

The Innovation Race

Experimental Evidence on Advanced Technologies

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The opinions expressed are those of the authors and do not reflect the views of the Bank of Italy. Experiment is registered at AEA-RCT registry under AEARCTR-0016177, ethical approval from the joint committee of Goethe University Frankfurt-Mainz University.

Research Question

Adoption of new technologies (e.g., AI, robotics) may (or may not) diffuse through firms' networks

Innovation races can be modeled as global games in which firms **interact strategically**:

- ▶ **In belief space**: firms learn about productivity from other firms' beliefs and actions
- ▶ **In action space**: strategic complementarities in competition

Research question: measure experimentally strategic complementarities in adoption of new technologies

Strategic Complementarities

- ▶ Theory: Cooper and John (1988), Angeletos et al. (2007), Angeletos and Pavan (2004), Huo and Takayama (2024)
- ▶ Mostly tested in labs (e.g., Cooper et al. 1990; Cooper et al. 1992; Nagel 1995)
- ▶ This is the first large-scale field experiment on **strategic complementarities** (≈ 3980 firms)
 - 1 Strategic complementarities in **beliefs**: firms learn from adoption of other firms about productivity
 - 2 Strategic complementarities in **actions**

Experiment Design

We include a **randomized experiment** within a well-established firms' survey conducted by the Bank of Italy, which ensures high quality responses and match with administrative data:

- 1 Elicit **prior beliefs on competitors' adoption** of AI/robotics
- 2 **Information provision (RCT) experiment**: 50% of the subjects provided with information about technology adoption among similar firms (potential competitors)
- 3 Elicit **posterior beliefs** to capture updating
- 4 Measure **intended future adoption**
- 5 Track **actual adoption** and firm outcomes (ongoing)

Findings

- ▶ Substantial **misperceptions**:
 - ▶ Firms largely underestimated competitors' adoption
- ▶ Providing information markedly shifts **posterior beliefs** about competitors' future behavior
- ▶ Belief updating increases **intended robotics adoption** by **6.7 pp.** (17.8% relative to baseline):
 - ▶ Effects are stronger for firms with below-median market shares and for firms that did not receive public financial incentives
- ▶ No significant effects for AI adoption, possibly due to higher uncertainty

Contribution

- ▶ Firms' Strategic Complementarities with Administrative Data: Jaffe (1986), Bloom et al. (2013), Bilgin et al. (2025)

Contribution: experimental evidence on strategic complementarities

- ▶ Innovation Adoption and Diffusion: Comin and Hobijn (2010), Kalyani et al. (2025), Menkhoff (2025)

Contribution: provide evidence that firms' misperceptions about competitors' adoption can be a significant source of under-investment

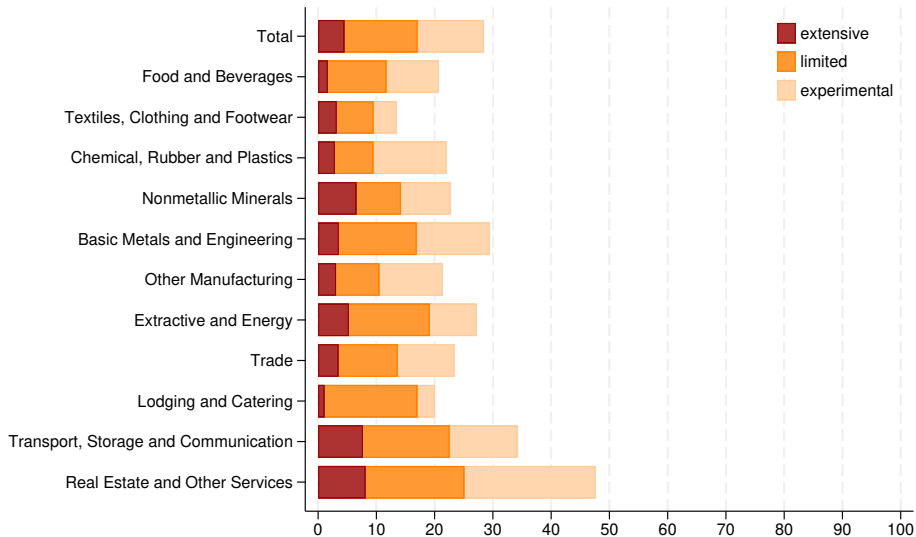
Data and Stylized Facts

Data

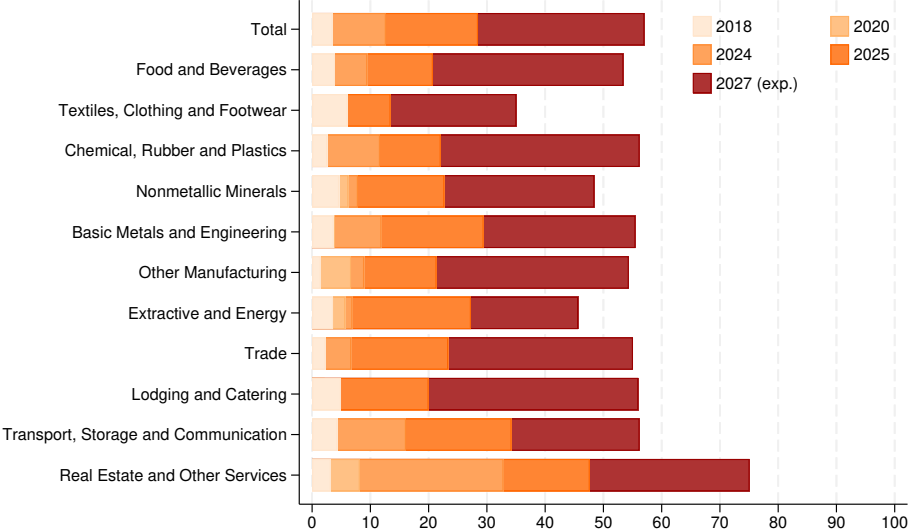
► Survey on Industrial and Service Firms (INVIND)

- Conducted annually by the Bank of Italy since 1984 on ≈ 4000 firms with > 20 employees
 - Standard survey module collects info on investments, gross sales, workforce and other economic variables
 - Info on AI/robotics adoption since 2016
 - 2025 wave: included our module with RCT
 - 2026 wave (ongoing): follow-up questions to same firms (large panel component)
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- Other data used for validation and heterogeneity analysis: balance-sheet data (CADS), electronic invoices, customs data

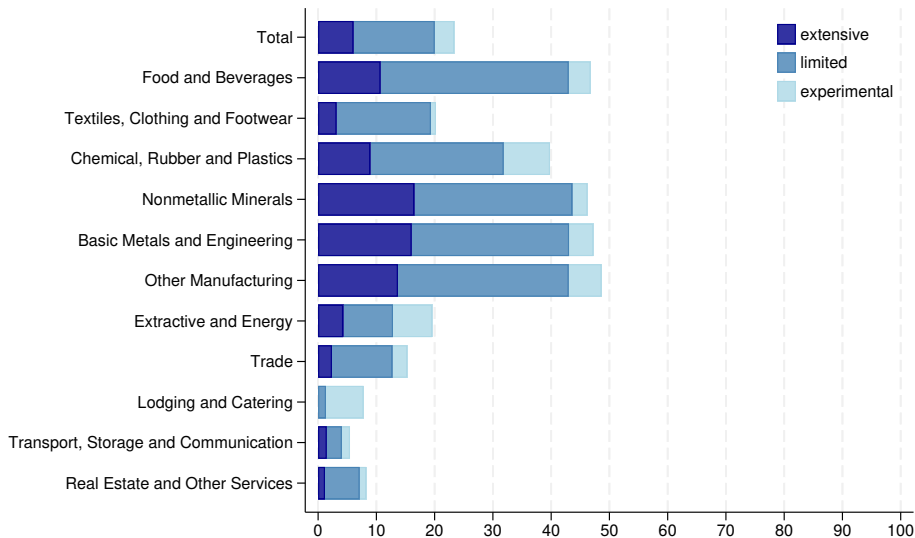
AI Use, Intensity



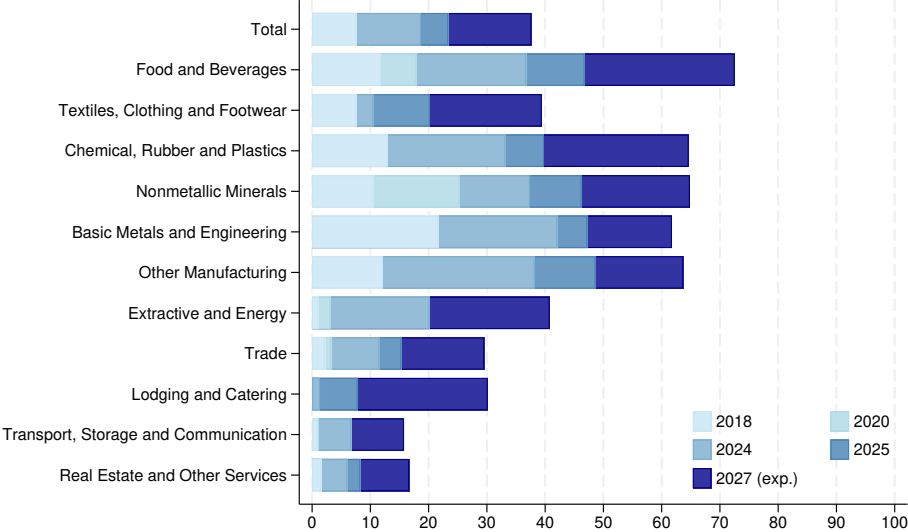
AI Use, Over Time



Robotics Use, Intensity

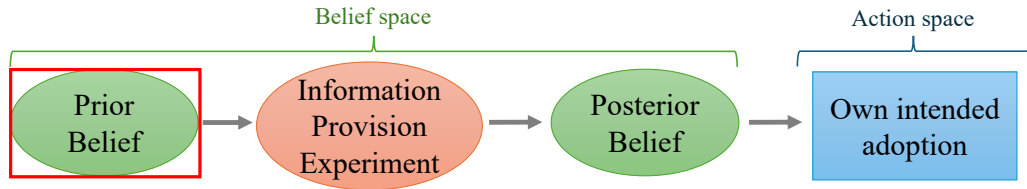


Robotics Use, Over Time



Research Design

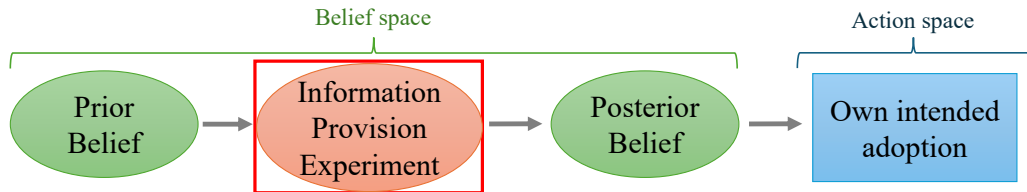
Research Design: Prior Belief



In your opinion, what is the **share of companies similar to yours** in terms of sector and size, potentially your competitors, that are **currently using robotics and/or AI**?

[replies in 10 equally spaced bins, e.g. less than 10%, between 10.1 and 20%, etc.]

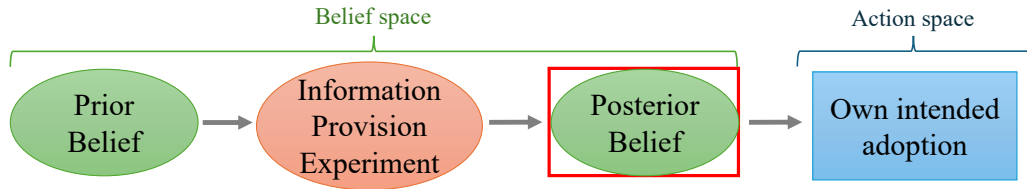
Research Design: Information Treatment



The [findings of the last survey](#) showed that the share of companies similar to yours in terms of sector and size, potentially your competitors, that were using or planning to use robotics and/or AI was: X.X%

- ▶ **22 different treatments:** 11 sectors x 2 size classes
- ▶ Info provided to a **random sample of 50% of firms** in each sector x size cell

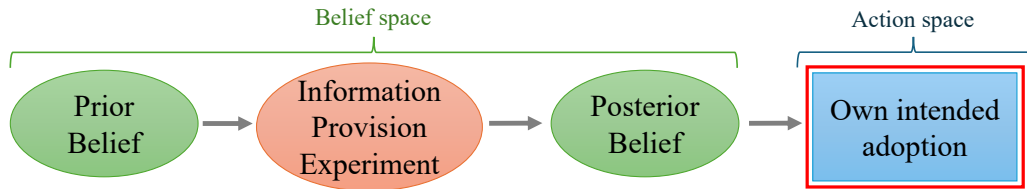
Research Design: Posterior Belief



What do you think will be the **share of companies similar to yours** in terms of sector and size, potentially your competitors, **using these advanced technologies in 2027?**

[replies in 10 equally spaced bins, e.g., less than 10%, between 10.1 and 20%, etc.]

Research Design: Own Adoption



How do you [plan to use AI/robotics](#) in your company, as part of your production process and/or support activities, [by 2027](#)?

[1 = extensive use; 2 = limited use; 3 = only experimental use; 4 = we do not currently use this technology]

Conceptual Framework and Econometric Implementation

Conceptual Framework

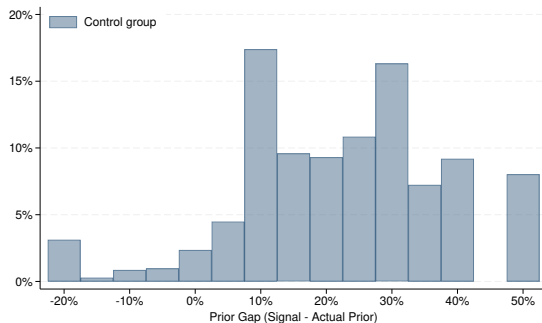
Global games: strategic interaction under incomplete information solved in two stages:

- ▶ Stage 1: **belief update** based on own signal and others' actions
- ▶ Stage 2: **action**, Bayes-Nash game

Stage 1: Belief Update

- ▶ Exogenous return to adoption (θ) is unobserved
- ▶ Firms hold different beliefs about θ (prior) and update them (posterior) after observing a public signal (information treatment)
- ▶ The signal conveys information on:
 - ▶ fundamental return to adoption (**learning channel**)
 - ▶ competitors' adoption, that strengthens the incentives for own adoption not to lag behind (**competition channel**)

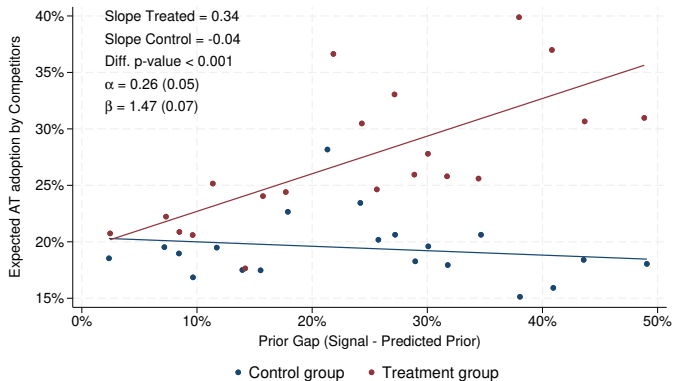
Mis-Perceptions



- ▶ x-axis: difference between true adoption rate and firms' prior. Only 2% of firms report accurate priors; 93% underestimate competitors' adoption by at least 2.5 percentage points
- ▶ Use imputed priors to correct measurement error in the treatment group [Details](#)

Belief Updating: Econometric Specification

$$\underbrace{s_{i,t+1}}_{\text{Posterior Belief}} = \eta + \alpha \cdot \underbrace{\beta \cdot (s_{i,t}^T - s_{i,t}^0)}_{\text{Prior Gap}} + \underbrace{\beta \cdot s_{i,t}^0}_{\text{Prior Belief}} \quad \text{if } T_i = 1$$



Second Stage: Adoption

► Model

$$a_i = (1 - \delta)x_i + \underbrace{\delta z}_{\text{Learning channel}} + \underbrace{\lambda \frac{\delta(1 - \delta)}{1 - \lambda(1 - \delta)}(z - x_i)}_{\text{Competition channel}}, \quad \text{where } z = \text{info treatment}$$

► Econometric specification (2SLS):

$$a_{i,t+1} = \psi_0 + \psi_s \cdot s_{i,t+1} + \psi_2 \cdot (s_{i,t}^T - s_{i,t}^0) + \psi_3 \cdot s_{i,t}^0 + X_i \psi_X + \epsilon_i \quad (1)$$

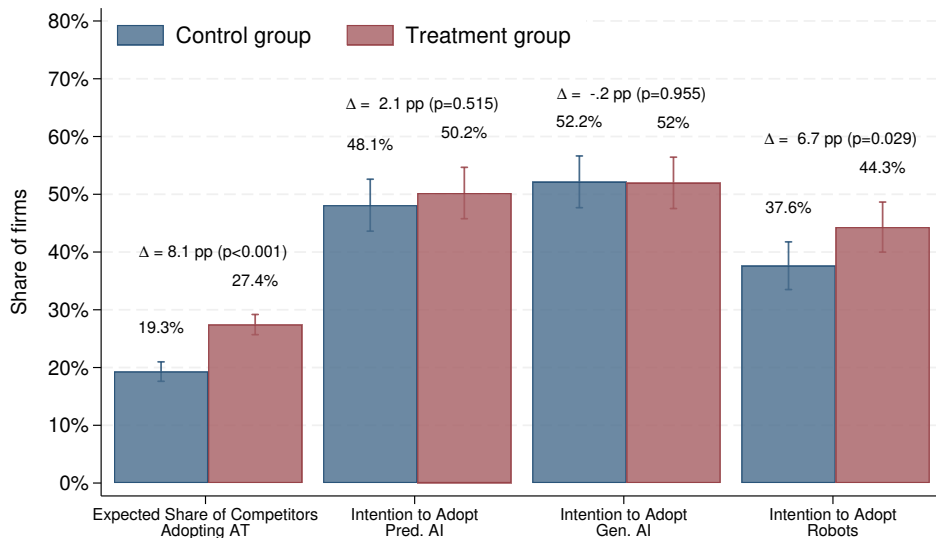
where $s_{i,t+1}$ (posterior belief) is endogenous and is **instrumented** by $T_i \cdot (s_{i,t}^T - s_{i,t}^0)$

Analogue of ψ_s in the model:

$$\frac{\partial k_i}{\partial z} = \underbrace{\delta}_{\text{Learning channel}} + \underbrace{\lambda \frac{\delta(1 - \delta)}{1 - \lambda(1 - \delta)}}_{\text{Competition channel}}. \quad (2)$$

ATE: Beliefs and Future Adoption

Falsification Test



2SLS Estimates

	Robotics						
	Pred.-AI	Gen.-AI	Robotics				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
PANEL (a): 2SLS REGRESSIONS							
Exp. AT Adoption by Competitors	0.008 (0.232)	0.057 (0.228)	0.735*** (0.208)				
PANEL (b): 2SLS: FIRST STAGE							
T_i * Prior gap	0.344*** (0.029)	0.343*** (0.029)	0.342*** (0.029)				
Observations	3,075	3,077	3,073				
Dep. Var.: Baseline Mean	48.1	52.0	37.7				
Kleibergen-Paap Wald F-statistic	134.8	132.9	132.7				

2SLS Estimates

				Robotics			
				Previous use			
	Pred.-AI	Gen.-AI	Robotics	No	Yes	(6)	(7)
	(1)	(2)	(3)	(4)	(5)		
PANEL (a): 2SLS REGRESSIONS							
Exp. AT Adoption by Competitors	0.008 (0.232)	0.057 (0.228)	0.735*** (0.208)	1.073*** (0.288)	0.179 (0.161)		
PANEL (b): 2SLS: FIRST STAGE							
T_i * Prior gap	0.344*** (0.029)	0.343*** (0.029)	0.342*** (0.029)	0.345*** (0.035)	0.350*** (0.048)		
Observations	3,075	3,077	3,073	1,949	1,124		
Dep. Var.: Baseline Mean	48.1	52.0	37.7	19.6	97.3		
Kleibergen-Paap Wald F-statistic	134.8	132.9	132.7	87.8	46.8		

2SLS Estimates

	Pred.-AI (1)	Gen.-AI (2)	Robotics (3)	Robotics			
				Previous use		Manager present	
				No (4)	Yes (5)	No (6)	Yes (7)
PANEL (a): 2SLS REGRESSIONS							
Exp. AT Adoption by Competitors	0.008 (0.232)	0.057 (0.228)	0.735*** (0.208)	1.073*** (0.288)	0.179 (0.161)	0.226 (0.275)	1.243*** (0.363)
PANEL (b): 2SLS: FIRST STAGE							
T_i * Prior gap	0.344*** (0.029)	0.343*** (0.029)	0.342*** (0.029)	0.345*** (0.035)	0.350*** (0.048)	0.397*** (0.041)	0.292*** (0.040)
Observations	3,075	3,077	3,073	1,949	1,124	1,217	1,749
Dep. Var.: Baseline Mean	48.1	52.0	37.7	19.6	97.3	34.3	38.3
Kleibergen-Paap Wald F-statistic	134.8	132.9	132.7	87.8	46.8	96.3	48.4

Heterogeneous Effects on Robotics

		Market Share		Herfindahl-Hirschman Index		Public Incentives	
	Total (1)	Below Median (2)	Above Median (3)	Below Median (4)	Above Median (5)	No (6)	Yes (7)
PANEL (a): 2SLS REGRESSIONS							
Exp. AT Adoption by Competitors	0.735*** (0.208)	1.139*** (0.366)	0.148 (0.240)	0.478** (0.234)	0.540 (0.413)	0.902*** (0.302)	0.457 (0.279)
PANEL (b): 2SLS: FIRST STAGE							
T_i * Prior gap	0.342*** (0.029)	0.329*** (0.049)	0.330*** (0.034)	0.297*** (0.034)	0.368*** (0.054)	0.336*** (0.041)	0.332*** (0.035)
Observations	3,073	912	2,161	1,106	1,967	1,594	1,479
Dep. Var.: Baseline Mean	37.7	31.8	43.5	31.2	43.8	26.4	59.1
Het. Var. Mean		0.0017	0.0157	0.0018	0.0073		
Kleibergen-Paap Wald F-statistic	132.7	46.1	87.2	31.6	118.7	68.6	79.4

Follow-up Survey: Preliminary Evidence

Learning vs Competition Channel

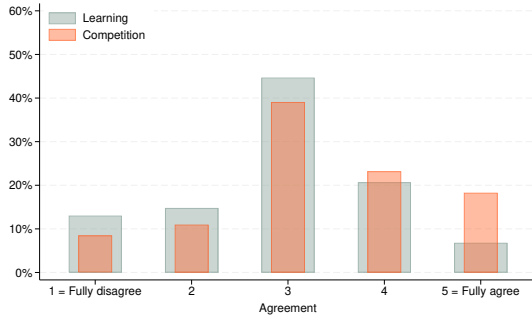
With reference to AI/robotics, to what extent do you agree with the following statements?

- ▶ **[Learning]** The use of these technologies by other **non-competitors** (e.g., foreign suppliers, companies operating in markets other than Italy) indicates their effectiveness and increases the likelihood of our company adopting the same technologies
- ▶ **[Competition]** The use of these technologies by our **competitors** increases the likelihood of our company adopting the same technologies, in order not to lose competitiveness

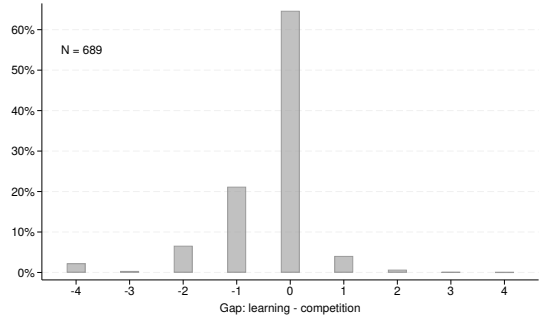
[indicate a value between 1 and 5, where 1 means 'fully disagree' and 5 means 'fully agree']

Learning vs Competition Channel

(a) LEARNING AND COMPETITION



(b) GAP



Conclusions

Conclusions

- ▶ Firms largely **underestimate** competitors' adoption
- ▶ We uncover evidence of **strategic complementarities** in beliefs and in action (mainly robotics)
- ▶ Low impact on AI likely due to large uncertainty
- ▶ **Ongoing/future research:**
 - ▶ 2026 follow-up survey:
 - ▶ evidence on **learning/competition channels**
 - ▶ long-term effects on **beliefs** about competitors' adoption
 - ▶ **actual AI/robotics adoption**
 - ▶ Effects on **other outcomes**: loan applications (credit registry); employment and wages (employer-employee matched dataset); imports of robots (custom data)

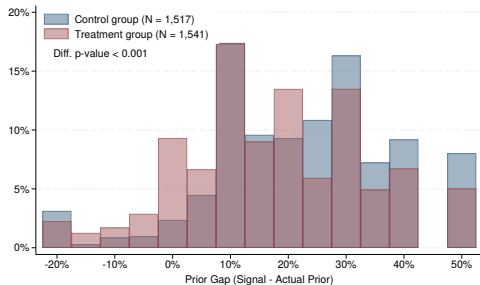
Thank you!

Appendix

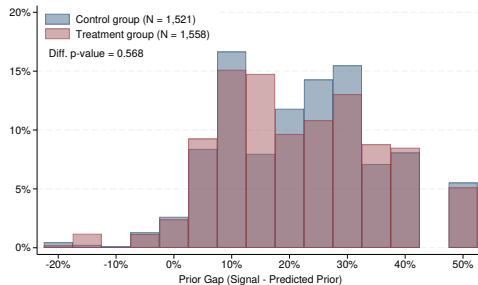
Imputation of Prior Beliefs

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(a) RAW PRIORS



(b) PREDICTED PRIORS



Notes: The difference in p-value refers to the Epps-Singleton test of the null hypothesis that the distribution of the prior gap in the control and in the treated group are identical.

Falsification Test: ATE on Prior Adoption

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