How many Years Does It Take for AI Adopting Firms to Realize Productivity Effects?

Nam, Choong Hyun

Bank of Korea

December 12, 2025

Table of Contents

1. Intro

- Despite recent advance of AI technology, aggregate productivity growth remains sluggish.
  - Redux of Solow's Productivity Paradox
- There may be substantial time lags before the productivity effects of AI adoption are realized (Brynjolfsson & Syverson, 2019).
  - Realizing productivity gains from a new technology requires long-term cumulative investments.
- Then, how long does it take for the productivity gains from AI adoption to materialize?
  - We empirically examine whether the productivity effects of AI gradually strengthen with a lag after the initial adoption.

2. Literature Review - productivity effects of AI

1. AI-related Hiring Data
   - Babina et al.(2024): No significant productivity effects.
2. AI-related Patent Filings
   - Alderucci et al.(2020): U.S. manufacturing firms; (+) correlation.
   - Damioli et al.(2021): Sample of 5,257 global firms; (+) correlation.
3. Firm-level AI Adoption Surveys
   - Acemoglu et al.(2022): U.S. firms; (+) correlation, but becomes insignificant when controlling for other new techs.
   - Calvino & Fontanelli(2023): 9 OECD countries; (+) correlation, but drop sharply when controlling for firms' innovation capabilities.
   - Czarnitzki et al.(2023):German firms; (+) correlation.
   - Song et al.(2021): Korean manufacturing firms; not significant.

3. Overview of AI Diffusion

- The analysis is based on panel data from the Survey of Business Activities, provided by the Ministry of Data & Statistics in Korea.
  - Since 2017, the survey annually collects information on AI adoption for all South Korean firms with $\geq$ 50 employees, covering all industries.
- AI adoption remains 6.4% of firms in 2023, but these adopters account for 23.3% of total employment.

Figure 1: The number of AI-adopting firms

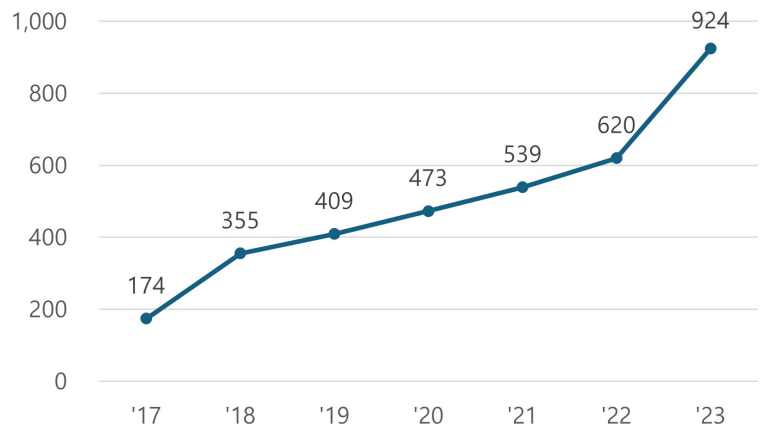
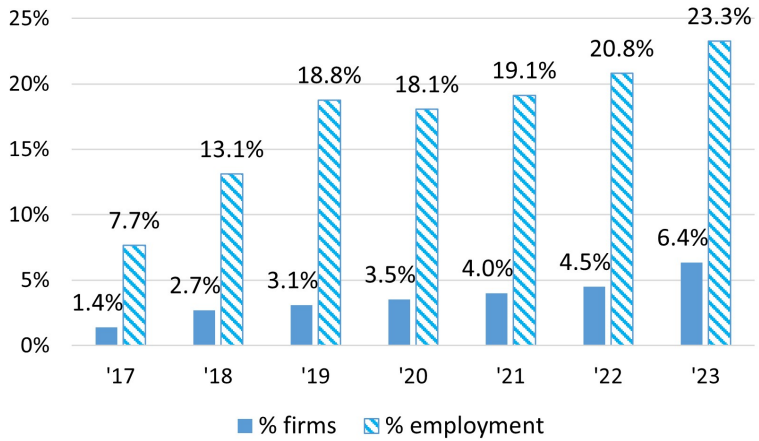


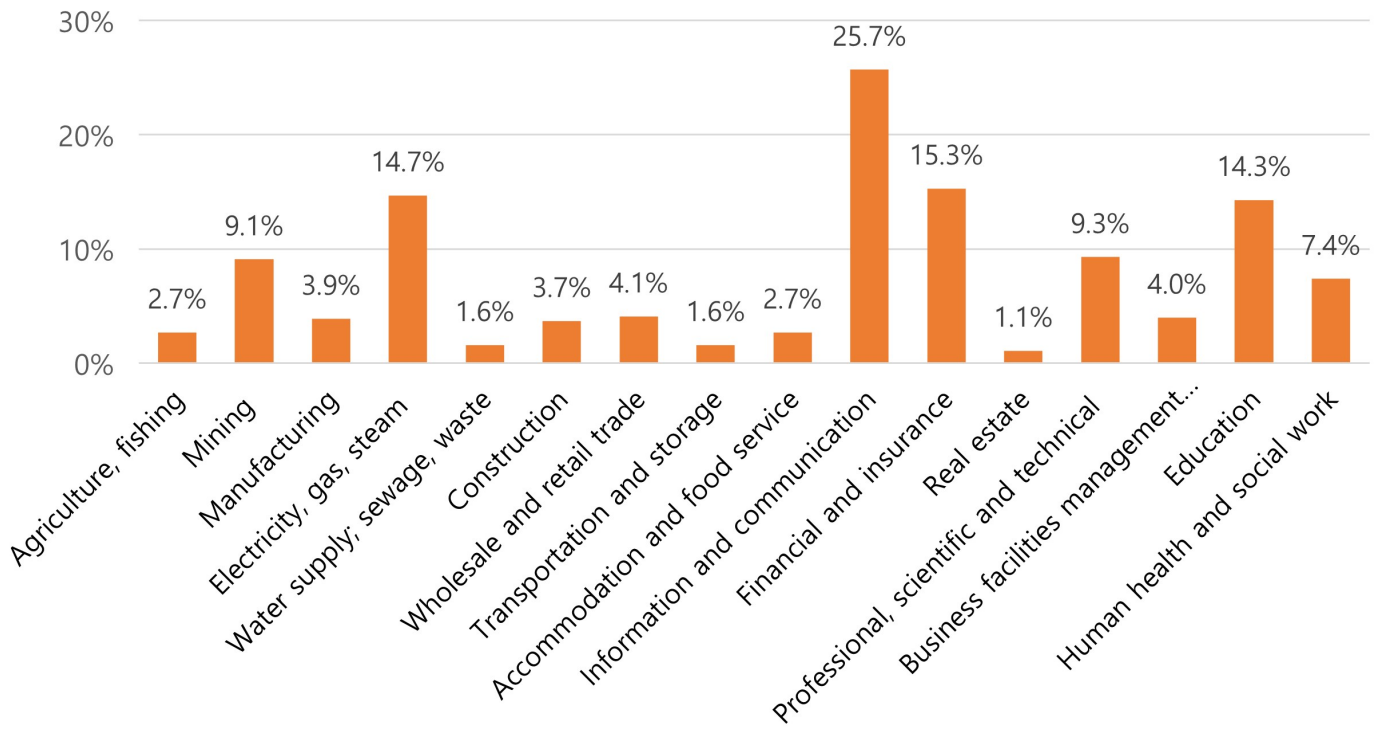
Figure 2: AI adoption rate



AI adoption by industry

- AI-adopting firms are found across all industries, but adoption rates differ substantially.

Figure 3: AI adoption rate by industry (2023)



Productivity distribution of AI-adopting firms

- In this study, labor productivity is defined as value added per worker.
- AI-adopting firms are more productive than non-adopters on aveage, but there is substantial heterogeneity across firms.

Figure 4: avg. labor productivity

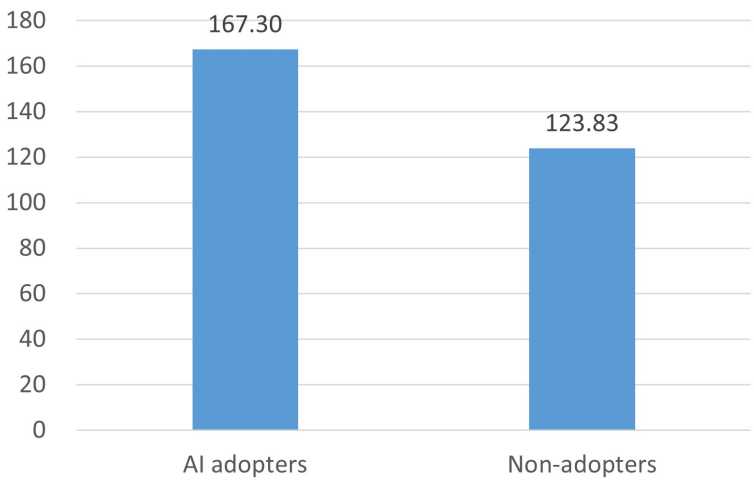
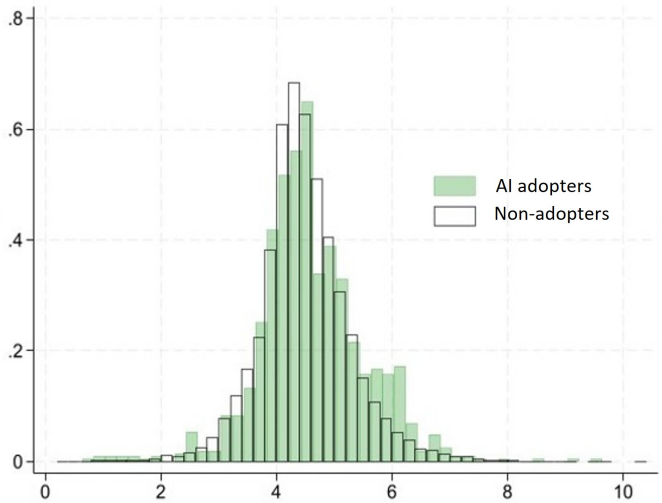


Figure 5: dist. of log labor productivity



The share of top-50% firms among AI-adopters

- The share of Top 50% firms, by labor productivity or employment, among AI-adopting firms has been declining since 2019.
  - This pattern is more pronounced among first-time AI-adopters.

Figure 6: Top 50% by labor productivity

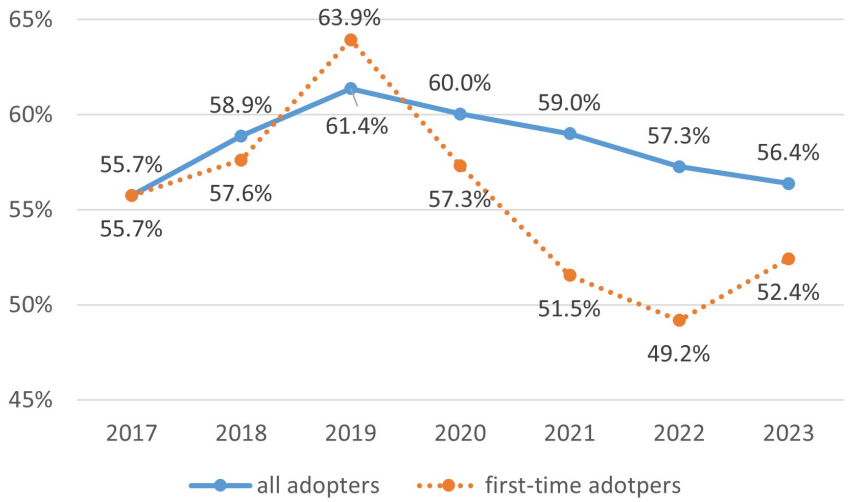
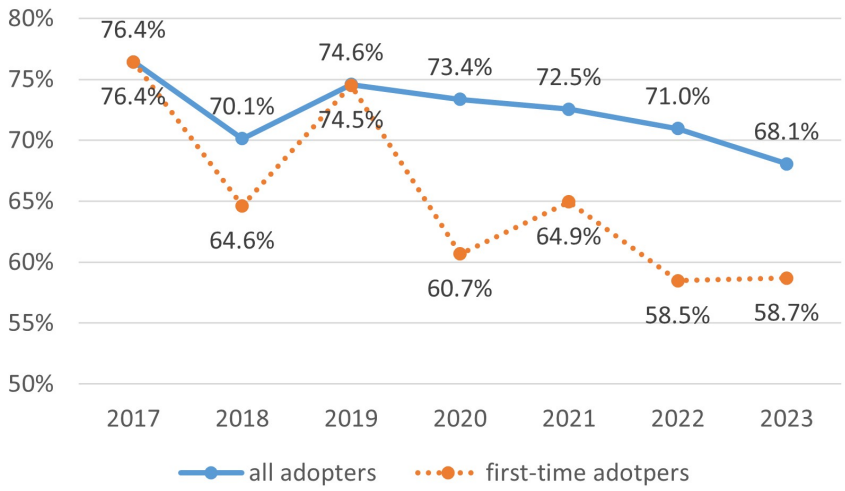


Figure 7: Top 50% by employment



Dist. of AI adopters across Prod. deciles - 2019 vs 2023

- AI adopters are more likely to be in higher productivity deciles than non-adopters, but this differential declined in 2023.
  - For the first-time AI adopters, the share in the top deciles declined even further in 2023.

Figure 8: All AI adopters

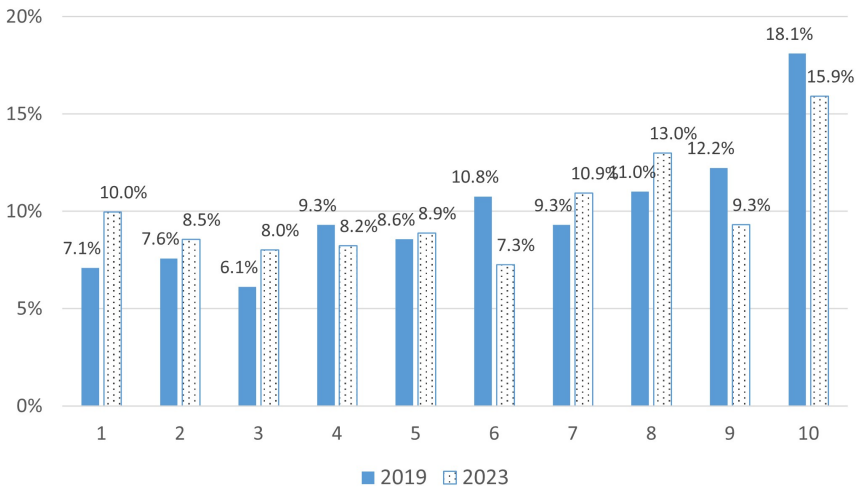
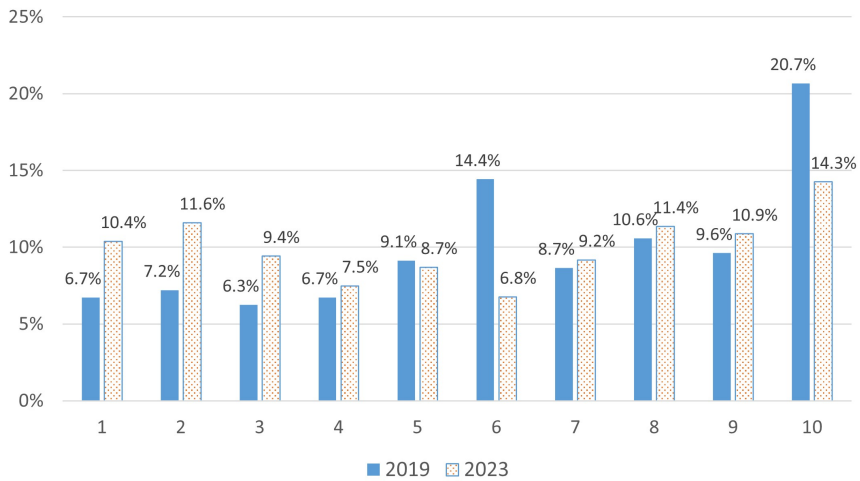


Figure 9: First-time AI adopters



4. The effects of AI adoption

- AI adopters may be more productive than non-adopters not because of AI, but because they differ from non-adopters in several dimensions.
  - ex) AI adopters tend to be larger and have higher capital intensity than non-adopters.

- To address endogeneity, a set of control variables is included in the regression:

$$\ln y_{i,t} = \alpha + \beta_1 \cdot D_{i,t}^{AI} + \beta_2 \cdot X_{i,t} + \mu_t + \mu_j + \epsilon_{i,t} \tag{1}$$

$y_{i,t}$: firm i's labor productivity, employment or value added
$X_{i,t}$: firm characteristics ; μ_j; industry fixed effect μ_j year fixed effect
i: firm, j: industry, t: year

The effects of AI adoption - OLS

- No significant contemporaneous productivity effect of AI adoption after controlling for firm characteristics.

Table 1: The effects of AI adoption on firm outcomes

Dep. var.	(1) labor prod.	(2) labor prod.	(3) emp.	(4) value add.
AI adoption(0/1)	0.135***	-0.004	0.914***	1.048***
	(0.023)	(0.021)	(0.047)	(0.058)
$K_{tangible}/L$	-	0.116***	-	-
$K_{intangible}/L$	-	0.070***	-	-
Export(0/1)	-	0.132***	-	-
Conglomerates(0/1)	-	0.258***	-	-
Employment(deciles)	N	Y	N	N
Observations	90,879	90,667	90,891	90,879
R-squared	0.241	0.328	0.214	0.188

The productivity effect of AI adoption by year

- The coefficient of AI adoption peaks in 2019 and declines thereafter, but becomes statistically insignificant in all years once controls are included.

Table 2: AI adoption × Year-dummy interaction terms

Dep. var.	(1) labor prod.	(2) labor prod.
AI×2017	0.027	-0.102
AI×2018	0.104**	-0.003
AI×2019	0.208***	0.050
AI×2020	0.195***	0.040
AI×2021	0.146***	0.001
AI×2022	0.123***	-0.024
AI×2023	0.106***	-0.020
Controls	N	Y
Observations	90,879	90,667
R-squared	0.241	0.328

Productivity effects by the primary field of AI adoption

- The coefficient is largest for the primary use of "marketing strategy" or "organizational management" and smallest for "product development".
  - but becomes statistically insignificant once the sample is restricted to the top 50% of firms by labor productivity.

Table 3: Productivity effect of AI by primary field of use

Dep. var. : labor prod.	(1)	(2)	(3)
AI× product development	0.074**	-0.055**	0.003
AI× production process	0.270***	0.081*	0.031
AI× sales	0.136***	0.012	-0.006
AI× marketing strategy	0.303***	0.141***	0.030
AI× organizational management	0.292***	0.144***	0.030
Controls	N	Y	Y
Top 50% by labor prod.	N	N	Y
Observations	90,879	90,667	45,472
R-squared	0.241	0.328	0.557

Lagged effects of AI adoption - Event Study

- Even if AI adoption has no contemporaneous effect, its impact may strengthen over time; therefore, we conduct an event-study analysis.
- To esimated the lagged effects of AI adoption on various firm outcomes:

$$y_{i,t} = \sum_{\ell} \beta_{\ell} \cdot D^{AI}_{i,t-\ell} + \delta_i + \mu_s + \mu_t + \epsilon_{i,t} \tag{2}$$

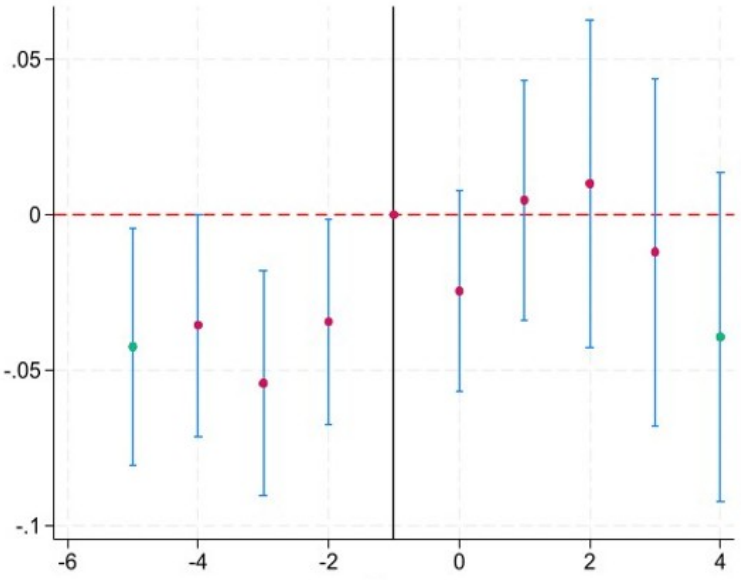
y: Firm outcomes likely affected by AI adoption
ℓ (lead-lag) : $=0$ for the year of first adoption
δ_i : firm fixed-effect ; μ_j : industry dumies ; μ_t : year dummies

- Firms already using AI in the first survey year(2017) are excluded as the initial adoption year is unknown.

Lagged effects on labor productivity

- Up to 4–5 years after initial adoption, labor productivity shows no significant divergence from non-adopters.

Figure 10: Lagged effect of AI adoption on labor prod.



Note: 1) Horizontal axis: ℓ (=0 in the year of first adoption)
Vertical line: 95% confidence interval
2) green obs. : $\ell \geq 4$ (lag) or $\ell \leq -5$ (lead)

Lagged effects on firm size

- AI-adopting firms grow significantly faster in both value added and employment than non-adopters, but this reflects a pre-trend that predates the adoption of AI.

Figure 11: Value added (log)

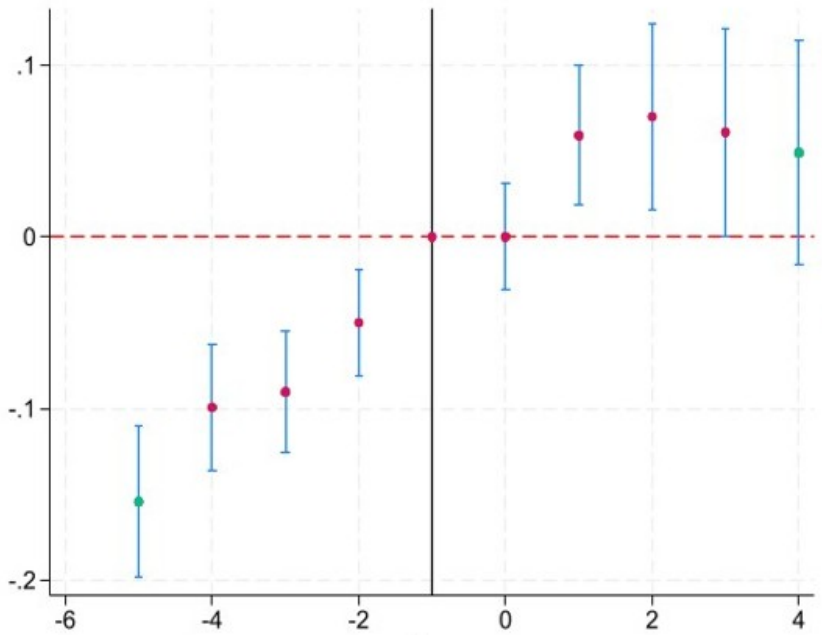
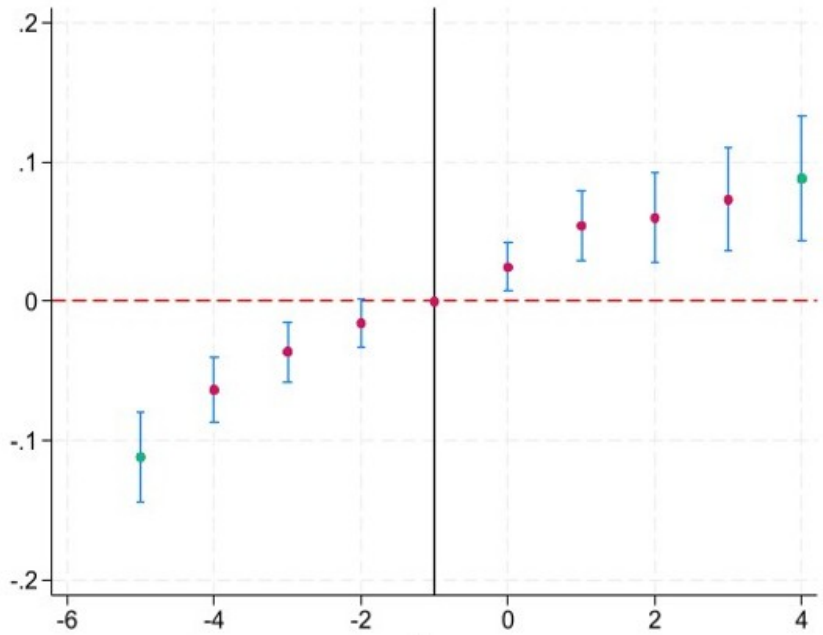


Figure 12: Employees (log)



Lagged effects on firm size: ever-AI adopters only

- Once the sample is restricted to firms that ever adopted AI to address pre-trend concerns, the estimated growth effects of AI adoption are no longer statistically significant.

Figure 13: Value added

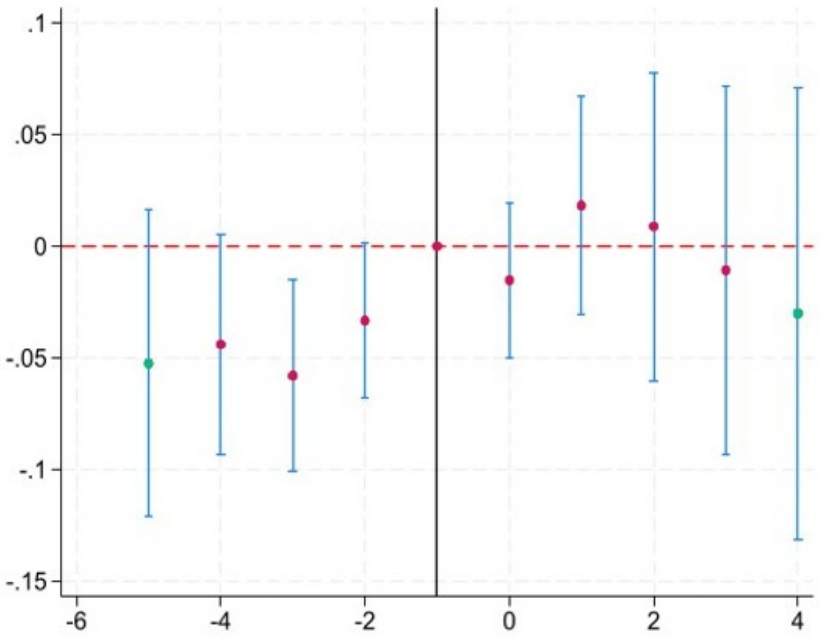
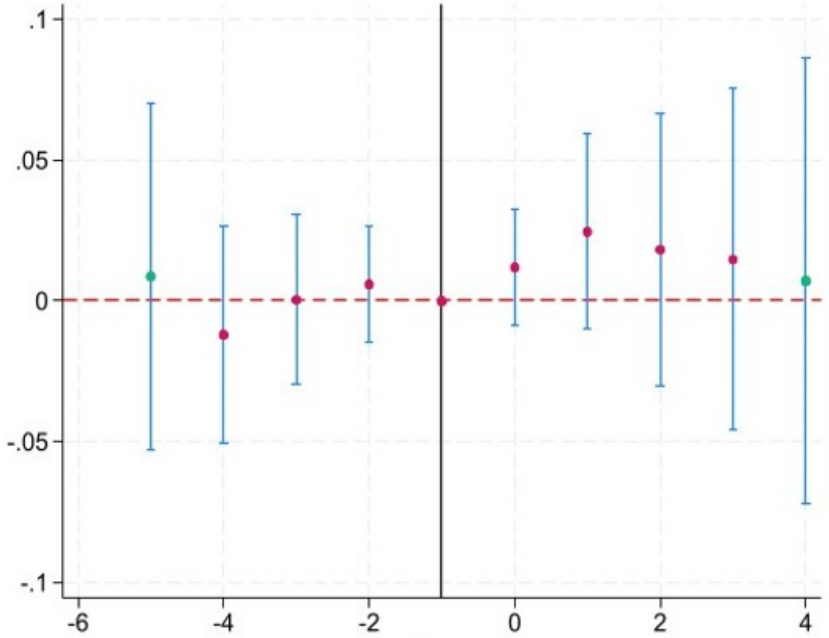


Figure 14: Employees



Lagged effects on innovation activities

- The increase in R&D spending appears immediately after initial adoption but begins to fade from the second year, while intangible investment shows no significant rise.

Figure 15: Total R&D spending (log)

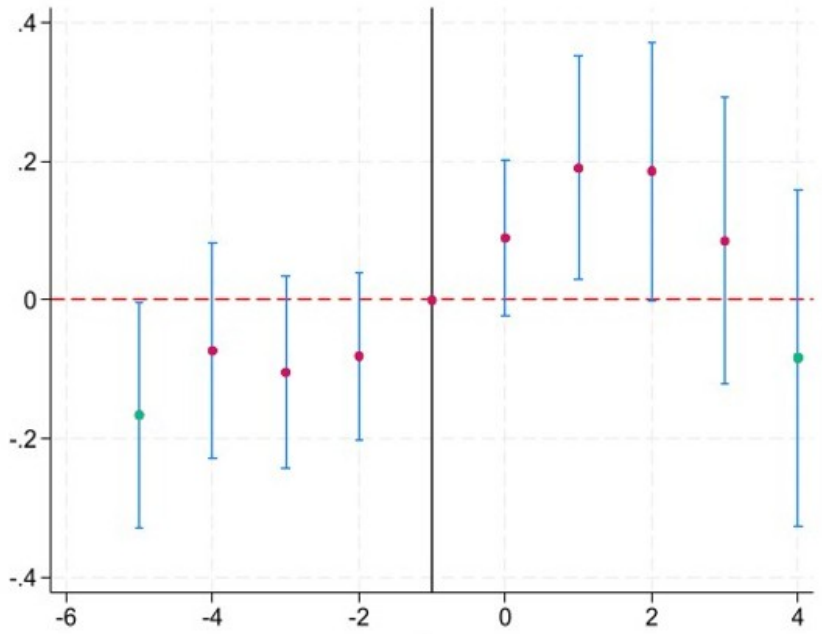
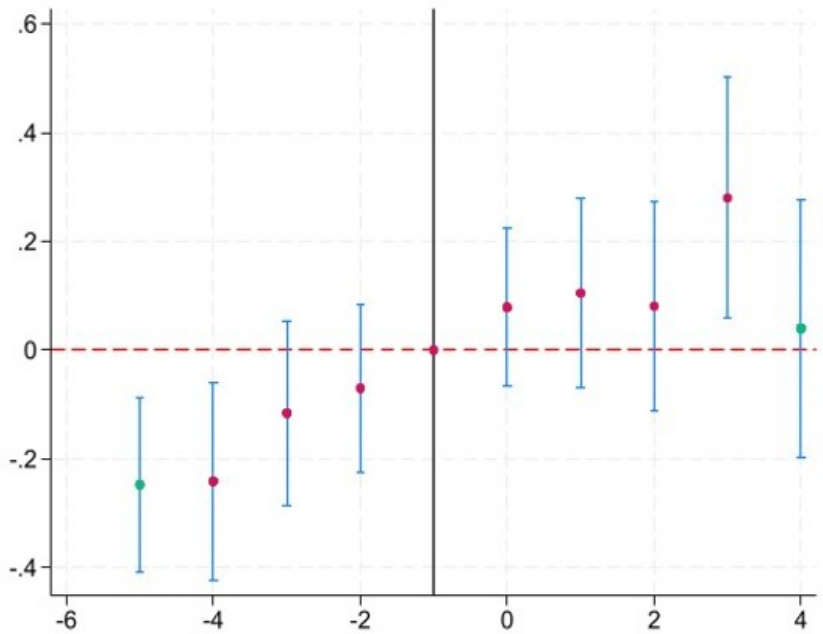


Figure 16: $\Delta K_{intangible}$ (log)



Lagged effects on new business entry

- New business entry rises sharply in the year of initial AI adoption, but this effect dissipates from the second year onward.

Figure 17: New Business Entry (1/0)

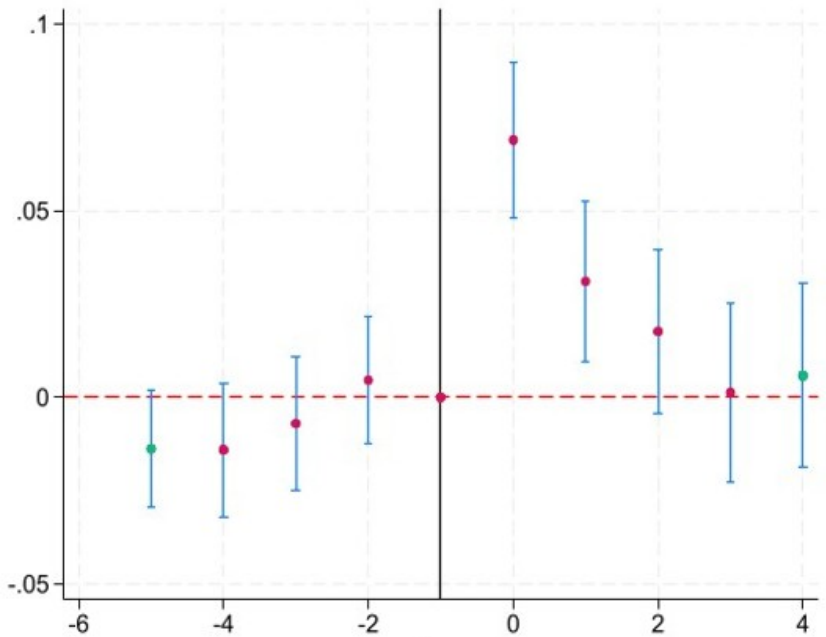
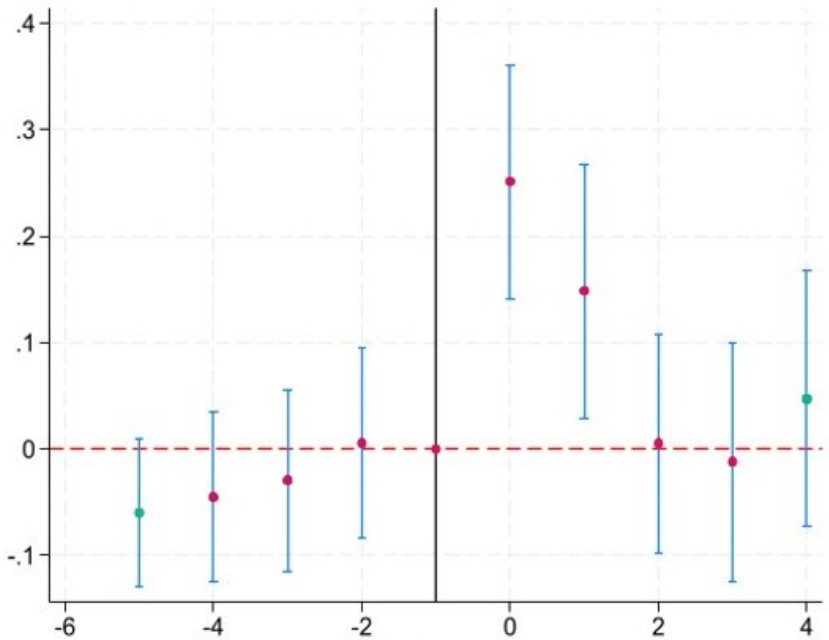


Figure 18: New Business Sales



Other innovation indicators: patents

- The number of patents rises after AI adoption, but it had already been on a steeper upward trajectory prior to adoption.
- Even when the sample is restricted to firms that ever adopted AI, the effects on the number of patents remain significant.

Figure 19: Patents (log)

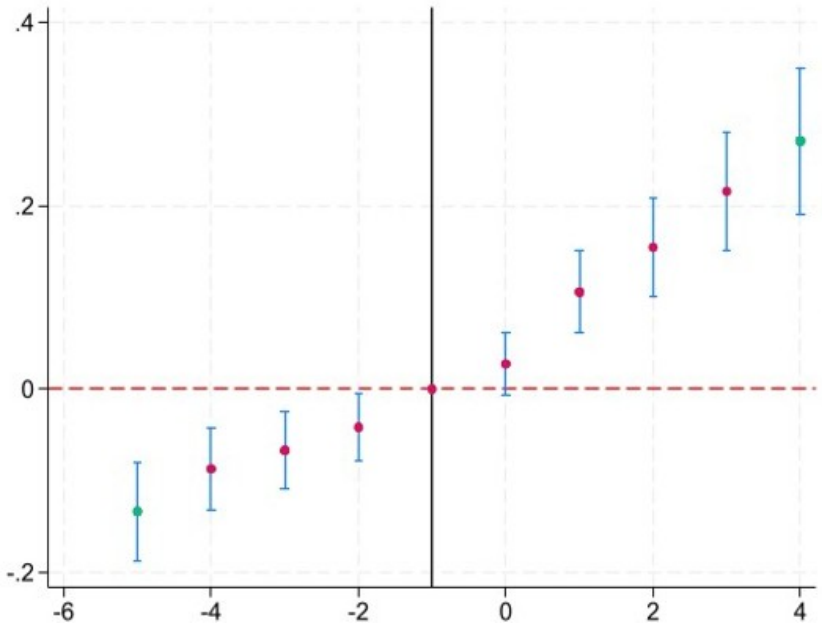
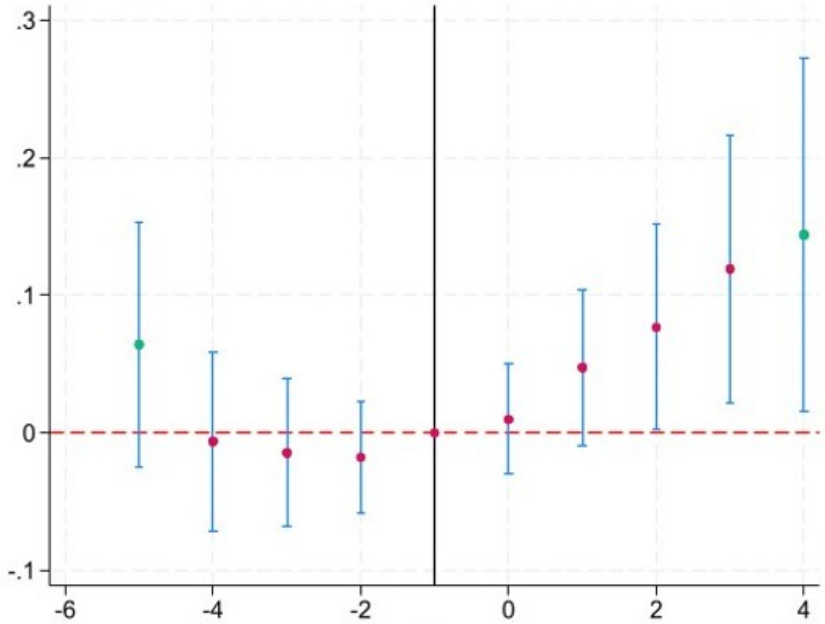


Figure 20: Patents (log, ever-adopters)



5. Conclusion

- AI adoption in South Korea began with high-productivity firms and is spreading to lower-productivity firms, resulting in almost one-fourth of surveyed workers employed by AI-adopting firms.
- Although AI-adopting firms are more productive than non-adopters, the productivity differentials are declining over time and becomes insignificant once firm characteristics are controlled for.
- AI-adoption has no significant effect on productivity, either contemporaneously or within 5 years after initial adoption.
- AI-adoption has not induced a sustained increase in investments, which may partly explain the limited productivity effects.
  - However, certain measures of innovation, including new business entry, increased following AI adoption.