Artificial Intelligence and Robots: Implication for Employment and Productivity

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Introduction

- The influence of Artificial Intelligence (AI) on the labor market differs in several ways from that of previous technological advancements such as software and robotics.
  - Autor, Levy, and Murnane (2003) highlight that software development primarily displaces workers engaged in cognitive and manual tasks that adhere to explicit rules.
  - Webb (2020) demonstrates that AI can substitute both routine and non-routine manual and cognitive tasks, resulting in high-income and highly-educated workers being more exposed to AI.
- In this paper, we investigate if adopting AI and Robots have different implications for the labor market such as
  - Employment and Productivity

Introduction: Employment

- Historically, there have been persistent concerns that technological advancements would displace workers.
  - The Luddite movement of the early 19th century.
  - These concerns have not been realized, as evidenced by the rise in the employment-to-population ratio during the 20th century
- Despite these reassurances, the rapid adoption of robots and AI has reignited fears.
  - Acemoglu and Restrepo (2020) provide robust evidence of the negative impact of robots on employment across U.S. commuting zones, asserting that the effects of robots are distinct from those of other forms of capital and technology.
  - Brynjolfsson and McAfee (2014) argue that AI, which emulates human cognitive tasks, tends to substitute rather than complement workers, further exacerbating concerns about job displacement
  - The declining trend in the employment-population ratio throughout the 21st century supports this view.

Introduction: Productivity

- The majority of research supports the notion that firms adopting robotic technologies exhibit increased productivity.
- Studies are even more optimistic about the positive impact of AI on productivity.
- Robots excel in physical, repetitive tasks whereas AI drives productivity in cognitive and decision-making processes.
- The question is, are there differences between robots and AI in enhancing productivity?

Literature: Employment

- Based on industry data, Autor and Salomons (2018) and Dauth et al. (2021) find that although the direct own-industry effect is negative, the positive indirect effects offset this initial impact, resulting in a net positive effect overall.
- Graetz and Michaels (2018), using panel data on robot adoption within industries across seventeen countries from 1993 to 2007, find that while robots reduce the employment share of low-skilled workers, they do not significantly decrease total employment.
- Even at the firm level, evidence suggests that the adoption of robots does not necessarily lead to decreased employment.
  - Koch et al. (2021) used a rich panel dataset of Spanish manufacturing firms over a 27-year period (1990-2016).
  - Zhang et al. (2023), utilizing a unique firm-level dataset of online job postings in Dongguan.
- The impact of AI on employment remains a developing area of study
  - Acemoglu et al. (2022), based on online vacancy postings find some evidence of reducing employment at the firm level, but the aggregate impact is too small to be detectible.
  - Alderucci et al. (2020) find that firms with AI-related innovations have 25% faster employment growth.

Literature: Productivity

- The majority of research supports the notion that firms adopting robotic technologies exhibit increased productivity.
  - Graetz and Michaels (2018), utilizing novel panel data on robot adoption within industries across seventeen countries from 1993 to 2007 find that increased robot use contributed to labor productivity growth.
  - Acemoglu and Restrepo (2020) confirm that robot adoption at the industry level is associated with greater value added and labor productivity in the U.S.
  - Li et al. (2024) identify a positive causal effect of robot adoption on firm productivity based on firm-level data from China..
- Studies are even more optimistic about the positive impact of AI on productivity.
  - Babian et al. (2024) find that firms investing in AI experience higher growth in sales and market valuations.
  - In experiments, both Peng et al. (2023) and Noy and Zhang (2023) find that workers exposed to generative AI exhibit higher productivity.
  - Brynjolfsson et al. (2023) also find that in the actual workplace, access to generative AI assistance increases the productivity of agents by 14%.

Contributions of the Paper

- First, we examine how the adoption of robots and AI influences both employment and productivity within a unified framework, using the same sample.
  - Typically, robots excel in physical, repetitive tasks, often replacing human labor, whereas AI drives productivity in cognitive and decision-making processes, more frequently augmenting human work.
- Second, rather than indirectly identifying robot or AI adoption through patents or job postings, we directly identify firms that adopt either robots or AI.
- Finally, instead of relying on regional or macro-level data, we use firm-level data to investigate the immediate impact of robot or AI adoption at the firm level.
  - This firm-level analysis allows us to match treated and control firms using propensity scores, thereby minimizing the potential non-equivalence of characteristics between the treatment and control groups.

What we find in this paper

- We find that the impact of AI and robots on employment and productivity is quite different.
- The introduction of robots has a negative impact on employment, and there is no evidence that robot adoption increases productivity.
- On the other hand, the adoption of AI increases both employment and productivity.

Data

- The Survey of Business Activities, conducted annually by the Korean Statistical Office.
  - This survey targets firms in all industries in Korea with at least 50 regular employees and a capital of at least 300 million Korean Won (approximately 220,000 US dollars).
  - It covers 13,824 corporations as of year 2022 across all industries.
  - The survey is principally conducted through site visits, but some items have been substituted with administrative data from the National Tax Service and other sources.

Data (cont.)

- The survey introduced a questionnaire on the adoption of digital technologies starting in 2017.
- Specifically, it inquires whether any of the following nine digital technologies are adopted: (1) AI, (2) robots, (3) Internet of Things, (4) cloud computing, (5) big data, (6) mobile technologies and services (including 5G), (7) blockchain, (8) 3D printing, and (9) augmented reality (AR)/virtual reality (VR).
- A firm is classified as using AI or robots if it indicates in a survey that it utilizes these technologies in any of the following areas: product development, marketing strategies, production processes, organizational management, or sales objectives.

The Summary Statistics

	Robots	AI	Both	None	All
Permanent Employment	5.83	5.83	6.82	4.84	4.87
	(1.56)	(1.60)	(1.88)	(1.05)	(1.08)
Temporary Employment	3.54	3.42	4.51	2.63	2.67
	(2.06)	(2.02)	(2.12)	(1.81)	(1.82)
Total Employment	5.86	5.89	6.87	4.92	4.95
	(1.58)	(1.61)	(1.89)	(1.07)	(1.10)
Sales	7.28	7.13	8.60	5.95	5.98
	(2.08)	(2.28)	(2.47)	(1.45)	(1.49)
Labor Productivity	-0.05	-0.03	0.23	-0.26	-0.25
	(0.78)	(0.92)	(0.88)	(0.80)	(0.80)
Labor Share	0.72	0.73	0.66	0.77	0.77
	(0.60)	(0.63)	(0.54)	(0.59)	(0.59)
Parent Company	0.30	0.32	0.34	0.26	0.26
	(0.46)	(0.47)	(0.48)	(0.44)	(0.44)
Stock Listing	0.30	0.35	0.44	0.14	0.14
	(0.46)	(0.48)	(0.50)	(0.34)	(0.35)
Capital Intensity	0.12	-0.49	0.12	-0.51	-0.50
	(1.25)	(1.66)	(1.48)	(2.01)	(1.99)
R&D Intensity	-4.21	-4.01	-4.42	-4.43	-4.41
	(1.55)	(1.79)	(1.93)	(1.51)	(1.52)
Share of Manufacturing Wo	-0.67	-1.04	-1.00	-0.73	-0.73
rkers	(0.89)	(1.18)	(1.17)	(0.89)	(0.90)
Exporter	0.87	0.73	0.87	0.80	0.80
	(0.33)	(0.44)	(0.34)	(0.40)	(0.40)
Importer	0.90	0.75	0.87	0.82	0.82
	(0.30)	(0.43)	(0.34)	(0.38)	(0.38)
Foreign owned	0.14	0.09	0.16	0.10	0.10
	(0.35)	(0.28)	(0.37)	(0.30)	(0.30)
Observations	945	1806	297	72221	74675

The Summary Statistics

- Firms adopting robots and/or AI are generally larger in terms of both employment and sales.
- Labor productivity is also higher among these firms.
- The labor share is similar across all classifications, except for firms that adopt both robots and AI, which exhibit a lower labor share.
- Firms that adopt robots and/or AI are more likely to be publicly listed on the stock market.
- Capital intensity is higher for firms that adopt these technologies.
- R&D intensity is elevated, and the share of manufacturing workers is lower specifically among firms that adopt AI or both technologies.
- Notably, only firms that adopt robots are more likely to be foreign-owned.

Which Firms Adopt Robots and AI?

- Following Koch et al. (2021), we set up the equation as follows:

$$Robots_i = \beta \emptyset_{i0} + \beta F_{i0} + \beta G_{i0} + \mu_{s0} + \varepsilon_i$$

  - The dependent variable is an indicator variable for robot use for firm i
  - $\emptyset_{i0}$ is a firm-specific size or productivity variable in the base year
  - F_{i0} is a vector of factor intensity variables in the base year
  - G_{i0} is a vector of globalization variables in the base year
  - μ_{s0} represents industry-base-year fixed effects
  - ε_i is the error term.

Robot Adoption (OLS)

OLS	Robot adoption (0/1 indicator)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.004***	0.007***	0.004***	0.007***	0.005***	0.007***	0.005***	0.007***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Labor Productivity					-0.003**	-0.005	-0.002**	-0.005
					(0.001)	(0.003)	(0.001)	(0.005)
Capital Intensity	0.001	-0.005***		-0.005**	0.001***	-0.004***		-0.004***
	(0.000)	(0.001)		(0.001)	(0.001)	(0.001)		(0.001)
R&D Intensity	0.019***	0.021		0.021***	0.018***	0.021***		0.020***
	(0.004)	(0.006)		(0.007)	(0.004)	(0.006)		(0.007)
Share of Manufacturing employment		-0.010**		-0.010**		-0.010**		-0.010**
		(0.004)		(0.004)		(0.004)		(0.005)
Average Wage		0.003		0.002		0.008		0.008
		(0.004)		(0.004)		(0.006)		(0.007)
Exporter			0.000	0.000			0.001	0.000
			(0.001)	(0.001)			(0.001)	(0.001)
Importer			0.001**	0.002			0.001	0.002
			(0.001)	(0.001)			(0.001)	(0.001)
Foreign Owned			-0.000	0.005			-0.000	0.005
			(0.001)	(0.004)			(0.002)	(0.004)
Observations	35826	14237	65852	13249	35826	14237	35626	14237
R-Squared	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.02

Robot Adoption (Probit)

Probit	Robot adoption (0/1 indicator)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.24***	0.26***	0.21***	0.25***	0.25***	0.26***	0.26***	0.26***
	(0.02)	(0.03)	(0.01)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)
Labor Productivity					-0.11	0.02	-0.15**	0.00
					(0.08)	(0.15)	(0.07)	(0.15)
Capital Intensity	-0.05	-0.38***		-0.38***	0.03	-0.38***		-0.38***
	(0.04)	(0.07)		(0.07)	(0.04)	(0.08)		(0.08)
R&D Intensity	1.07***	0.81***		0.78***	1.03***	0.82***		0.78***
	(0.20)	(0.27)		(0.29)	(0.20)	(0.27)		(0.29)
Share of		-0.45**		-0.46**		-0.45**		-0.46**
Manufacturing		(0.20)		(0.20)		(0.20)		(0.21)
employment								
Average Wage		0.23*		0.26		0.21		0.25
		(0.13)		(0.16)		(0.19)		(0.21)
Exporter			-0.02	0.07			0.03	0.07
			(0.07)	(0.14)			(0.10)	(0.14)
Importer			0.19**	0.49**			0.17	0.49***
			(0.08)	(0.19)			(0.12)	(0.19)
Foreign Owned			0.02	0.13			0.02	0.13
			(0.06)	(0.10)			(0.09)	(0.10)
Observations	35826	14237	65852	13249	35826	14237	35626	13249
Pseudo R-Squared	0.13	0.13	0.09	0.14	0.13	0.13	0.14	0.14

AI Adoption (OLS)

OLS	AI adoption (0/1 indicator)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.013***	0.013***	0.010***	0.015***	0.014***	0.015***	0.013***	0.015***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)
Labor Productivity					-0.005***	-0.017***	-0.007***	-0.018***
					(0.002)	(0.005)	(0.002)	(0.006)
Capital Intensity	-0.001	-0.001		-0.004***	-0.000	-0.001		-0.001
	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)		(0.002)
R&D Intensity	0.221***	0.150***		0.163***	0.220***	0.146***		0.159***
	(0.031)	(0.036)		(0.040)	(0.031)	(0.036)		(0.040)
Share of		-0.015***		-0.015***		-0.016***		-0.016***
Manufacturing		(0.004)		(0.005)		(0.004)		(0.005)
employment								
Average Wage		-0.007		-0.005		0.012		0.014**
		(0.005)		(0.006)		(0.008)		(0.009)
Exporter			-0.003	-0.004			-0.002	-0.004
			(0.002)	(0.003)			(0.002)	(0.003)
Importer			-0.004**	0.001			-0.005	0.000
			(0.002)	(0.003)			(0.002)	(0.003)
Foreign Owned			-0.009***	-0.008**			-0.010***	-0.007*
			(0.001)	(0.004)			(0.002)	(0.004)
Observations	35163	14178	64880	13195	35163	14178	34976	13195
R-Squared	0.03	0.03	0.02	0.04	0.02	0.04	0.02	0.04

AI Adoption (Probit)

Probit	AI adoption (0/1 indicator)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sales	0.26***	0.30***	0.21***	0.31***	0.27***	0.31***	0.26***	0.32***
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Labor Productivity					-0.11***	-0.30**	-0.16***	-0.29**
					(0.04)	(0.12)	(0.04)	(0.12)
Capital Intensity	-0.07***	-0.13***		-0.15**	-0.05**	-0.08**		-0.10**
	(0.02)	(0.04)		(0.04)	(0.02)	(0.04)		(0.04)
R&D Intensity	2.64***	2.23***		2.28***	2.63***	2.18***		2.24***
	(0.26)	(0.33)		(0.36)	(0.26)	(0.33)		(0.36)
Share of		-0.63***		-0.60***		-0.65***		-0.62***
Manufacturing		(0.17)		(0.17)		(0.17)		(0.17)
employment								
Average Wage		-0.20		-0.16		0.15		0.17
		(0.15)		(0.16)		(0.21)		(0.22)
Exporter			-0.09*	-0.15			-0.08	-0.15
			(0.05)	(0.11)			(0.07)	(0.11)
Importer			-0.08	0.18			0.04	0.17
			(0.05)	(0.14)			(0.07)	(0.13)
Foreign Owned			-0.25***	-0.11			-0.23***	-0.09
			(0.05)	(0.11)			(0.07)	(0.11)
Observations	35163	14178	64880	13195	35163	14178	34976	13195
Pseudo R-Squared	0.13	0.18	0.09	0.18	0.14	0.18	0.11	0.19

Findings in Tables 2&3 (Robots)

- Larger firms are more likely to adopt robots.
  - An increase by the standard deviation of the firm's base-year sales increases the probability of adopting robots by 3% (=0.007*1.49).
- Conversely, firms with lower capital intensity (and thus greater reliance on labor) are more likely to adopt robots.
- Higher-skill firms are more inclined to adopt robots.
- The primary motivation for adopting robots may not be to reduce the proportion of manufacturing workers.
- While foreign-owned firms are more likely to adopt robots, foreign trade is not associated with robot adoption.
- Robot adoption may be associated with import substitution. (probit estimation only)

Findings in Tables 2&3 (AI)

- The signs of the coefficients are generally similar to those for robot adoption.
- However, the coefficient for R&D intensity is much more statistically significant, indicating that AI adoption is strongly associated with higher skill levels.
- Another noteworthy difference is that the coefficients for the global variables—foreign ownership, exports, and imports—are all negative, suggesting that AI adoption is primarily driven by domestic factors.
- Additionally, while the coefficient for labor productivity is negative, the coefficient for average wage is positive and statistically significant, indicating that one of the main motivations for adopting AI is to reduce labor costs.

The Impact of Robot and AI Adoption on Employment and Productivity: DID Analysis

- To address the limitations of the standard Two-Way Fixed Effects (TWFE) method, we estimate two-group/two-period (2x2) estimator to analyze each pair of observations separately.
- This analysis categorizes the data into two distinct periods: Period 1 and Period 2.
  - Period 1 serves as the control year, representing the year before robot adoption, while Period 2 extends from the year of adoption up to four subsequent years.
  - For instance, to assess the impact of robot adoption in 2017 on the firm in the same year, we designate 2016 as Period 1 and 2017 as Period 2, applying the 2x2 estimator to the data from these two years.
- Similarly, to analyze impacts in subsequent years such as 2018, we retain 2016 as Period 1 and treat 2018 as Period 2, conducting our analysis with data from these two years.

The Impact of Robot and AI Adoption on Employment and Productivity: DID Analysis

- A modification of the standard two-way fixed effects (TWFE):

$$Employment_{itp} = \alpha + \beta_1 Year_p + \beta_2 Robot_{itp} + \beta_3 Year_p * Robot_{itp} + \gamma X_{itp} + \epsilon_{itp}$$

  - $Employment_{it}$ represents the log of employment for firm i
  - $Year_p$ is a period dummy
  - $Robot_{itp}$ is a robot dummy that takes one if the firm i adopted robots in the treatment year and zero otherwise
  - X_{isp} denotes the characteristics of firm i: we include an industry dummy and additional control variables as needed.
  - ϵ_{itp} is the error term

- To assess the impact on productivity, we replace the dependent variable with $Productivity_{itp}$.

The Impact of Robot Adoption on Permanent Employment: DID Analysis

	The Dependent Variable: Permanent Employment				
	ATET	Treatment Year	Control year	Measurement year	Observations
T					
	0.06	2017	2016	2017	22,588
	(0.06)				
	-0.01	2018	2017	2018	23,162
	(0.04)				
	-0.01	2019	2018	2019	24,555
	(0.10)				
	-0.01	2020	2019	2020	24,607
	(0.09)				
	0.03	2021	2020	2021	24,776
	(0.04)				
T+1					
	0.13	2017	2016	2018	23,886
	(0.08)				
	0.01	2018	2017	2019	23,249
	(0.07)				
	0.03	2019	2018	2020	24,524
	(0.06)				
	-0.08	2020	2019	2021	24,673
	(0.06)				
T+2					
	0.12	2017	2016	2019	23,972
	(0.10)				
	-0.01	2018	2017	2020	23,219
	(0.08)				
	0.07	2019	2018	2021	24,587
	(0.08)				
T+3					
	0.12	2017	2016	2020	23,941
	(0.13)				
	0.06	2018	2017	2021	23,283
	(0.11)				
T+4					
	0.10	2017	2016	2021	24,166
	(0.17)				

The Impact of Robot Adoption on Temporary Employment: DID Analysis

	The Dependent Variable: Temporary Employment				
	ATET	Treatment year	Control year	Measurement year	Observations
T					
	-0.24	2017	2016	2017	6,060
	(0.53)				
	0.08	2018	2017	2018	6,122
	(0.23)				
	0.24	2019	2018	2019	6,460
	(0.55)				
	-0.67	2020	2019	2020	6,567
	(0.72)				
	0.34	2021	2020	2021	7,050
	(0.54)				
T+1					
	-0.57	2017	2016	2018	6,549
	(1.06)				
	0.40	2018	2017	2019	5,971
	(0.57)				
	0.47	2019	2018	2020	6,739
	(0.87)				
	0.25	2020	2019	2021	6,733
	(0.62)				
T+2					
	-1.68	2017	2016	2019	6,391
	(1.91)				
	-0.01	2018	2017	2020	6,243
	(0.98)				
	0.51	2019	2018	2021	6,902
	(0.87)				
T+3					
	-0.51	2017	2016	2020	6,667
	(0.52)				
	0.31	2018	2017	2021	6,409
	(0.83)				
T+4					
	-0.83***	2017	2016	2021	6,830
	(0.11)				

The Impact of Robot Adoption on Labor Productivity: DID Analysis

	The Dependent Variable: Labor Productivity				
	ATET	Treatment year	Control year	Measurement year	Observations
T					
	0.11	2017	2016	2017	15,640
	(0.17)				
	-0.04	2018	2017	2018	22,553
	(0.06)				
	-0.13	2019	2018	2019	24,555
	(0.10)				
	-0.06	2020	2019	2020	24,606
	(0.13)				
	-0.07	2021	2020	2021	24,775
	(0.08)				
T+1					
	0.44	2017	2016	2018	17,548
	(0.40)				
	-0.15	2018	2017	2019	22,640
	(0.11)				
	-0.06	2019	2018	2020	24,523
	(0.13)				
	-0.11	2020	2019	2021	24,673
	(0.13)				
T+2					
	0.34**	2017	2016	2019	17,634
	(0.18)				
	-0.12	2018	2017	2020	22,609
	(0.12)				
	-0.03	2019	2018	2021	24,587
	(0.11)				
T+3					
	0.19	2017	2016	2020	17,602
	(0.36)				
	-0.19	2018	2017	2021	22,674
	(0.17)				
T+4					
	0.33	2017	2016	2021	17,668
	(0.24)				

Findings in Tables 4&5

- Overall, the standard DID approach suggests that robot adoption neither substitutes for nor increases labor, whether it is permanent or temporary.
- The impact of robot adoption on labor productivity is not statistically significant.
  - This finding is puzzling, as previous studies in the literature generally conclude that robot adoption enhances firm-level productivity.
  - We believe that this outcome may be closely related to the unique context in Korea, where the primary motivation for adopting robots may not be to replace labor or increase labor productivity.
  - Korea is known for having quite militant labor unions, and in many cases, firms may introduce robots to alleviate pressure from these unions by avoiding the need to hire additional workers.
- The standard DID approach shows that the impact of AI on employment and labor productivity is not statistically significant.

Limitations of the Above Methodology

- The potential non-equivalence of characteristics between the treatment and control groups implies that covariates could introduce a bias in estimating the treatment effect.
  - Ideally, we would observe the counterfactual scenario—specifically, how the same firm would have performed had it not adopted robots or AI—and then compare it with the firm's actual performance post-adoption.
  - However, such a counterfactual scenario is not directly observable.

Propensity Score Matching (PSM)

- We compare treated firms with similar but untreated firms.
- For this purpose, we utilize Propensity Score Matching (PSM).
  - We constructed a counterfactual group using a logit regression model to estimate the likelihood of adopting robots or AI in 2016.
  - Key regressors in the model included total employment (both permanent and temporary workers), labor productivity, a parent company dummy, and industry dummies.
  - This approach allows for a precise assessment of the impact of robot adoption on employment for 2017 (T) by comparing changes in employment between these matched pairs.
  - For subsequent analyses, such as the impact in 2018 (T+1), we maintained the same matched groups and calculated the treatment effect based on employment differences from 2016 to 2018.
- To account for the possibility that the impact of robot adoption in 2018 may differ from that in 2019, we repeated the procedure for firms adopting robots in 2018.

The Impact of Robot Adoption on Permanent Employment: PSM

Permanent Employment					
Robot	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	-0.04	0.01	0.04	-0.07	0.03
	(0.04)	(0.04)	(0.03)	(0.07)	(0.03)
observations	5064	9889	11399	11371	11721
T+1	-0.11	0.12*	-0.02	-0.05	
	(0.07)	(0.07)	(0.05)	(0.05)	
observations	4857	9479	10577	10826	
T+2	0.09	0.15	0.00		
	(0.21)	(0.11)	(0.13)		
observations	4653	8843	10106		
T+3	1.37*	0.13			
	(0.83)	(0.09)			
observations	4349	8470			
T+4	0.13				
	(0.34)				
observations	4178				

The Impact of Robot Adoption on Temporary Employment: PSM

Temporary Employment				
Robot	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	0.01	0.10**	1.45	0.08
	(0.15)	(0.05)	(1.28)	(0.39)
observations	1952	1764	1793	2064
T+1	-0.47	-0.38	-0.05	
	(0.53)	(0.31)	(0.29)	
observations	1472	1436	1667	
T+2	0.28	0.20		
	(0.49)	(0.37)		
observations	1233	1432		
T+3	-0.083			
	(0.96)			
observations	1217			

The Impact of Robot Adoption on Labor Productivity: PSM

Labor Productivity					
Robot	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	0.04	-0.12	-0.02	-0.06	-0.12*
	(0.12)	(0.09)	(0.09)	(0.13)	(0.07)
observations	4471	9737	11267	11181	11565
T+1	0.46**	-0.25**	-0.04	0.14	
	(0.22)	(0.11)	(0.12)	(0.09)	
observations	4780	9331	10380	10653	
T+2	-0.05	0.00	-0.09		
	(0.08)	(0.15)	(0.13)		
observations	4591	8665	9929		
T+3	-0.12	0.09			
	(0.29)	(0.11)			
observations	4267	8324			
T+4	-0.37				
	(0.67)				
observations	4101				

The Impact of Robot Adoption on Labor Share: PSM

Labor Productivity					
Robot	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	0.04	-0.12	-0.02	-0.06	-0.12*
	(0.12)	(0.09)	(0.09)	(0.13)	(0.07)
observations	4471	9737	11267	11181	11565
T+1	0.46**	-0.25**	-0.04	0.14	
	(0.22)	(0.11)	(0.12)	(0.09)	
observations	4780	9331	10380	10653	
T+2	-0.05	0.00	-0.09		
	(0.08)	(0.15)	(0.13)		
observations	4591	8665	9929		
T+3	-0.12	0.09			
	(0.29)	(0.11)			
observations	4267	8324			
T+4	-0.37				
	(0.67)				
observations	4101				

The Impact of AI Adoption on Permanent Employment: PSM

Permanent Employment					
AI	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	-0.06	0.02	0.02	0.16*	0.05
	(0.06)	(0.03)	(0.04)	(0.1)	(0.04)
observations	5020	9723	11383	11088	11464
T+1	-0.04	-0.01	0.09	0.10*	
	(0.08)	(0.06)	(0.07)	(0.06)	
observations	4806	9313	10535	10547	
T+2	0.05	-0.11	0.14*		
	(0.1)	(0.07)	(0.07)		
observations	4604	8672	10050		
T+3	0.12	0.03			
	(0.17)	(0.05)			
observations	4295	8302			
T+4	0.12				
	(0.16)				
observations	4124				

The Impact of AI Adoption on Temporary Employment: PSM

Temporary Employment					
AI	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	-0.11	0.61***	0.09	0.48	0.36
	(0.43)	(0.22)	(0.20)	(0.37)	(0.38)
observations	1909	1878	1894	1685	1949
T+1	-0.47	0.60*	-0.34	0.43*	
	(0.49)	(0.35)	(0.42)	(0.24)	
observations	1691	1409	1496	1562	
T+2	-0.13	0.71	-1.26***		
	(0.63)	(0.47)	(0.42)		
observations	1376	1172	1492		
T+3	1.61*	0.47			
	(0.96)	(0.48)			
observations	1244	1153			
T+4	0.03				
	(0.54)				
observations	1199				

The Impact of AI Adoption on Labor Productivity: PSM

Labor Productivity					
AI	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	-0.01	-0.01	0.06	-0.11	0.04
	(0.10)	(0.06)	(0.06)	(0.13)	(0.06)
observations	4458	9578	11253	10907	11311
T+1	0.24	-0.05	0.04	0.13	
	(0.23)	(0.07)	(0.14)	(0.11)	
observations	4734	9171	10343	10379	
T+2	0.31**	-0.05	0.22*		
	(0.16)	(0.08)	(0.13)		
observations	4545	8502	9871		
T+3	0.08	0.24**			
	(0.18)	(0.10)			
observations	4213	8156			
T+4	0.14				
	(0.31)				
observations	4050				

The Impact of AI Adoption on Labor Share: PSM

Labor Share					
AI	Initial Year 2017	Initial Year 2018	Initial Year 2019	Initial Year 2020	Initial Year 2021
T	0.06	0.04	-0.06	0.16	-0.92
	(0.14)	(0.03)	(0.04)	(0.38)	(0.65)
observations	4677	9723	11383	11086	11464
T+1	-0.32*	0.01	0.02	-0.03	
	(0.18)	(0.03)	(0.32)	(0.06)	
observations	4806	9313	10532	10547	
T+2	-0.43	-0.02	-0.46*		
	(0.26)	(0.22)	(0.25)		
observations	4604	8671	10050		
T+3	-0.4	-0.02			
	(0.55)	(0.07)			
observations	4294	8302			
T+4	0.16				
	(0.66)				
observations	4124				

Findings in Tables 6 (Robots)

- There is some evidence that firms that adopted robots increased either permanent or temporary workers.
- However, the evidence shows that firms that adopted robots experienced a decline in labor productivity.
  - Remember the unique context in Korea, where the primary motivation for adopting robots may not be to replace labor or increase labor productivity.

Findings in Tables 7 (AI)

- Firms that adopted AI increased either permanent or temporary workers.
  - Firms that adopted AI after 2019 hired more permanent workers.
  - Firms that adopted AI before 2019 hired more temporary workers.
- While these firms experienced an increase either in permanent or temporary employment, there is a general increase in labor productivity associated with AI adoption.
  - It takes about two-three years for the labor productivity to rise
- The increase in labor productivity associated with AI adoption led to a decrease in labor share for some firms.
  - This indicates a potential shift in the distribution of value, favoring capital income within these firms following the adoption of AI technology.

Conclusion

- While adopting both robots and AI increases either permanent or temporary employment, only firms that adopted AI experience productivity gains.
- However, the increase in labor productivity associated with AI adoption led to a decrease in labor share for some firms, indicating a potential shift in the distribution of value, favoring capital income.
- Our findings cannot be generalized to the entire economy without considering additional factors.