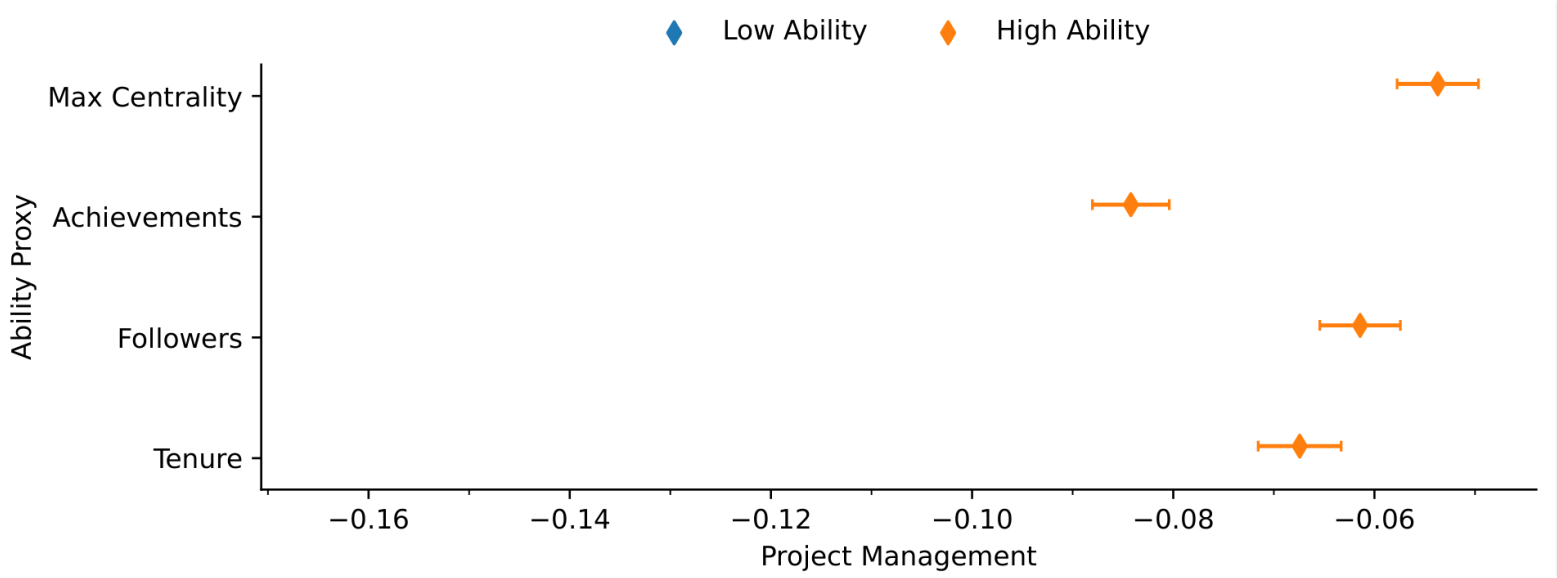

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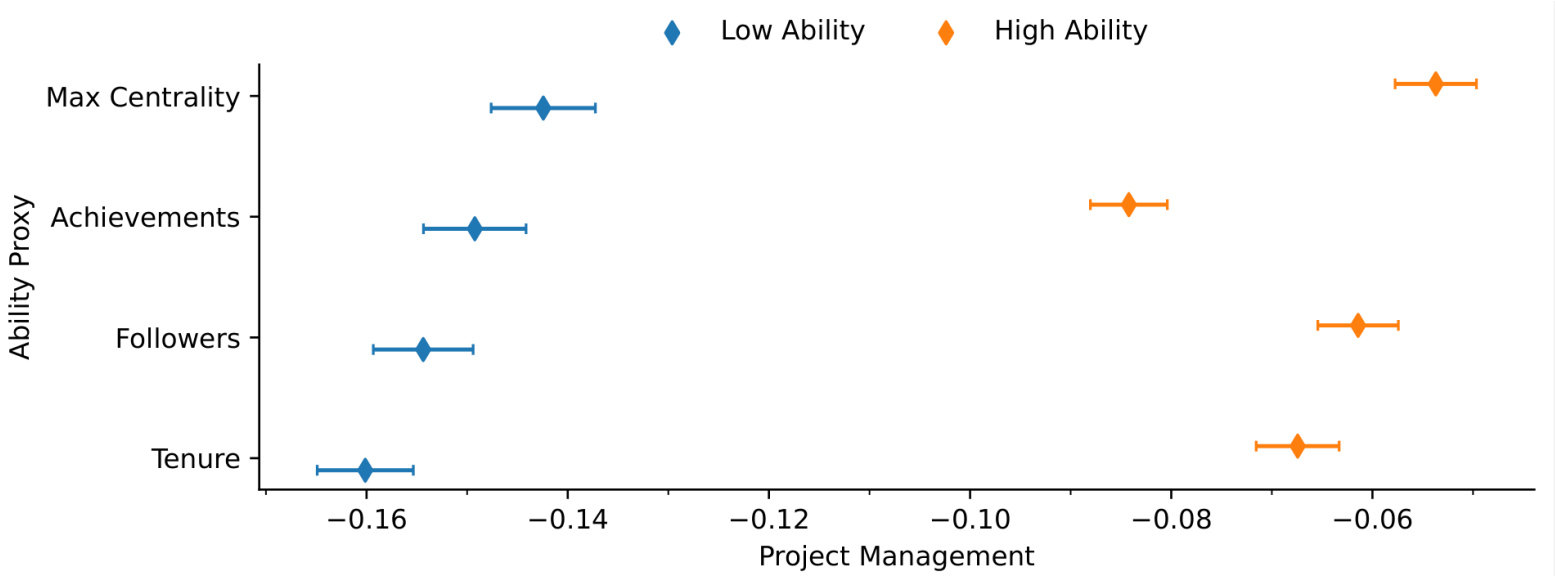
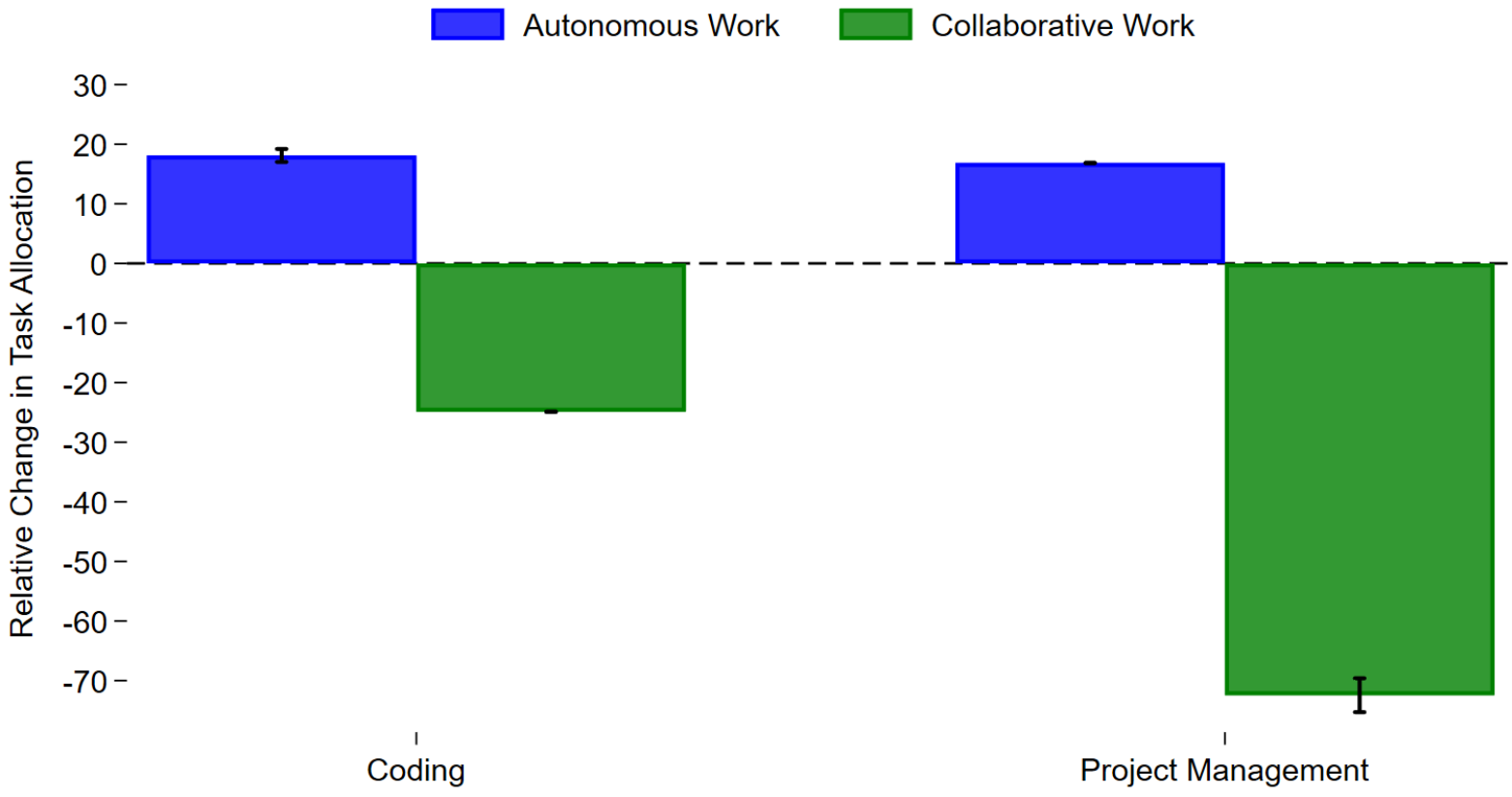


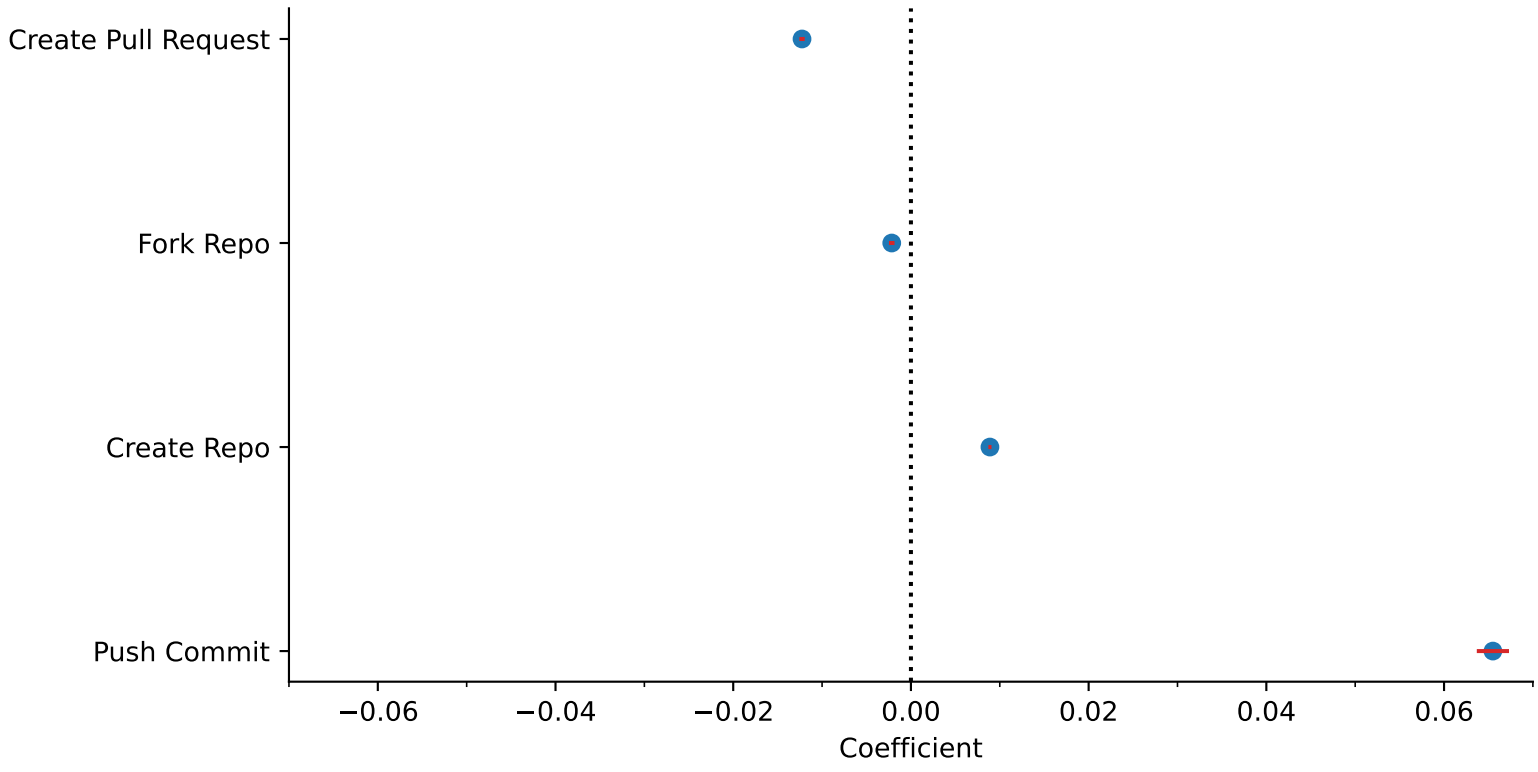
- Indicative of learning for low from high ability developers (AI training data)

Distributional effects

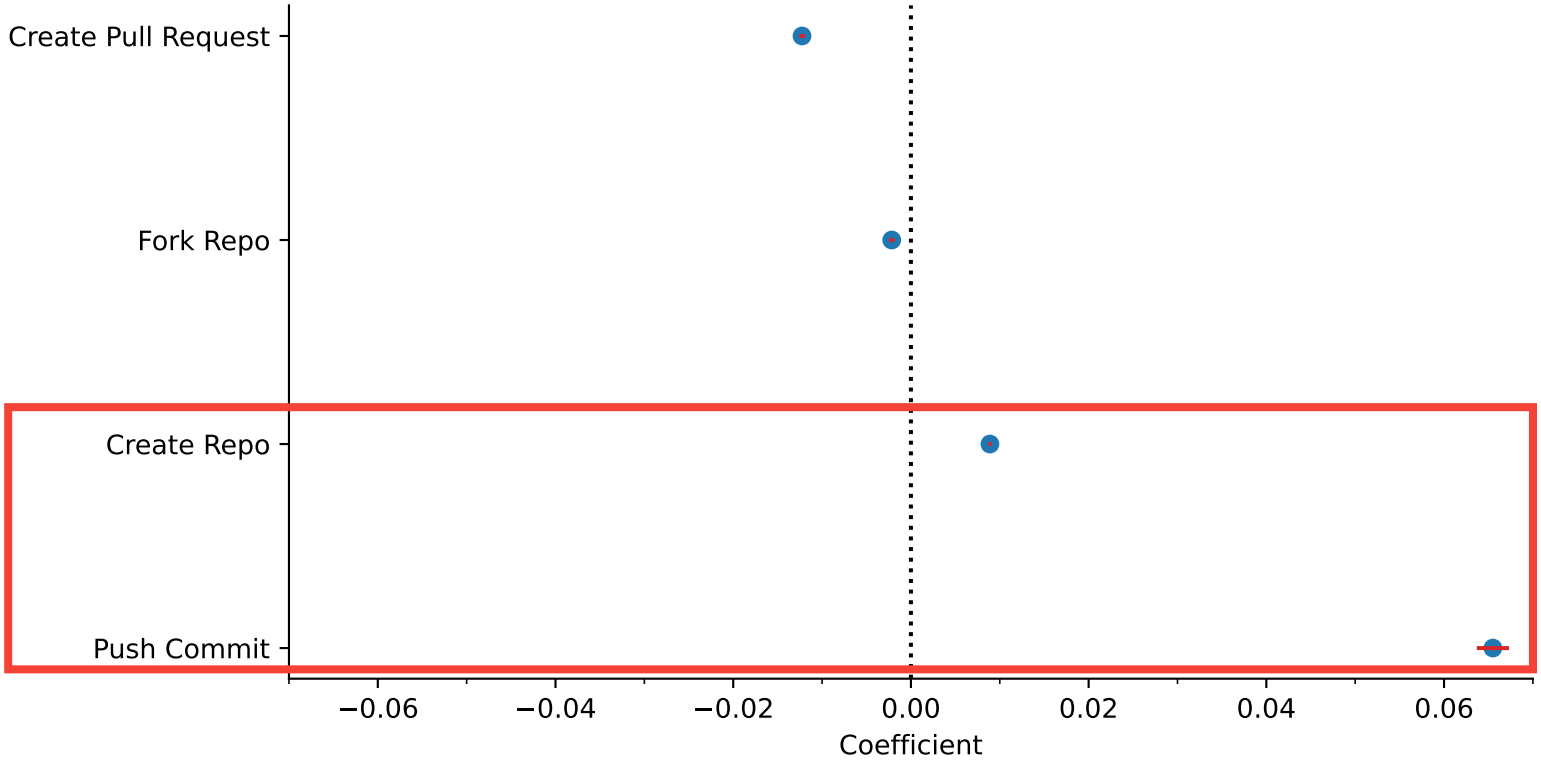
Copilot increases autonomous work



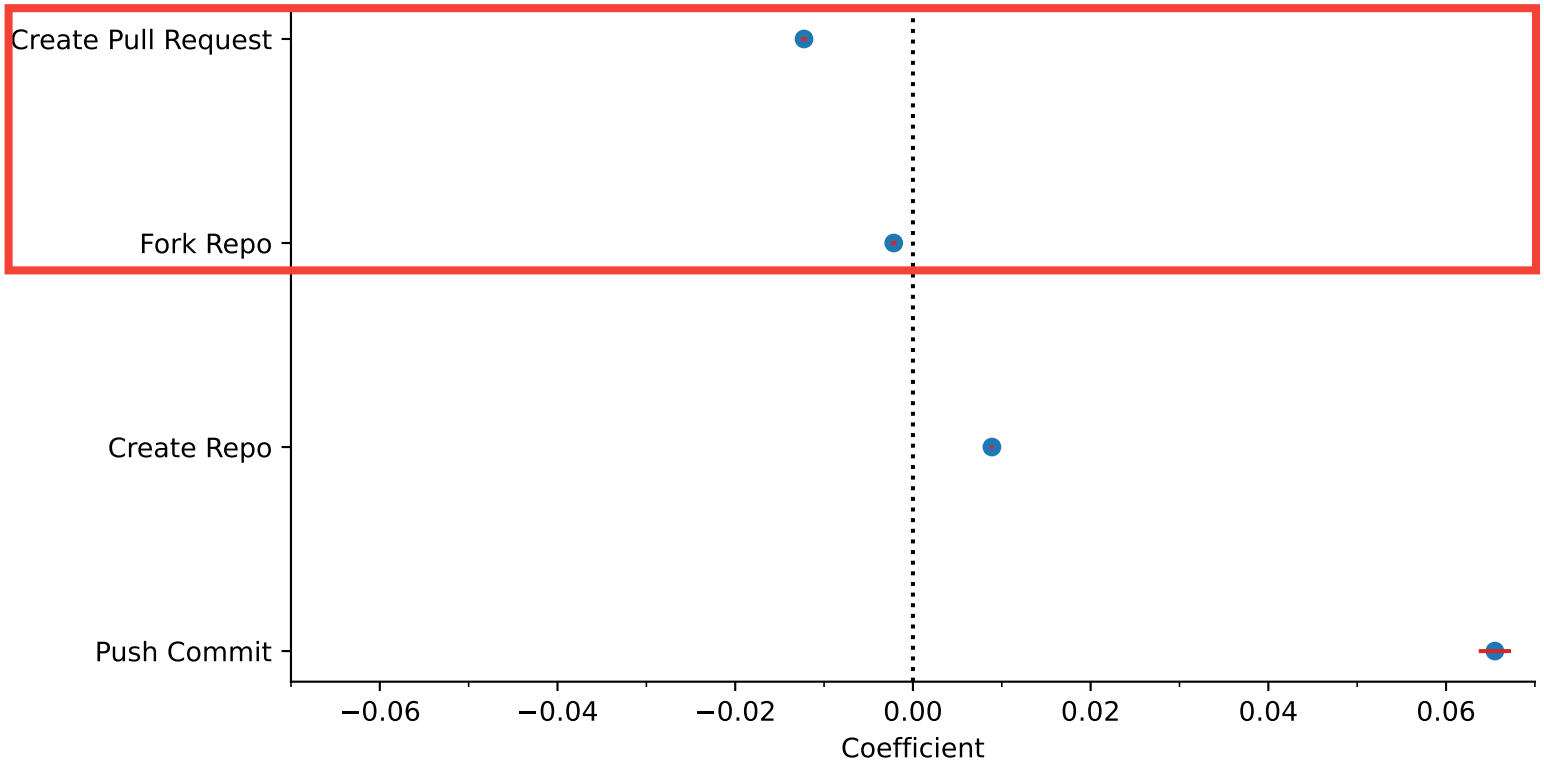
Granular coding effects



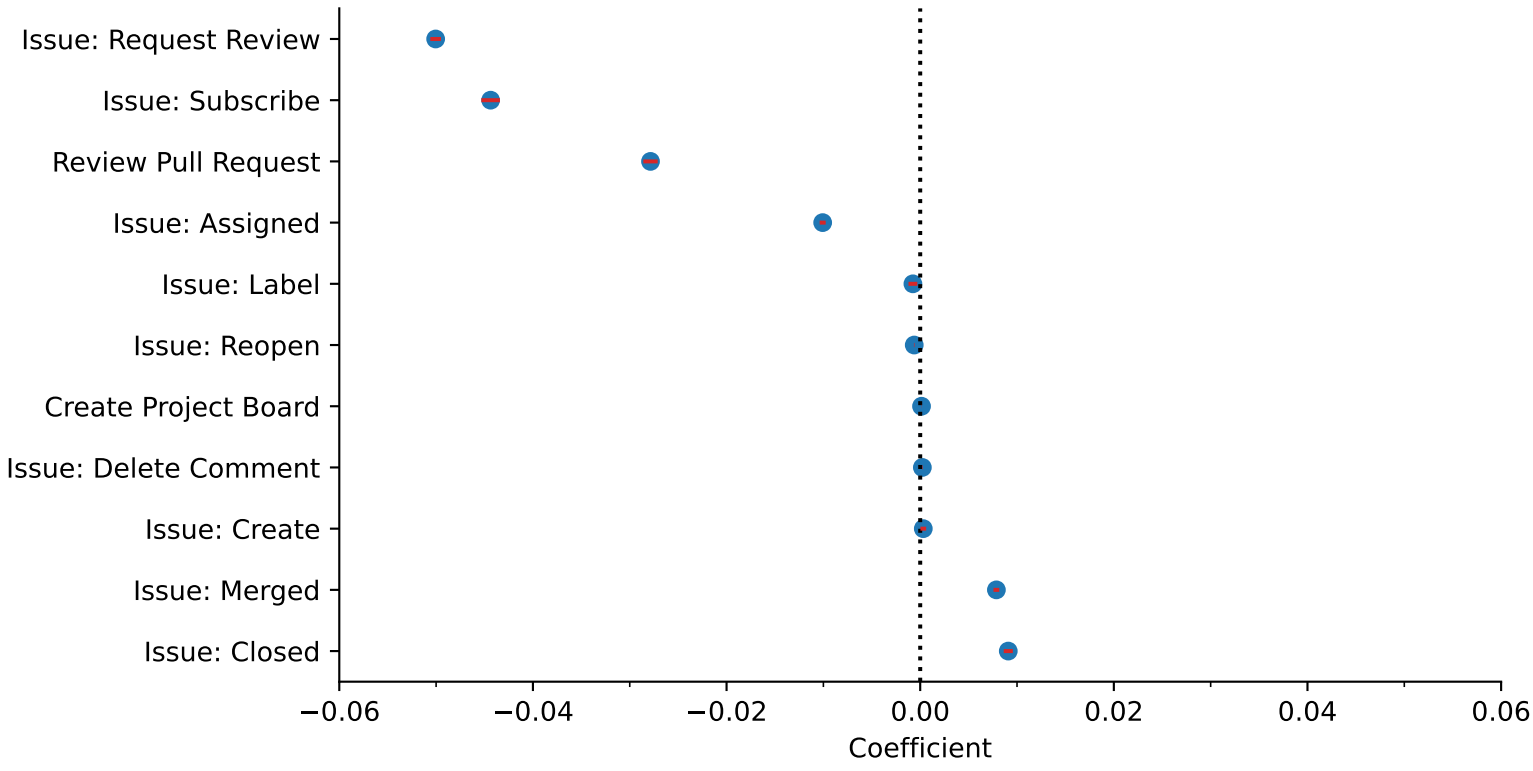
Granular coding effects for autonomous work



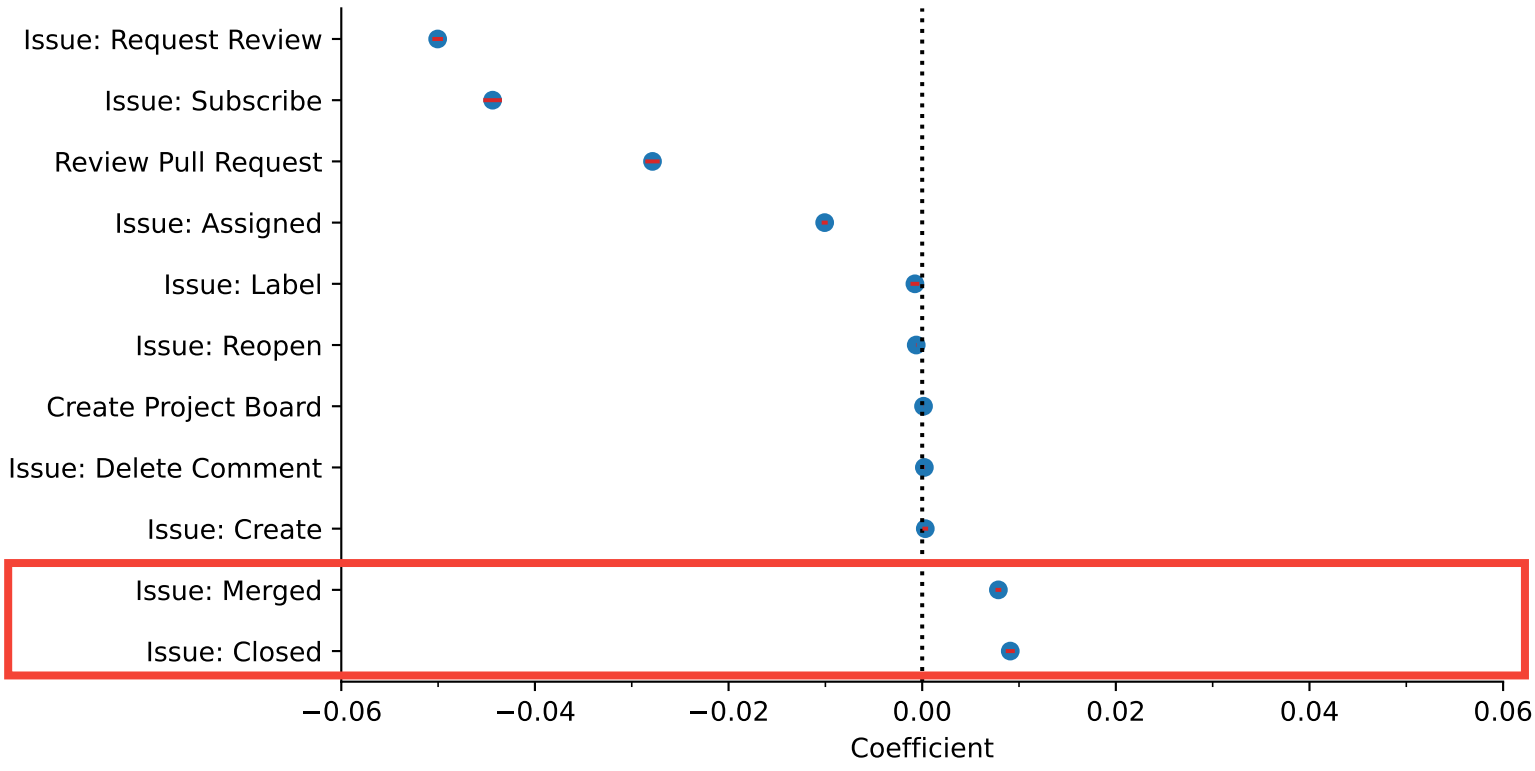
Granular coding effects for collaborative work



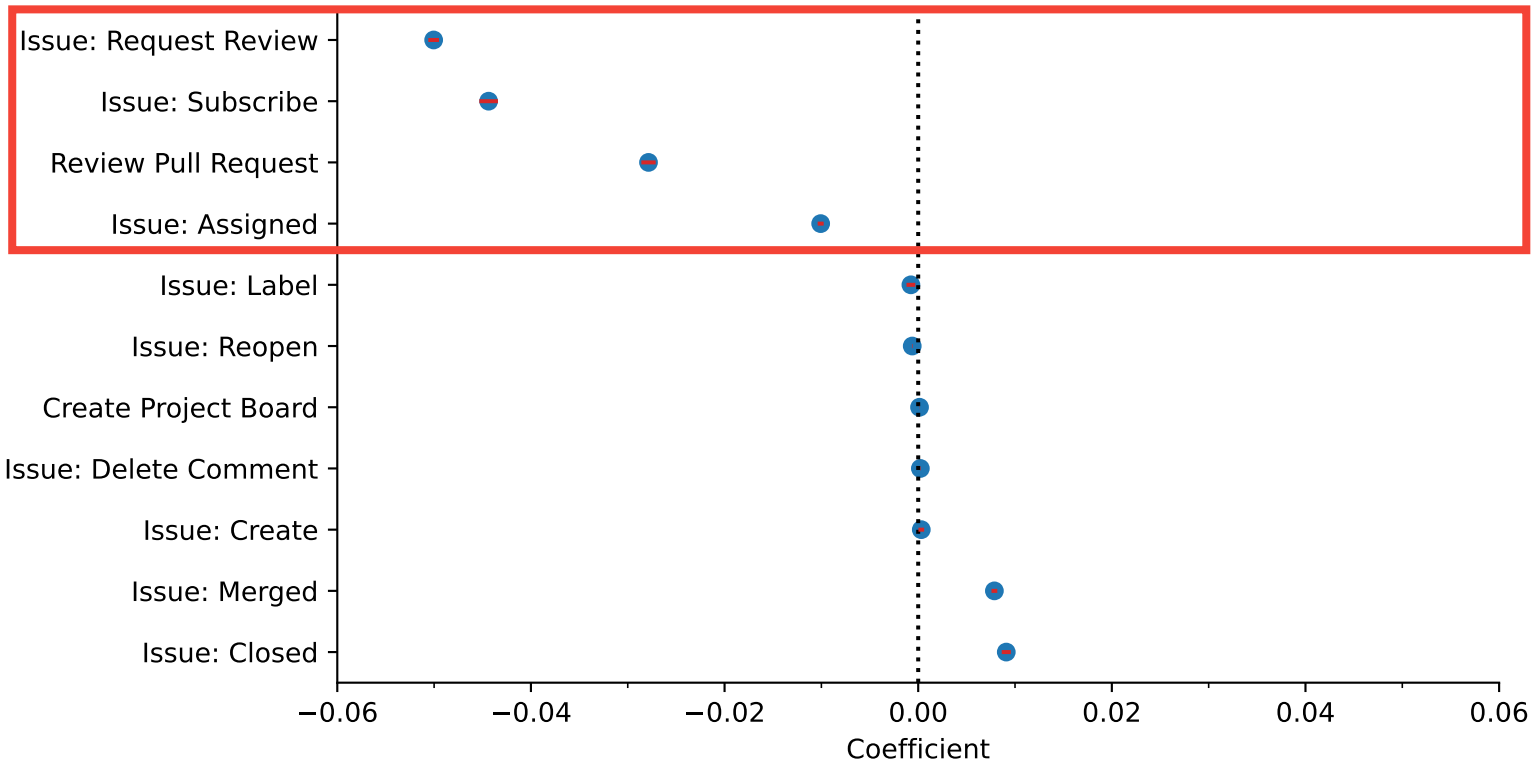
Granular project management effects



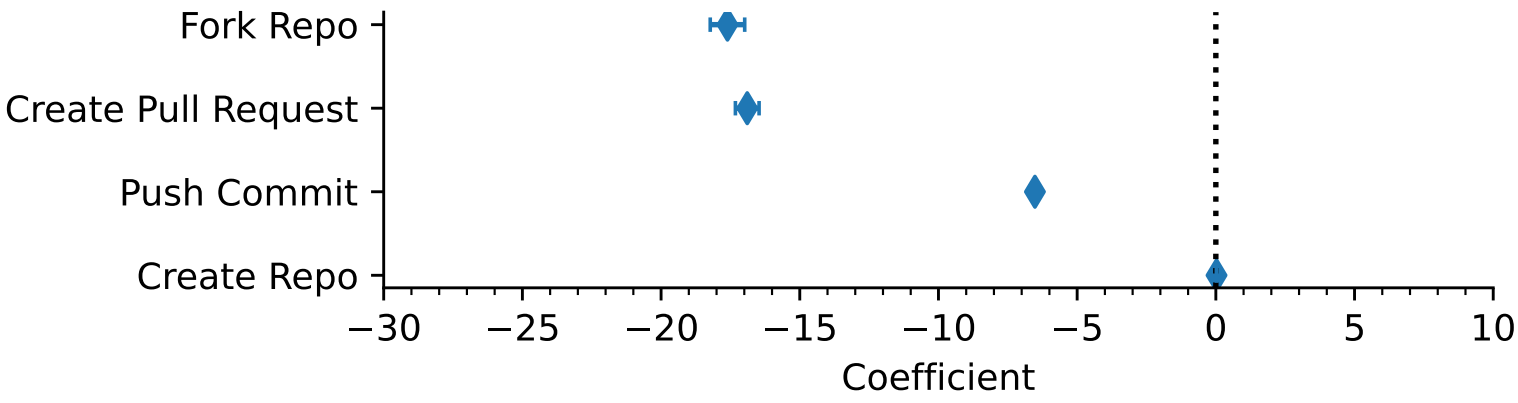
Granular project management effects for autonomous work



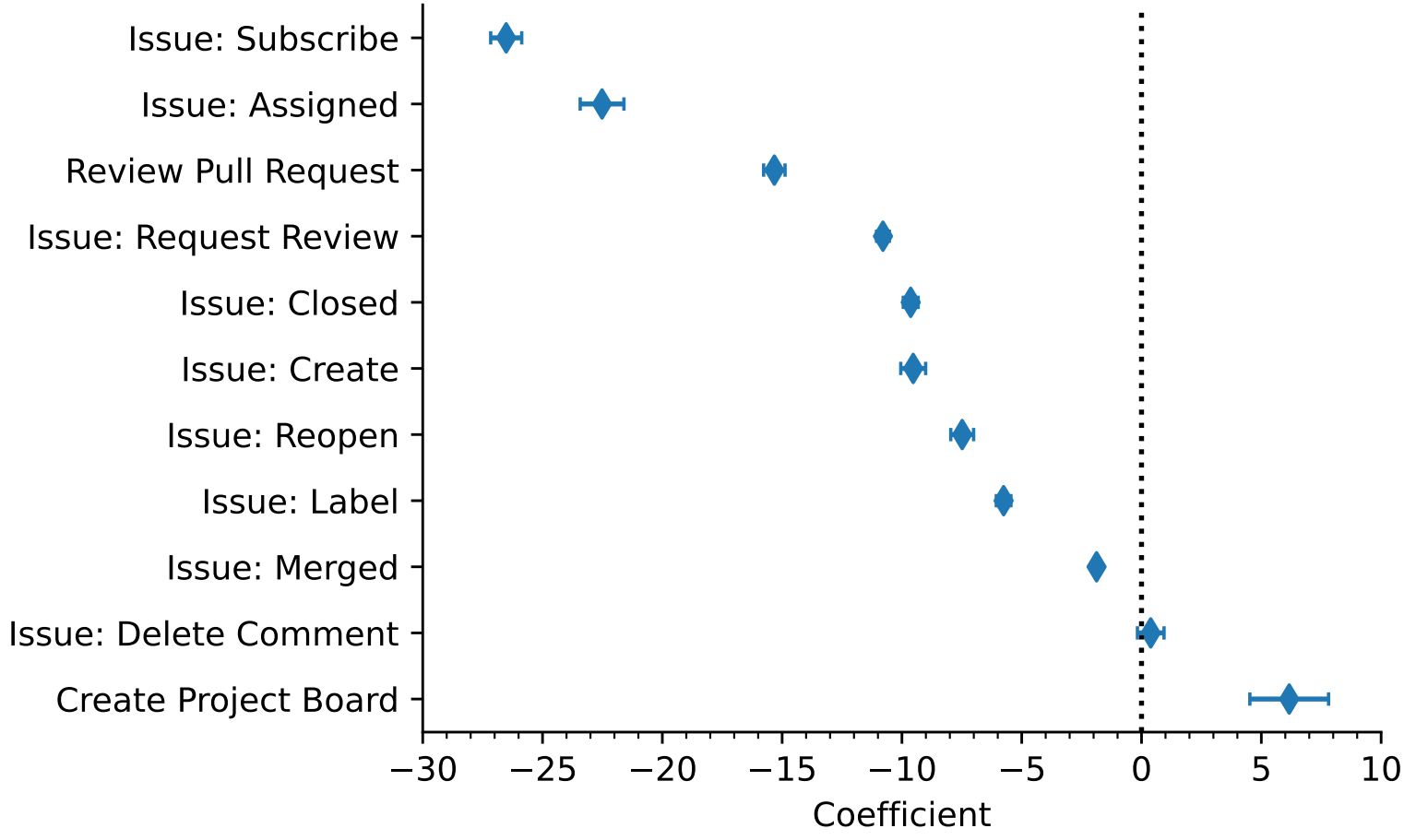
Granular project management effects for collaborative work



Collaborators drop for coding



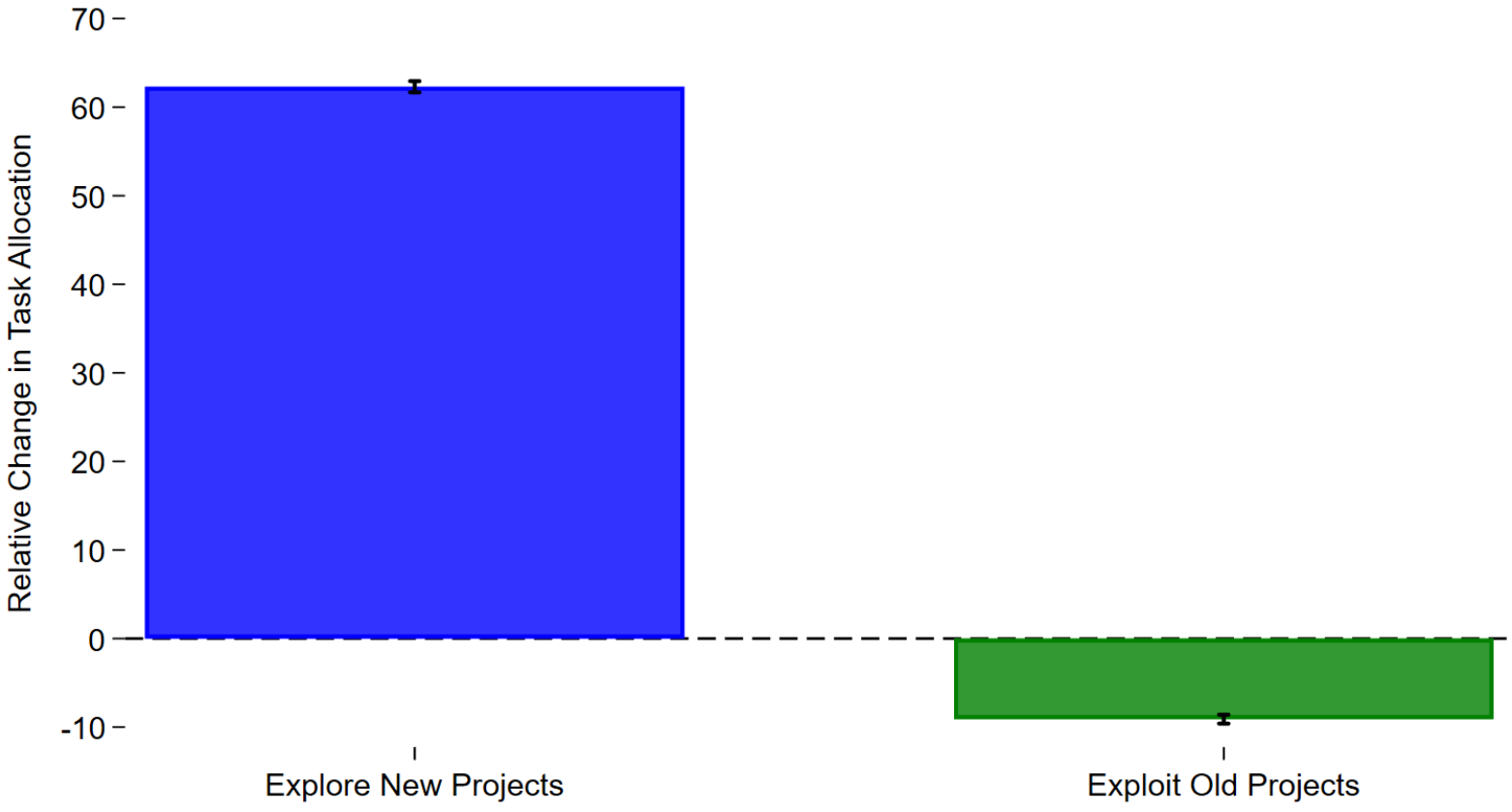
Collaborators drop for project management



⇒ **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***	1.8135***
	(0.075)	(0.077)
Baseline	9.2448***	8.3208***
	(0.047)	(0.048)
Rel. TE (%)	18.95	21.79
N	181,798	170,433
Controls		✓

$\Rightarrow$ 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***	0.0140***
	(0.000)	(0.000)
Baseline	11.691***	11.690***
	(0.000)	(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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