Do Digital Technologies Complement or Substitute for Human Labor?

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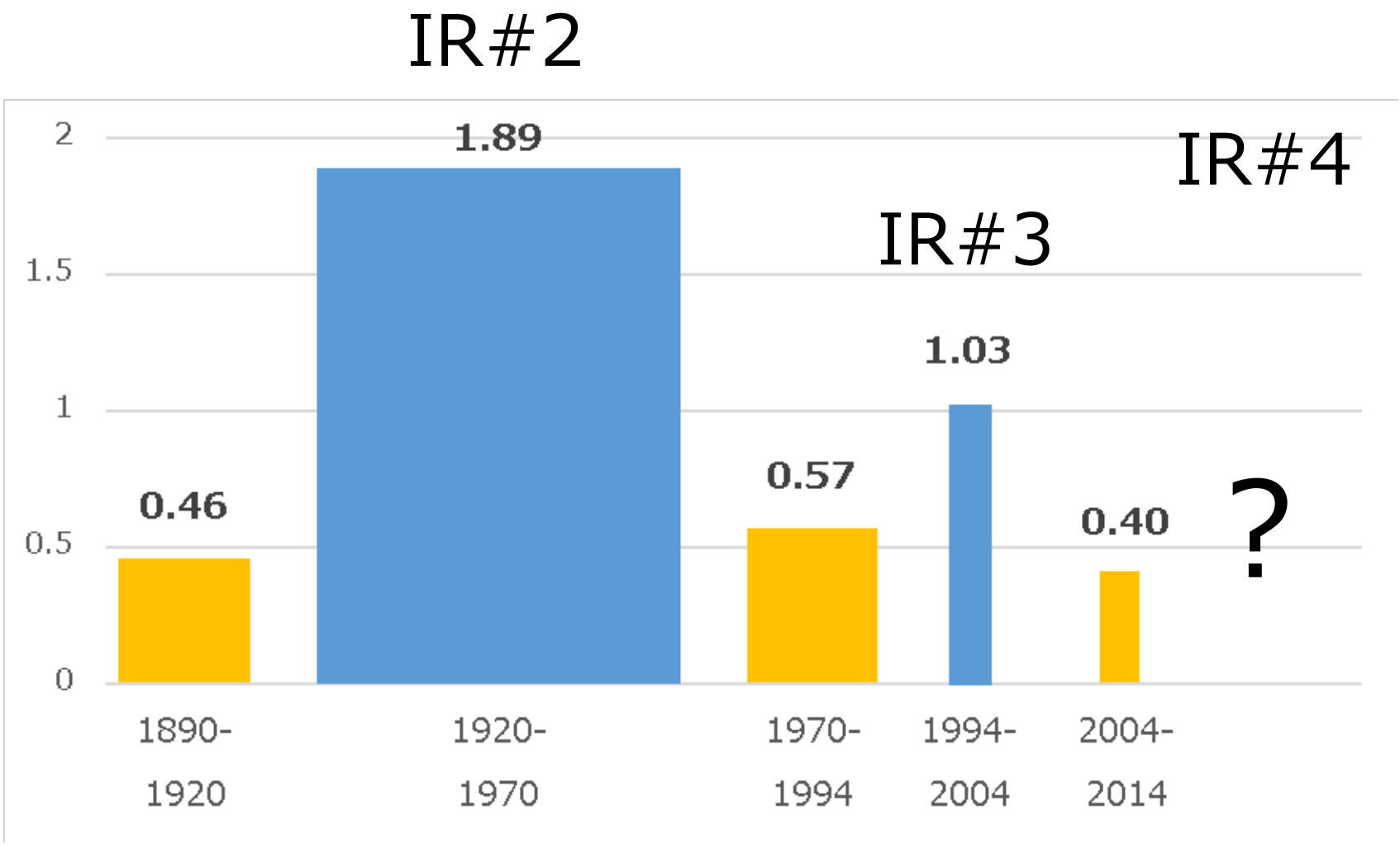
Motivation

- Digital technologies are now being introduced. Some fear that they may lose their jobs.

- According to Frey and Osborne (2017) that tries to estimate the effect of new digital technologies employing machine learning, 47 percent of total US employment is potentially automatable over a decade or two.

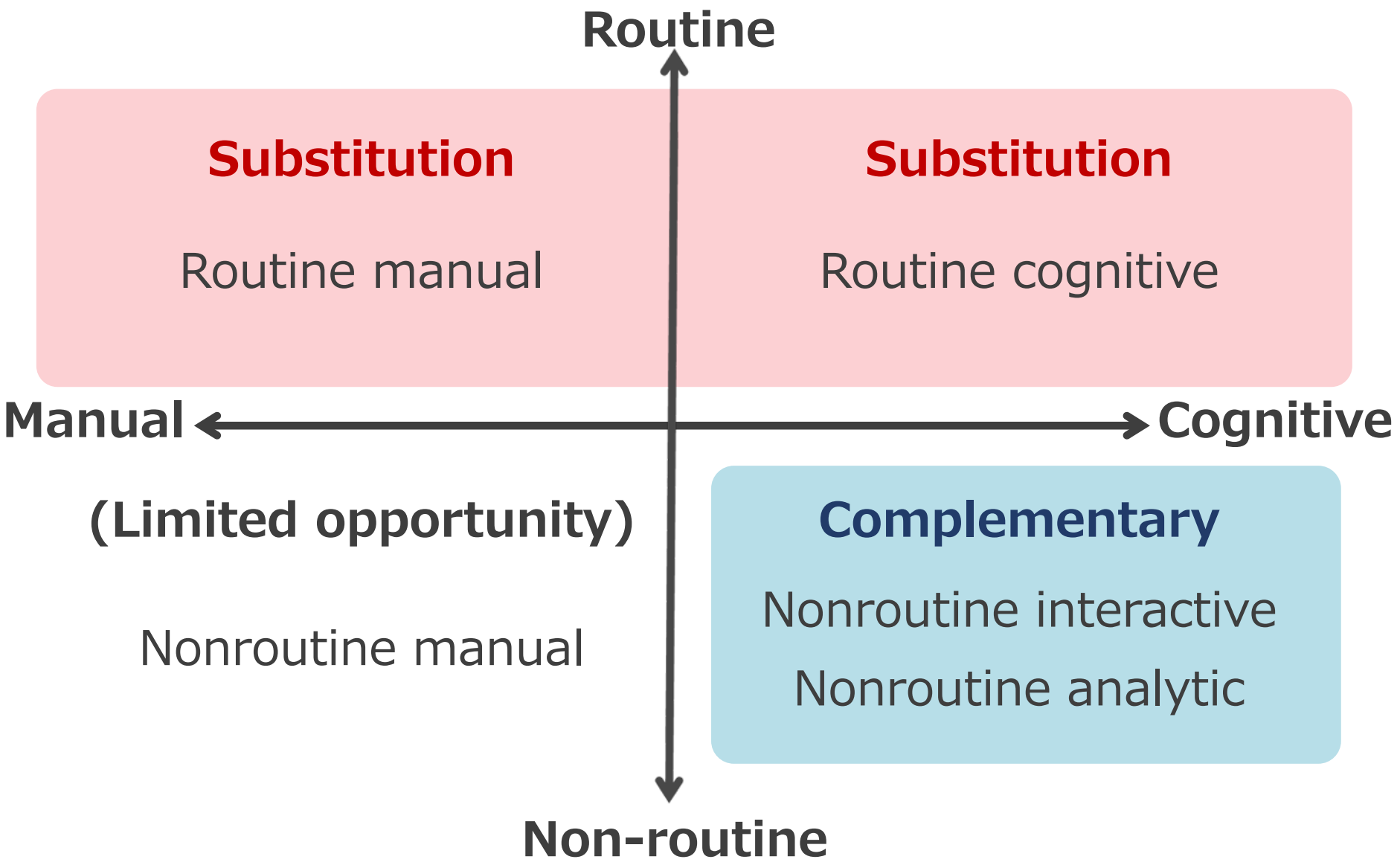
- Few empirical studies have examined the effect of new digital technologies on employment.

Annualized Growth Rates of TFP



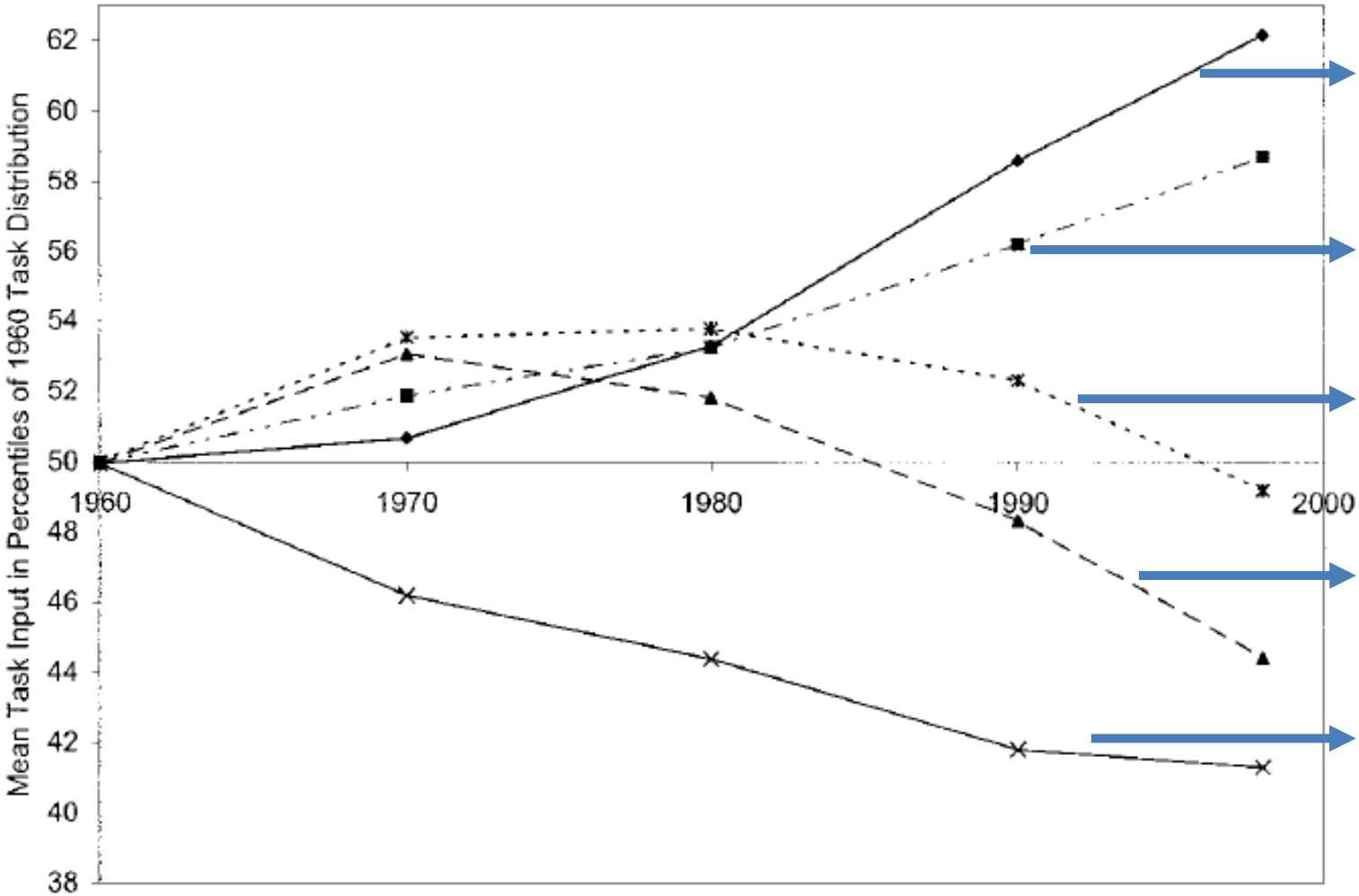
(source) Based on Gordon (2016) and authors.

The Informal Task Framework, ALM(2003)



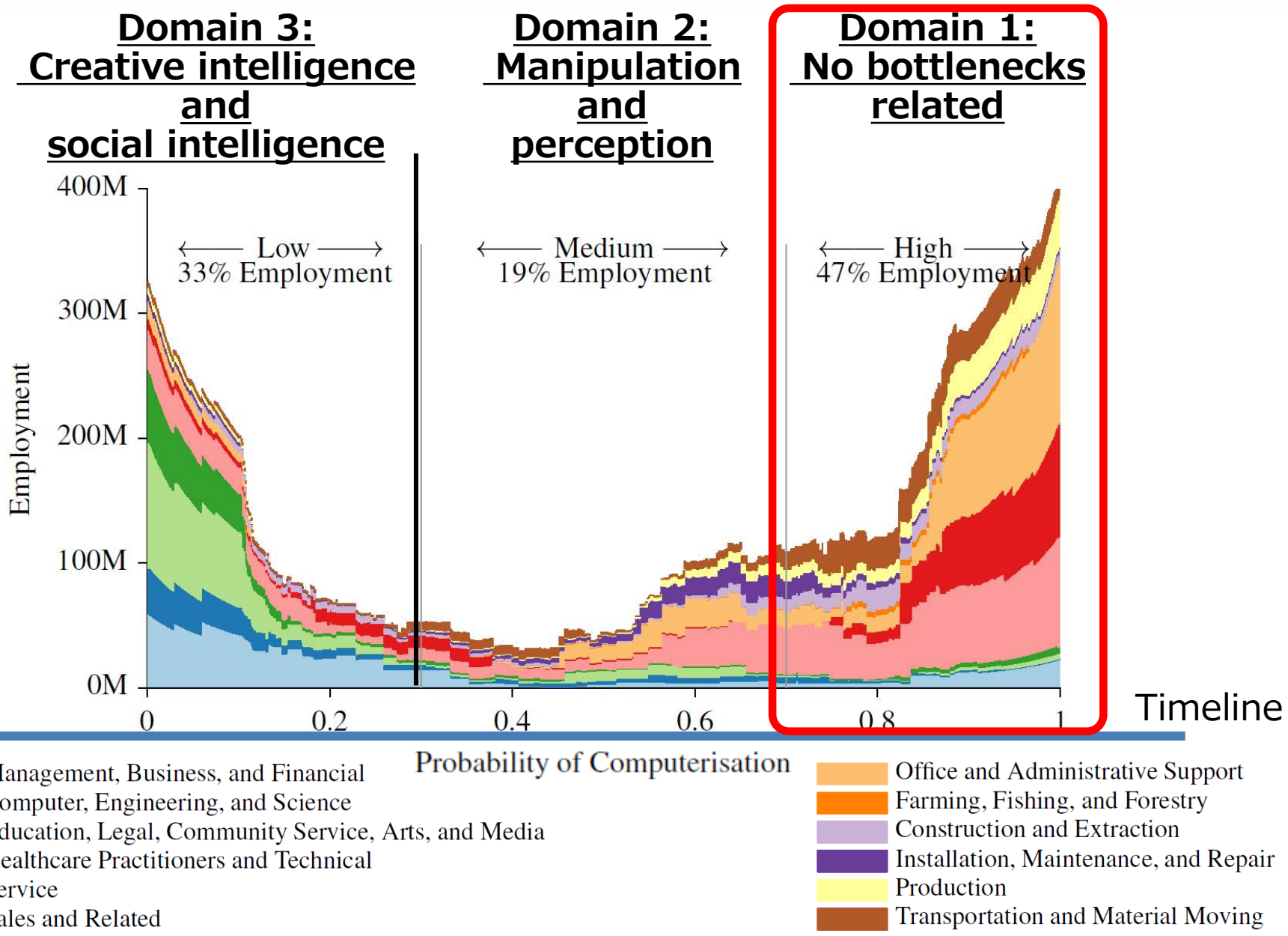
(source) Based on ALM (2003) and authors.

Trends in Routine and Nonroutine Task Input, 1960-1998, ALM(2003)



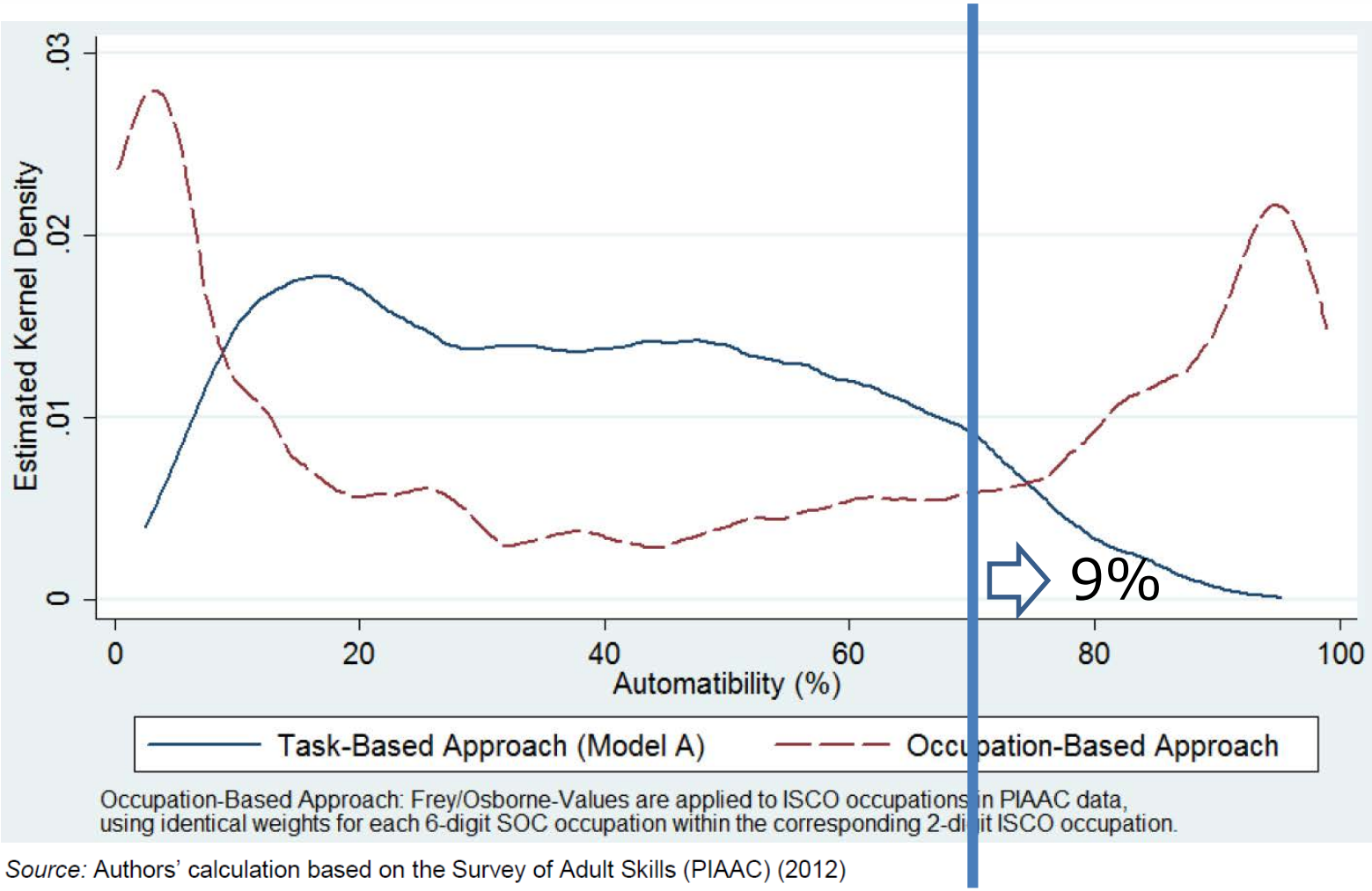
(source) Based on ALM (2003) and authors.

Employment Affected by Computerization, FO(2017)



(source) Based on FO (2017) and authors.

Distribution of Automatability (Task-Based vs. Occupation-Based Approach), AGZ（2016）



Source: Authors' calculation based on the Survey of Adult Skills (PIAAC) (2012)

Automatability = 70%

(source) Based on AGZ (2016) and authors.

KS（2019）: Online Survey

- Survey A

Scope of survey:

Five occupations, predicted high risk in FO (2017)

(receptionists and information clerks, account clerks, quality control technicians, retail salesperson, human resource coordinators)

Survey items:

Hours worked, Non-routine task intensity

- Survey B

Scope of survey:

Managers

Survey items:

Number of employees in managers' section

KS（2019）：Non-Routine Task Intensity

○Three dimensions of non-routineness in line with FO (2017)

Dimensions of NRTI KS (2019)	Engineering Bottlenecks FO (2017)
Repetition	Manipulation and perception
Decision making	Creative Intelligence
Communication	Social Intelligence

$$NRTI_{i,k,t} = \sum_{j} Vol_{i,j,t} \times Int_{i,j,k,t}$$

Vol : time allocation rate for each task
Int : the degree of non-routineness

KS（2019）: Example of Intensity Question 1

Occupation: Receptionists and information clerks				
Task	Answers: Past degree of repetition (Norminal)			
	True	Somewhat true	Somewhat not true	Not true
Communicate with customers directly	☐	☐	☑	☐
Communicate with customers indirectly (via phone or email)	☐	☑	☐	☐
Compile, copy, sort, and file records	☑	☐	☐	☐
Other	☐	☐	☐	☑

Task	*Int*: Past degree of repetition (Integral)
Communicate with customers directly	3
Communicate with customers indirectly (via phone or email)	2
Compile, copy, sort, and file records	1
Other	4

KS（2019）: Example of Intensity Question 2

Occupation: Receptionists and information clerks				
Task	*Vol*: Percentage of time allocation		*Int*: Degree of repetition	
	Past (*t=0*)	Current (*t=1*)	Past (*t=0*)	Current (*t=1*)
Communicate with customers directly	20	50	3	4
Communicate with customers indirectly (via phone or email)	40	20	2	2
Compile, copy, sort, and file records	30	10	1	1
Other	10	20	4	4

$$NRTI1_{1,0} = \sum_j (Vol_{1,j,0} * \frac{1}{100}) \times (Int1_{1,j,0})$$

$$=0.2*3+0.4*2+0.3*1+0.1*4=2.1$$

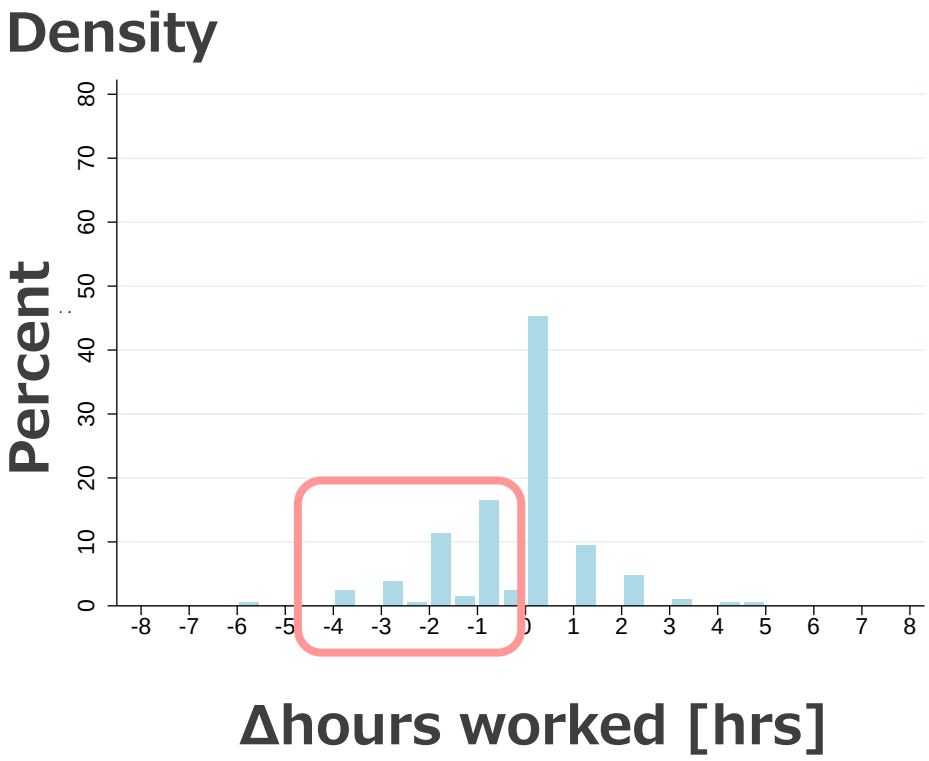
$$NRTI1_{1,1} = \sum_j (Vol_{1,j,1} * \frac{1}{100}) \times (Int1_{1,j,1})$$

$$=0.5*4+0.2*2+0.1*1+0.2*4=3.3$$

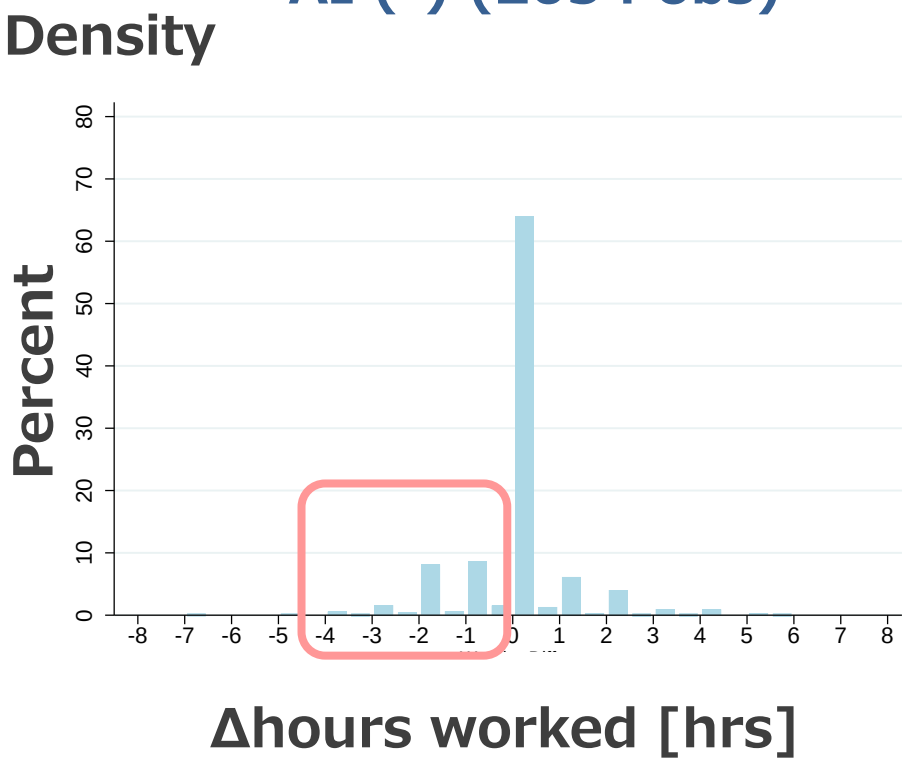
$$\Delta NRTI1_1 = NRTI1_{1,1} - NRTI1_{1,0} = 3.3-2.1=1.2$$

KS (2019): Difference in Hours Worked

Treatment group : AI (+) (212 obs)

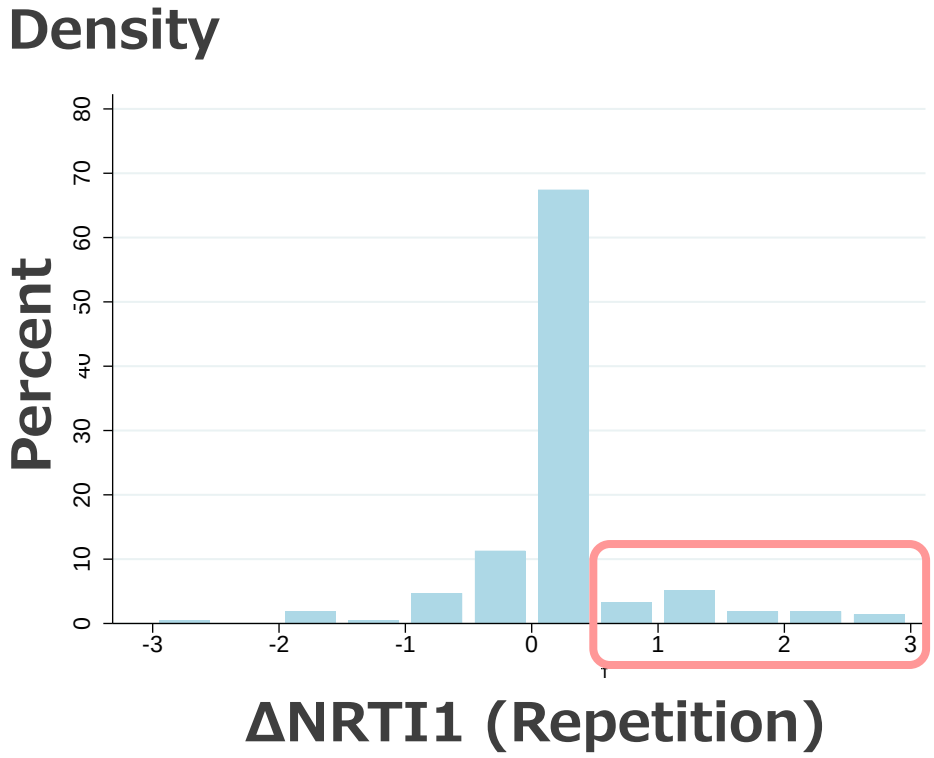


Control group: AI (-) (2054 obs)

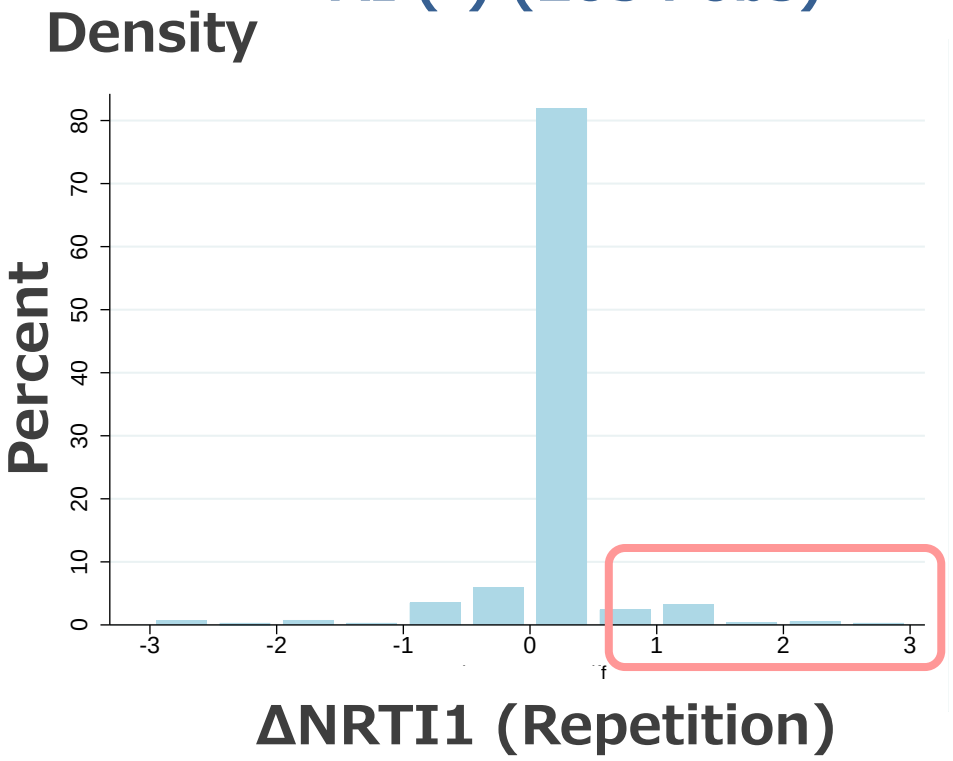


KS (2019): Difference in NRTI (Repetition)

Treatment group : AI (+) (212 obs)



Control group: AI (-) (2054 obs)



Firms: cost minimization

Y: Aggregate output $y(x)$: Output of task x

$$\ln Y = \int_{N-1}^{N} \ln y(x) dx \quad (1)$$

the services of a unit measure of tasks $x \in [N-1, N]$

$y(x)$: Output of task x

$$y(x) = \begin{cases} \gamma_L(x) l(x) + \gamma_M(x) m(x) & if\ x \in [N-1, I] \\ \gamma_L(x) l(x) & if\ x \in (I, N] \end{cases} \quad (2)$$

KS(2019): Model2

Households:

$$\max U_j = \begin{cases} \max\limits_{c_j, l_j} u_j(c_j, l_j) \;\; s.t.\; c_j = w l_j, l_j \leq 1 \;\; if \;\; l_j > 0 \\ \bar{u}_j \qquad\qquad\qquad\qquad if \;\; l_j = 0 \end{cases} \tag{3}$$

Labor demand in equilibrium:

$$L = (N - I)\frac{Y}{w} \tag{5}$$

$$\frac{d\ln L}{dI} = \underbrace{\frac{d\ln(N-I)}{dI}}_{\text{Displacement Effect (-)}} + \underbrace{\frac{d\ln(Y/w)}{dI}}_{\text{Productivity Effect (+ or -)}} \tag{6}$$

KS (2019)：Regression Equation

$$L_{i,t} = \alpha + \beta_1\left(Treat_{i,t} * After_{i,t}\right) + \beta_2 Treat_{i,t} + \beta_3 After_{i,t} + \sum_k \gamma_k X_{k,i,t} + \varepsilon_{i,t}$$

$L_{i,t}$ ：Dependent Variable（Hours Worked, Employment, NRTI）

$Treat_{i,t}$ ：Treatment Group＝ 1 , Control Group＝ 0

$After_{i,t}$ ：Before Introduction of AI＝ 0 ,
After Introduction of AI ＝ 1

$X_{i,t}$ ：Attribute Data（Gender, Age, Education, Firm size e.t.c.）

KS (2019): Estimation Results (Hours Worked) Overall

	(1)		(2)	
$Treat_{i,t} \times After_{i,t}$	-0.287	***	-0.287	***
	(0.086)		(0.086)	
$Treat_{i,t}$	0.284	***	0.227	**
	(0.096)		(0.096)	
$After_{i,t}$	-0.122	***	-0.122	***
	(0.026)		(0.026)	
Income	No		Yes	
Obs.	2,266		2,266	

(Note) Standard errors are in parentheses. Figures are given in hours.
*, **, and *** denotes statistical significance at the 10, 5, and 1 percent level respectively.

KS (2019) : Estimation Results (Employment)

	ln(Total)		ln(Regular employees)		ln(Contract employees)	ln(Temporary staff)	ln(Casual employees)
	(1)		(2)		(3)	(4)	(5)
$Treat_{i,t} \times After_{i,t}$	0.020		0.024	*	0.001	0.030	-0.018
	(0.013)		(0.013)		(0.016)	(0.023)	(0.025)
$Treat_{i,t}$	0.780	***	0.656	***	0.242	0.077	0.347
	(0.141)		(0.142)		(0.198)	(0.279)	(0.463)
$After_{i,t}$	0.027	***	0.016	***	0.004	0.001	0.005
	(0.004)		(0.004)		(0.006)	(0.009)	(0.015)
Obs.	1,982		1,895		851	351	91

(Note) Standard errors are in parentheses. Figures are given in log natural employment.
*, **, and *** denotes statistical significance at the 10, 5, and 1 percent level respectively.

KS (2019): Estimation Results (NRTI) Overall

	NRTI1 (Repetition)				NRTI2 (Decision making)				NRTI3 (Communication)			
	(1)		(2)		(3)		(4)		(5)		(6)	
$Treat_{i,t} \times After_{i,t}$	0.087	**	0.087	**	-0.007		-0.007		0.010		0.010	
	(0.037)		(0.037)		(0.049)		(0.049)		(0.028)		(0.028)	
$Treat_{i,t}$	0.063		-0.003		-0.060		-0.090	*	0.008		-0.013	
	(0.066)		(0.066)		(0.053)		(0.053)		(0.055)		(0.055)	
$After_{i,t}$	-0.004		-0.004		0.210	***	0.210	***	-0.021	**	-0.021	**
	(0.011)		(0.011)		(0.015)		(0.015)		(0.008)		(0.008)	
Income	No		Yes		No		Yes		No		Yes	
Obs.	2,266		2,266		2,266		2,266		2,266		2,266	

(Note) Standard errors are in parentheses.
*, **, and *** denotes statistical significance at the 10, 5, and 1 percent level respectively.

KS (2019): Estimation Results (Hours Worked) by Occupations

	(1)		(2)	
$Treat_{i,t} \times After_{i,t}$				
1. Receptionists and information clerks				
	-0.235		-0.268	
	(0.322)		(0.323)	
2. Account clerks				
	-0.375	**	-0.393	***
	(0.147)		(0.147)	
3. Quality control technicians				
	0.181		0.162	
	(0.208)		(0.209)	
4. Retail salespersons				
	0.160		0.115	
	(0.286)		(0.286)	
5. Human resource coordinators				
	-0.428	***	-0.403	***
	(0.114)		(0.114)	
$Treat_{i,t}$	0.224	**	0.284	***
	(0.096)		(0.096)	
$After_{i,t}$	-0.122	***	-0.122	***
	(0.026)		(0.026)	
Income	No		Yes	
Obs.	2,266		2,266	

(Note) Standard errors are in parentheses. Figures are given in hours.
*, **, and *** denotes statistical significance at the 10, 5, and 1 percent level respectively.

KS (2019): Estimation Results (NRTI) by Occupations

	NRTI1 (Repetition)		NRTI2 (Decision making)		NRTI3 (Communication)	
	(1)	(2)	(3)	(4)	(5)	(6)
$Treat_{i,t} \times After_{i,t}$						
1. Receptionists and information clerks						
	-0.059	-0.074	0.073	0.059	0.132	0.129
	(0.149)	(0.149)	(0.181)	(0.181)	(0.112)	(0.112)
2. Account clerks						
	0.083	0.082	-0.097	-0.088	-0.055	-0.054
	(0.067)	(0.067)	(0.083)	(0.083)	(0.050)	(0.050)
3. Quality control technicians						
	0.194 **	0.185 *	0.259 **	0.250 **	-0.106	-0.109
	(0.096)	(0.096)	(0.117)	(0.117)	(0.072)	(0.072)
4. Retail salespersons						
	-0.098	-0.124	-0.217	-0.240	-0.095	-0.099
	(0.132)	(0.132)	(0.161)	(0.161)	(0.099)	(0.099)
5. Human resource coordinators						
	0.102 **	0.110 **	-0.006	-0.004	0.078 **	0.079 **
	(0.051)	(0.051)	(0.064)	(0.064)	(0.038)	(0.038)
$Treat_{i,t}$	-0.002	0.064	-0.090 *	-0.059	-0.012	0.008
	(0.065)	(0.065)	(0.053)	(0.053)	(0.055)	(0.055)
$After_{i,t}$	-0.004	-0.004	0.210 ***	0.210 ***	-0.021 **	-0.021 **
	(0.011)	(0.011)	(0.015)	(0.015)	(0.008)	(0.008)
Income	No	Yes	No	Yes	No	Yes
Obs.	2,266	2,266	2,266	2,266	2,266	2,266

(Note) Standard errors are in parentheses.

*, **, and *** denotes statistical significance at the 10, 5, and 1 percent level respectively.

KS (2019): Conclusion 1 (Overall)

- Complement or Substitute for Human Labor ?

  1. reduced hours worked.
  2. increased regular employees.

→ Both complement and substitute

- The Effect on Tasks

  The introduction of AI increased NRTI (repetition), while significant effect is not observed on NRTI (decision making) and NRTI (communication).

→ In line with FO (2017)

KS (2019): Conclusion 2 (Limitation and Future Issues)

- Limitation
  - FO, AGZ; Prediction over next one or two decades
  - KS (2019); Effects in these three years

  →Longer-term effects still remain to be seen.

- Future Issues

  1. Extension of survey

  → Larger scale survey covering all occupations
  or
  Use of official statistics capturing AI

  2.Effect on wage and income distribution

KS (2019): References

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