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The Effects of Artificial Intelligence and Robotics on Business and Employment: Evidence from a survey on Japanese firms

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The Effects of Artificial Intelligence and Robotics on Business and Employment: Evidence from a survey on Japanese firms*

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Abstract

This study presents new evidence on firms' attitudes toward artificial intelligence (AI) and robotics, as well as their attitude toward the impacts of these new technologies on future business and employment prospects. The data used in this paper are the results of our original survey of more than 3,000 Japanese firms. The major findings can be summarized as follows. First, firms operating in the service industry have a positive attitude on the effects of AI-related technologies, suggesting the importance of paying attention to "AI-using industries." Second, we observe complementarity between AI-related technologies and the skill level of employees. This finding suggests that in order to accelerate the development and diffusion of AI and to maintain employment opportunities, it will be necessary to upgrade human capital. Third, firms that engage in global markets tend to have a positive attitude toward the impacts of AI-related technologies, indicating that globalization of economic activities will facilitate the development and diffusion of these new technologies.

Keywords: Artificial intelligence, Robotics, Big data, AI-using industry, Skill
JEL Classification: O33, J23, J24

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The Effects of Artificial Intelligence and Robotics on Business and Employment: Evidence from a Survey for Japanese Firms

1. Introduction

This study presents evidence on the attitude of firms regarding artificial intelligence (AI), robotics, and Big Data, ―sometimes referred to as the "Fourth Industrial Revolution"―as well as their views in respect to the impacts that these new technologies may have on future business and employment. The analysis uses original survey data from more than 3,000 Japanese firms operating in both the manufacturing and service sectors.

Since the 1990s, productivity growth of the service sector has accelerated in the U.S. due to the "IT Revolution." However, recent studies have noted that the productivity effects of traditional types of IT had already been exhausted by mid-2000 (Fernald, 2015). Development and diffusion of the next generation of General Purpose Technologies (GPTs), including AI and robotics, may substantially impact the future economy and society.

Under these circumstances, the Japanese Government has begun efforts to develop and diffuse robotics and AI technologies. The Robot Revolution Initiative Council was established in 2014 and published a report in 2015 titled "New Robot Strategy," which includes a five-year action plan to actualize the robot revolution. The Artificial Intelligence Research Center was established in the National Institute of Advanced Industrial Science and Technology (AIST) in 2015. The purpose of this Center is to promote research by industry and research institutions of basic AI technologies and their application to solving real-world problems. The "Japan Revitalization Strategy 2015", which is the core growth strategy of the Japanese government, seeks to modify industrial and employment structures through the utilization of IoT (Internet of Things), Big Data, and AI.

In spite of enthusiastic interest regarding the AI revolution in policy circles, there is a lag in the economic research of AI and robotics. Currently, there are two types of studies on this subject: 1) theoretical arguments from the viewpoint of growth theory and 2) inferences from past innovations voiced by labor economists. In the field of growth theory, the "singularity" hypothesis has been widely discussed. According to a standard endogenous growth model, if AI and robots increasingly replace labor, then capital share will rise, and the economic growth rate will accelerate. If AI and robots were to completely replace labor, growth rates would explode (Fernald and Jones, 2014). However, using economic growth theory and available data, Nordhaus (2015) conducted several calculations whether we are rapidly approaching to singularity and concluded that we will not reach this point in the near future.

In the field of labor economics, substitution of human labor by AI and robots is hotly discussed. Although this discussion is a natural extension of numerous studies on the relationship between ICT and labor, the estimation by Frey and Osborne (2013) on the number of jobs at risk to be replaced by future computerization, including advances in Machine Learning (ML) and Mobile Robotics (MR), has attracted the attention of media and policy practitioners to this issue. According to Frey and Osborne (2013), roughly 47 percent of the total US employment is at risk for computerization. However, according to Autor (2015), automation and technological progress has not led to the obsolescence of human labor. In fact, automation and labor are highly complementary, particularly for employees that are adaptable, creative, and solutions-oriented. Based on the historical lessons learned since the Industrial Revolution, Mokyr *et al*. (2015) argue that computers and robots will create new products and services and that these product innovations will result in unimaginable new occupations.

However, these arguments are inferences from past experiences and are not based on existing data or information regarding AI and robotics.[1] The purpose of this study is to present new empirical findings on this issue using data from an original survey of Japanese firms. Special attention is paid to the complementarity between the skill of human resources and AI-related technologies and between globalization and these technologies. There are numerous studies on the complementarity/substitutability of ICT and the skill of workers. Earlier studies have produced evidence based on the skill-biased nature of ICT that indicate skilled labor and ICT are complementary (for example, Krueger, 1993; Doms *et al*., 1997; Autor *et al*., 1998; Bresnahan *et al*., 2002). More recent studies (for example, Autor, *et al*., 2006, 2008; Goos and Manning, 2007; Van Reenen, 2011; Goos *et al*., 2014) have indicated that ICT substitutes routine tasks conducted by middle-skill employees, which results in the “polarization” of the labor market. However, the relationship between AI-related technologies and human skills has not yet been explicitly studied.

The results of this study can be summarized as follows: First, service sector firms generally have a positive attitude towards the use of Big Data and the impacts of AI and robotics, suggesting the importance of paying attention to “AI-using industries”, as well as “AI-producing industries.” Second, we observe complementarity between AI-related technologies and the skill level of firm employees. The complementarity is more prominent for employees with a postgraduate education. This finding suggests that in order to accelerate the development and diffusion of AI-related technologies and to maintain employment opportunities, it is necessary to upgrade human capital. Third, firms that operate in global markets report a

[1] Exceptions include international comparison of AI-related patent applications (Lechevalier *et al*., 2014), and empirical study on the economic impacts of industrial robots (Graetz and Michaels, 2015).

positive attitude toward the impact of AI-related technologies, indicating that globalization of economic activities will facilitate the development and diffusion of the new technologies and that the converse would also be true.

The remainder of this study is organized as follows: Section 2 explains the survey data utilized for the study and the method of analysis. Section 3 reports the descriptive findings regarding the attitude of firms on Big Data, AI, and robotics followed by a presentation of simple regression results on the relationship between various characteristics of firms and their attitudes toward the new technologies. Section 4 summarizes the study's conclusions and policy implications.

2. Outline of the Survey and the Method of Analysis

The data used in this paper originate from the Survey of Corporate Management and Economic Policy (RIETI). The survey was conducted from October to December 2015 to a variety of public and private Japanese firms operating in both manufacturing and service industries.[2] A total of 3,438 firms responded to the survey (response rate is 22.9%). The breakdown of firms by industry are as follows: manufacturing 1,647 (48.1%), ICT 199 (5.8%), wholesale 639 (18.6%), retail 403 (11.8%), services 395 (11.5%), and other industries 144 (4.2%).[3] The survey inquiry was wide-ranging, but in this study, we focus on three questions related to Big Data, AI, and robotics, as well as basic firm characteristics available from the survey, such as industry, firm size (total number of employees), and employee composition.

Results from these three multiple choice questions are described in detail. The first is a simple query regarding the use of Big Data: "How does your firm think about Big Data?" The four possible responses were 1) "already using for business," 2) "intend to use future business," 3) "not related to our business," and 4) "don't have any idea." We should note that although AI is not a prerequisite for using Big Data, AI and Big Data are complementary in business applications. That is, the availability of Big Data will enhance the use of AI on one hand, and the progress of AI technologies will accelerate the accumulation of Big Data on the other hand.

The second question investigates the possible impact of AI and robotics on businesses: "How does your firm think about the impact of the development and diffusion of AI and robotics on the future business of your firm?" The five possible responses were 1) "significant positive

[2] The survey is designed to be linked with the Basic Survey of Japanese Business Structure and Activities (Ministry of Economy, Trade and Industry: METI).

[3] Industry classifications of the remaining 11 firms are unknown. The percentages are calculated excluding "unknown" firms from the denominator.

impact," 2) "positive impact," 3) "neither positive nor negative," 4) "negative impact," and 5) "significant negative impact."

The third question investigates the possible impact of AI and robotics on employment: "How does your firm think about the impact of the development and diffusion of AI and robotics on the future employment of your firm?" The four possible responses were 1) "increase in the number of employees," 2) "decrease in the number of employees," 3) "no impact on the number of employees," and 4) "don't have any idea."

In this study, we provide a descriptive analysis of the data. We report simple tabulation results of the questions and cross-tabulate the answers with firm characteristics, such as industry, firm size, and workforce composition. Next, we run simple ordered-probit estimations to compare firm characteristics to their attitude regarding Big Data, AI, and robotics (referred in this paper as "AI-related technologies"). The firm characteristics used as explanatory variables include the industry (manufacturing, ICT, wholesale, retail, services, and other industries), firm size (log number of employees), geographic market area of the firms' products/services (city, prefecture, Japan, Asia, and world), and existence of labor unions. The industry and the geographic market area are dummy variables: manufacturing industry and city are used as reference categories. Due to fierce competition in the development and use of AI-related technologies world-wide, we expect that firms engaged in global markets tend to have positive attitudes toward the business application of AI-related technologies.

It is important to note that the survey collects rich information regarding the characteristics of the firms' employees. Specifically, the employees' education—the ratio of employees graduated from university or more and the ratio of employees holding postgraduate degrees as the subset—, average age, female ratio, and the ratio of non-standard workers are surveyed. We analyze the association between employee characteristics and the firms' attitude to AI-related technologies. We hypothesize that attitudes of firms with many employees that have complementary skills with AI-related new technologies will be positive toward the impacts of the new technologies. Conversely, firms with many low skilled employees would engender negative views about the impacts of the development and diffusion of AI-related technologies on their business and employment.

This study does not seek to uncover causal relationship; the purpose is to present new evidence from cross-sectional survey data. Major variables and their summary statistics are shown in Table 1.[4] For example, the sample means of the shares of university graduates and

[4] We removed firms whose reported number of standard employees was larger than the total number of employees and firms with extremely low figures of average age of their employees as outliers. As observed from Table 2, several firms exhibit a very small number of employees. In conducting ordered-probit estimation, we checked the robustness of the results by excluding such firms.

postgraduate degree holders are 37.8% and 2.4%, and the standard deviations are, respectively, 27.1% and 5.9%, indicating that skill levels are well-dispersed among sample firms.

3. Results

3.1 Overview

The share of firms currently using Big Data for their business is notably small (3.0%), but 18.1% of firms intend to use Big Data in future business (Table 2). However, a relatively large number (39.5%) of firms responded “don’t have any idea,” reflecting that business applications of Big Data are not yet well understood. By industry, a positive attitude to using Big Data (sum of the shares of firms “already using for business” and “intend to use in future business”) is highest for the ICT industry (50.5%) followed by services (27.7%), retail (26.9%) and manufacturing (20.7%). It becomes clear that firms in the non-manufacturing sector have positive attitudes toward the use of Big Data, which aligns with the well-known fact that IT-using industries reap the benefits of the “IT revolution” (Stiroh, 2002; Pilat *et al*., 2002; Oliner *et al*., 2007). While not reported in the table, the mean size of firms showing a positive attitude (816 employees) is larger than that of firms that responded “not related to our business” (253 employees), and the difference is statistically significant at the 1% level.

Responses regarding the impact of the development and diffusion of AI and robotics on the future business (Table 3) are as follows: positive responses (27.5%: sum of the “significant positive impact” (3.9%) and “positive impact” (23.6%)) are far larger than the negative responses (1.3%: “negative impact” (1.0%) and “significant negative impact” (0.3%)), although more than 70% of the firms do not have a clear outlook (responded as “neither positive nor negative”). By industry, firms operating in the ICT industry reported the most positive attitude to the impacts of AI and robotics (42.3%) followed by manufacturing firms (32.5%). However, many firms in service industries exhibited a positive attitude. The mean size of firms indicating a positive attitude (607 employees) is larger than that of a negative attitude (298 employees), and the difference is statistically significant at the 1% level.

The perception of the impact of AI and robotics on employment (Table 4) is generally negative: 21.8% of firms responded that the development and diffusion of new technologies will decrease the number of their employees, and the share of firms expecting positive effects on their employment is notably small (3.7%). However, 28.6% of firms expect no impact of AI and robotics on their employment and 45.8% of firms responded as “don’t have any idea.” By industry, with an exception of the ICT industry, the number of firms expecting a negative employment effect is larger than those expecting a positive employment effect. However, as mentioned in the introduction, innovative technologies, such as AI and robotics, may create new employment opportunities that are currently unimaginable, and technology-intensive emerging firms may create many new occupations. When cross-tabulating the results of the two questions, firms afraid of the negative impact of AI and robotics on their business tend to have negative views on their employment.

Lessons learned from the “IT revolution” indicate that it is likely that firms with relatively low-skilled employees were affected negatively by the “Fourth Industrial Revolution”, and those with highly skilled employees reap the benefit of the revolution. To analyze this technology-skill complementarity, we compare the relationship between the attitude toward new technologies and the education level of employees (Table 5). Firms indicating a positive attitude toward Big Data (“already using for business” and “intend to use in future business”) have highly educated employees. The ratios of university graduates and postgraduate degree holders of these firms are 11.9% points and 1.9% points higher than the ratios of firms responding that Big Data is unrelated to their business, and the differences are both statistically significant at the 1% level.

Similar relationships can be observed regarding firm attitudes toward the impact of AI and robotics on business. Firms expecting positive outcomes on their business have significantly higher ratios of university graduates (2.5% points) and employees with postgraduate degrees (1.8% points) than other firms. This technology-skill complementarity is confirmed after controlling for firm size and industry by the ordered-probit estimations reported in the next subsection (Tables 7). Conversely, the ratio of university graduates is 5.9% points lower among firms that anticipate a negative impact from AI and robotics on their employment than those expecting positive or neutral impacts. To summarize, these results suggest complementarity between new AI-related technologies and employees’ skill levels.

Interest in the development and application of Big Data, AI, and robotics is not limited to Japan, and fierce international competition is expected in this new frontier. In this regard, we cross-tabulate the geographic market area of the firms’ products/services (city, prefecture, Japan, Asia, and world) and the attitude to the AI-related technologies. Firms selling their products/services globally tend to exhibit positive attitudes toward Big Data, AI, and robotics (Table 6). 25.2% of firms having positive attitudes regarding the use of Big Data, and 28.6% of firms expecting AI and robotics to positively impact their business operate in global markets. These figures are higher than those for firms with non-positive attitudes (17.4% and 15.7%, respectively),[5] and the differences are both statistically significant at the 1% level. 21.4% of

[5] The ratios of the spatial market areas of the respondents are city (4.8%), prefecture (20.2%), Japan (55.7%), Asia (7.0%), and world (12.2%).

firms expecting a positive impact on their employment engage in global markets, which is higher than the figure for firms of non-positive expectations (18.6%), and the difference is statistically significant at the 5% level. It should be noted that the cross-sectional relationships described above do not necessarily mean causal relationships. The results should be interpreted as evidence of the interdependent relationship or complementarity between globalization and the use of new technologies.

3.2 Estimation Results

In this subsection, we report ordered-probit estimation results on the relationships between various firm characteristics and attitudes toward AI-related technologies (Table 7). As explained in section 2, the explanatory variables are industry (manufacturing, ICT, wholesale, retail, services, and other industries), firm size (log number of employees), the spatial market area of the firms' products/services (city, prefecture, Japan, Asia, and world), and the existence of labor unions, as well as employee composition (education, age, gender, and type of employment). Reference categories of dummy variables are "city" for the geographic area of market and "manufacturing" for industry, respectively.

Regression result regarding the use of Big Data is shown in column (1) of Table 7. In this estimation, firms that responded "don't have any idea" are removed from the sample. The dependent variable is the attitude toward the use of Big Data: "already using for business"=3, "intend to use in future business"=2 and "not related to our business"=1. Accordingly, positive and significant coefficients mean the characteristics are associated with a positive attitude toward the use of Big Data. The result indicates that the larger the size, the higher the education level of the employees, and the lower the average age of the employees, the firms are more active in using Big Data. It is noteworthy that the coefficients for the ratio of postgraduate education are far larger than those of university graduates, suggesting the threshold of the skill complementary to utilizing Big Data is relatively high.

We conducted an estimation using firm age (years since establishment) as an additional explanatory variable by linking the survey data with micro data of the Basic Survey of Japanese Business Structure and Activities (BSJBSA). The coefficient for firm age was statistically insignificant, and the size and significance level of the coefficient for the age of employees are unaffected (not reported in the table). That is, firms employing young workers have a positive attitude to use Big Data, irrespective of the firm age.

The coefficient for female ratio is positive and significant at the 5% level. We conjecture that it is important for firms serving wide range of consumers to collect detailed information on the needs of consumers and that such firms may be active in employing female employees and in utilizing customer data. The coefficient for the world market is positive and highly significant, confirming globalized firms have a positive attitude toward Big Data, after accounting for other firm characteristics. The coefficients for the ICT industry are positive and highly significant, but the coefficients for other service industries are generally insignificant with the exception of marginally positive coefficient for the wholesale industry. However, the insignificant differences mean that retail, service, and manufacturing firms all maintain a positive attitude.

Next, we report estimation result for query regarding the impact of AI and robotics on business. In this estimation, the order of the five response categories are reversed and used as the dependent variable. For example, “5” and “4” are assigned for the response of “significant positive impact,” and “positive impact,” respectively. Thus, the positive coefficient can be interpreted as positive attitude toward the effects of AI and robotics on business. According to the estimation result (column (2) of Table 7), the larger the firm, the higher the ratio of employees with postgraduate education, and the lower the average age of the employees, the more positive firms are regarding the effects of AI and robotics on their business.[6] However, the coefficients for the ratio of university graduates are positive but statistically insignificant, suggesting, similar to the finding for the use of Big Data, that the threshold of the complementary skill with the use of AI and robotics is relatively high.

The coefficients for the dummies for geographic market area monotonically increases as market areas widen, even after controlling for other firm characteristics. The result confirms the complementarity between globalization and the use of new technologies. The dummies for service industries are generally negative and significant with an exception of the ICT industry where the coefficients are positive and insignificant. After accounting for the other firm characteristics, manufacturing firms have a more positive view on the impact of AI and robotics on their future business.

Finally, estimation result for the impact of employment is reported in column (3) of Table 7. The dependent variable is the impact of AI and robotics on employment: “increase in the number of employees”=3, “no impact on the number of employees”=2, and “decrease in the number of employees”=1. In this estimation, firms responded “don’t have any idea” are removed from the sample. Again, a positive coefficient means a less negative view of the impact of AI-related technologies on employment. In this case, the coefficients for the ratio of employees with postgraduate education are positive but statistically insignificant. Conversely, the coefficients for the ratio of university graduates are positive and significant at the 5% level,

[6] The estimation result using firm age as an additional explanatory variable is similar to the result for the use of Big Data. The coefficient for firm age was statistically insignificant and the size and significance level of the coefficient for the age of employees are still highly significant.

indicating that firms with less educated employees have a more negative view on the effects of AI and robotics on their employment. The coefficients for the ratio of female employees and the ratio of non-standard employees are negative and statistically significant; suggesting these types of workers at the current skill level may be adversely affected by the diffusion of AI and robotics. In contrast to the previous two regression results, we do not observe systematic relationship among the coefficients for the geographic market area. The coefficients for the service industries dummies are all positive and highly significant, indicating that manufacturing firms used as the reference category view possible disemployment effects from the diffusion of AI and robotics more seriously.

The estimation results presented above using cross-sectional data cannot be interpreted as causality in econometric sense. For example, the positive association between education of employees and the attitude to the new technologies may be a result of the firms' use of AI and robotics and propensity to hire highly educated young employees. Similarly, firms actively using Big Data or AI tend to expand their activities globally, and this may have resulted in the positive association between globalization and a positive attitude to new technologies. Our tentative interpretation of these observed relationships is the indication of complementarity or bi-directional causality.

4. Conclusions

This study analyzes the attitude of firms toward AI, robotics, and Big Data, as well as their views regarding the impacts of these new technologies on future business and employment prospects. This analysis utilizes original survey data of more than 3,000 Japanese public and private firms operating in both the manufacturing and service sectors. Many speculative arguments have arisen regarding the economic and social impacts of the "Fourth Industrial Revolution," but quantitative evidence on this issue has rarely been presented. Although this study is limited to simple calculations from cross-sectional survey data and the information regarding the AI-related technologies includes subjective assessments, it presents novel findings regarding this topic.

The results of this study indicate the following: First, firms operating in the service sector generally have a positive attitude toward the use of Big Data and the impacts of AI and robotics. This finding suggests that we should pay attention to "AI-using industries" including a large number of service industries, similar to the experience from the "IT revolution." Because improving productivity performance of the service sector is imperative to enhance the potential growth rate of advanced economies, such as Japan, diffusion and application of AI-related technologies in the service sector are highly expected.

Second, we observe complementarity between AI and the skill level of the firms' employees. In particular, we should pay attention to the strong complementarity found at the relatively higher end of the skill distribution. This finding suggests that in order to accelerate the development and diffusion of AI-related technologies and, at the same time, to maintain employment opportunities, it is necessary to upgrade human capital, such as increasing the number of employees with postgraduate education. [7]

Third, firms operating in global markets reported a positive attitude toward the impact of AI-related technologies, indicating that globalization of economic activities, such as expanding economic partnership agreements (EPAs), will facilitate the development and diffusion of AI-related innovations, and active investment in utilizing these new technologies will promote further globalization of economic activities.

[7] Morikawa (2015) is an empirical study on the return to postgraduate education in Japan, which indicates the rate of return to postgraduate education exceeds 10%.

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Table 1 Variables and the summary statistics

Variables	Mean	SD	Min.	Max.	Nobs.
Ln regular employees	5.104	0.988	0	11.513	3,145
Ratio of university or more (%)	37.803	27.102	0	100	2,996
Ratio of postgraduates or more (%)	2.372	5.853	0	100	2,847
Mean age of employees	40.62	4.34	25	65	3,159
Female ratio	0.300	0.204	0	0.994	3,145
Non-standard ratio	0.243	0.248	0	0.993	3,145
Labor union dummy	0.318	0.466	0	1	3,281

(Note) The denominator to calculate the ratios of female and non-standard employees is the total number of regular employees (including part-time workers).

Table 2 Use of Big Data

	(1) Already using for business	(2) Intend to use in future business	(3) Not related to our business	(4) Don't have any idea
Manufacturing	2.7%	18.1%	35.7%	43.5%
ICT	8.5%	42.0%	25.5%	23.9%
Wholesale	1.5%	16.4%	41.1%	41.1%
Retail	4.3%	22.6%	35.4%	37.8%
Services	1.9%	25.8%	41.8%	30.5%
Other	4.4%	17.0%	41.5%	37.0%
Total	3.0%	20.5%	37.0%	39.5%

Table 3 Impact of AI and robotics on business

	(1) Significant positive	(2) Positive	(3) Neither positive nor negative	(4) Negative	(5) Significant negative
Manufacturing	4.7%	27.8%	66.5%	0.8%	0.2%
ICT	8.5%	33.9%	54.5%	3.2%	0.0%
Wholesale	1.8%	17.1%	79.8%	1.2%	0.2%
Retail	2.4%	18.4%	77.8%	0.8%	0.5%
Services	3.3%	18.4%	76.3%	1.1%	0.8%
Other	2.2%	17.8%	80.0%	0.0%	0.0%
Total	3.9%	23.6%	71.3%	1.0%	0.3%

Table 4 Impact of AI and robotics on employment

	(1) Increase	(2) No impact	(3) Decrease	(4) Don't have any idea
Manufacturing	3.0%	21.8%	29.3%	45.9%
ICT	15.9%	30.7%	13.8%	39.7%
Wholesale	2.0%	30.7%	13.9%	53.4%
Retail	1.9%	37.8%	16.8%	43.6%
Services	6.7%	42.3%	14.2%	36.8%
Other	0.7%	33.3%	15.6%	50.4%
Total	3.7%	28.6%	21.8%	45.8%

Table 5 Firms' attitudes on AI-related technologies and the education of their employees

A. Use of big data	Use/want to use	Unrelated to business	
Ratio of university or more (%)	47.0	35.1	***
Ratio of postgraduates or more (%)	3.9	1.9	***
B. Impact on business	Positive	Negative/neutral	
Ratio of university or more (%)	39.7	37.1	**
Ratio of postgraduates or more (%)	3.7	1.9	***
C. Impact on employment	Increase/neutral	Decrease	
Ratio of university or more (%)	39.1	33.1	***
Ratio of postgraduates or more (%)	2.4	2.1	

(Note) *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

Table 6 Ratios of firms serving global market by the attitude to AI-related technologies

	Positive	Negative	
A. Use of big data	25.2	17.4	***
B. Impact of AI and robotics on business	28.6	15.7	***
C. Impact of AI and robotics on employment	21.4	18.6	**

(Notes) The ratios of serving global market are the sum of the number of firms responded as their market to be Asia or world. *** and ** indicate statistical significance at the 1% and 5% levels, respectively.

Table 7 Firm characteristics and the attitude to AI-related technologies

Variables	(1)		(2)		(3)	
	Use of Big Data		Impact of AI and robotics on business		Impact of AI and robotics on employment	
Ln employees	0.2195	***	0.0783	***	0.0290	
	(0.0356)		(0.0289)		(0.0369)	
University or more	0.0061	***	0.0009		0.0034	**
	(0.0014)		(0.0011)		(0.0014)	
Postgraduate	0.0163	***	0.0218	***	0.0031	
	(0.0053)		(0.0045)		(0.0056)	
Mean age	-0.0262	***	-0.0166	***	0.0078	
	(0.0081)		(0.0062)		(0.0076)	
Female ratio	0.4447	**	-0.0611		-0.4261	**
	-0.1976		(0.1528)		(0.1907)	
Non-standard ratio	-0.1162		0.0418		-0.6908	***
	-0.1724		(0.1292)		(0.1669)	
Union dummy	-0.1267	*	-0.1146	**	0.0415	
	-0.0753		(0.0581)		(0.0728)	
Market: prefecture	0.1799		0.2210		0.2939	*
	(0.1810)		(0.1394)		(0.1641)	
Market: Japan	0.3283	*	0.2479	*	0.1119	
	(0.1819)		(0.1397)		(0.1657)	
Market: Asia	0.2259		0.3544	**	0.1946	
	(0.2190)		(0.1669)		(0.2030)	
Market: world	0.6717	***	0.6601	***	0.2012	
	(0.2062)		(0.1588)		(0.1920)	
ICT	0.3299	**	0.0338		0.8717	***
	(0.1313)		(0.1133)		(0.1429)	
Wholesale	-0.2060	**	-0.3725	***	0.3790	***
	(0.0996)		(0.0779)		(0.0986)	
Retail	0.0915		-0.2296	**	0.6299	***
	(0.1288)		(0.1018)		(0.1272)	
Services	-0.1618		-0.3747	***	0.8788	***
	(0.1133)		(0.0928)		(0.1076)	
Other industries	-0.0027		-0.2862	**	0.3674	*
	(0.1715)		(0.1392)		(0.1756)	
Nobs.	1,621		2,643		1,466	
Pseudo R^2	0.090		0.046		0.072	

(Notes) Ordered-probit estimation results with standard errors in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Firms responded “don’t have any idea” are dropped from the estimations of (1) and (3). The reference categories are “city” for the spatial area of market and “manufacturing” for industry, respectively.