Determinants of ICT and smart farming technology adoption by agricultural corporations in Japan

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Abstract

This study identified the determining factors of ICT&SF technology adoption intensity by Japanese agricultural corporations. Primary data were collected from a Japan nationwide questionnaire survey on "Business Development and Innovation in Agricultural Corporation Management" in the year 2019, 195 agricultural corporations in Japan were analyzed through descriptive analysis and negative binomial model. The results showed that 186 corporations out of 195 in the sample had adopted at least one ICT&SF technology components until 2019, indicating an overall adoption rate of 95.4%. The majority (84.6%) of corporations are limited companies and stock companies, and 87.2% of the corporations are qualified to own farmlands. For the profile of corporations' representatives, nearly half of the representatives are graduated from university. The empirical result demonstrated that the corporation attributes of institutional forms, human capital, profit targets, main crops and self-evaluation significantly affect the ICT&SF technologies adoption intensity by agricultural corporations. From a perspective of corporative representatives' characteristics, the younger decision-makers are more likely to introduce the ICT&SF technologies; the representatives who graduated from a specialized school and a vocational college tend to adopt more ICT & SF technologies.

Key words: agricultural corporations; ICT; Smart Farming technologies; adoption intensity; determinants

Introduction

Many scholars discuss that acute labor shortage by shrinking and aging of farmers has become one of the critical constraints of agricultural development in Japan. According to the 2020 census by the Ministry of Agriculture, Forestry and Fisheries (MAFF), the labor force mainly engaged in agriculture has decreased from 1.76 million in 2015 to 1.36 million in 2020. Alarmingly, more than 70% of farmers are above the age of 65 in 2020, compared to 65% in 2015 (MAFF, 2020). In this circumstance, the Japanese government encouraged the development smart agriculture vigorously in order to get rid of the restriction of agricultural labor shortage, improve agricultural production efficiency, and revitalize the development of agriculture and rural areas (MAFF, 2021). Moreover, the widespread utilization of information and communication technology (ICT) in the field of agriculture has been demonstrated a crucial role in optimizing the market activities, promoting the succession of agricultural skills, as well as boosting the development of agricultural informatization in Japan.

On the other side, a structural change towards consolidation is ongoing in Japanese agriculture: despite the decline of farm households, large-scale farming, as well as agricultural corporations, are increasing in recent decades (Nanseki, 2021; EU-JAPAN CENTRE FOR INDUSTRIAL COOPERATION ECOS GmbH, 2021). The increased agricultural corporations have become the backbone of realizing large-scale production, heightening strategic management of agribusiness, as well as accelerating industrial clusters. The intensive adoption of ICT and smart farming (SF) technologies by corporations is anticipated to provide technical optimization of agricultural production systems and food value chains, thereby ultimately contributing positively to the development of agriculture. Ogata et al. (2019) analyzed ICT Cost-Effectiveness of agricultural corporations by factor analysis. The results indicate the followings: (1) the factors of production visualization and accounting visualization appear to be related to human resource development; (2) factor score comparisons by farm characteristics revealed three points: livestock farms evaluate ICT cost-effectiveness to be higher than farms producing other goods in terms of enhancing profitability factor; farms with higher sales place a greater value on the production and accounting visualization factors than those with lower sales; and more employees farms place a higher value on the production visualization factor than smaller farms. Nanseki (2019) and Nanseki et al. (2016) cover interdisciplinary results based for ICT& SF technology by focusing rice farming. Bucci et al. (2021) discussed the factors affecting ICT adoption in Italian agriculture. The results turn out the internet access, web page, production standard, age, and educational background are the factors affecting successful adoption of management information systems in farms are. However, from these studies, determinants of ICT and smart farming technology adoption by agricultural corporations in Japan are not clear.

Against this circumstance, the objective of this paper is to identify the determining factors influencing the adoption of ICT& SF technologies by Japanese agricultural corporations.

Section 2 outlines the empirical models, followed by a description of the data source and variables used in the econometric analysis. Section 3 discusses the empirical results and Section 4 contains final conclusions.

Methodology and data

Methodology

Previous studies used to analyze the adoption of one particular or several agricultural technologies by applying ordered probit models, multinomial logit regressions, and double-hurdle models (Knowler and Bradshaw, 2007; Zhang et al., 2020). In this study, we investigate the intensity of ICT&SF technologies adopted by an agricultural corporation. The dependent variable is therefore a count variable that takes a non-negative integer value from 0 to 21. An appropriate analytical strategy is to employ the count data models to estimate the effect of the potential influencing factors on the number of technologies adopted (Cameron and Trivedi, 1986; Rahelizatovo and Gillespie, 2004; Isgin et al., 2008). The usual way to deal with count integer-valued is to assume a compound Poisson regression where the number of ICT&SF technologies used, the probability density function of Y is as followed:

$$f(y_i|x_i) = P(Y_i = y_i) = \frac{e^{\lambda}\lambda_i^{y_i}}{y_i!}, y_i = 0, 1, 2, 3\ldots \quad (1)$$

where y_i is of the total number of ICT&SF technologies adopted by an agricultural corporation i and x_i are expected determinants of ICT&SF adoption. The expected mean parameter (λ) of this function is defined as: $\lambda_i = \exp(x_i'\beta)$, the β parameters can be estimated by using the maximum likelihood procedure.

The Poisson model assumes the mean and variance of dependent variable to be equal; that is, λ_i=mean$(y_i|x_i)$= variance $(y_i|x_i)$. However, in the case where the conditional variance is greater than the conditional mean, over-dispersion is the most likely situation (Ehiakpor et al., 2021). The negative binomial (of which the Poisson is a special case) could be right count data procedure to accommodate the over-dispersion issue by modeling the variance as a function of the mean. The variance of negative binomial model is as follow:

$$var(Y_i|x_i) = \lambda_i + \alpha\lambda_i^2 \quad (2)$$

where α is the dispersion parameter to be estimated. The negative binomial model will be the same as the Poisson regression if α equals to zero. And its corresponding log-likelihood is: log L $=\sum_i log[\Pr(y_i)]$. In this study, the test indicated the existence of overdispersion, which

led to the choice of the negative binomial model[1].

Data

Data collection

The data used in this study are obtained from the survey of "Business Development and Innovation in Agricultural Corporation Management" conducted by the Laboratory of Farm and Management from Kyushu University in 2019 (Nanseki, 2021). Information was gathered through a mail questionnaire sent to agricultural corporations nationwide in Japan. The names of agricultural corporations are collected from relevant publication, reports, as well as the website of Japan Agricultural Corporations Association (https://hojin.or.jp/). The questionnaires were sent to 2,885 corporations and 505 corporations gave valid answers as to make the effective response rate at 18% (Nanseki, 2021). The outline and basic survey results is shown in Nanseki (2021).

In the survey, respondents were asked questions surrounding the matters relating to (1) basic information and operating policy of the corporations, including measures such as corporate form, location, year of establishment, stage of development, annual sales/ profit margin, operating targets in next 5 years, and so on; (2) the innovative realization of the corporations within the past 3 years; (3) the current status of ICT&SF technologies adoption; (4) detailed business contents, management strategy and self-evaluations; (5) social contribution of and perceptions on the Free Trade Agreements (FTA); (6) profile of corporate representatives such as age and education, etc. The completed questionnaires were screened for missing observations: we disregarded the missing value in key variables, especially the observations without sufficient supporting information on respondents' technology choice. In total 195 valid observations generated the sample for further analysis.

Variable description

The dependent variable used in this study refers to the number of technologies adopted by an agricultural corporation. It is a count variable which can be considered to approximate the intensity of corporations' technology adoption. Specifically, we count the number of the combined technology categories involved in both ICT and SF technologies. ICT is defined by Food and Agriculture Organization of the United Nations (FAO) as "a broader term for Information Technology (IT), which refers to all communication technologies, including the internet, wireless networks, cell phones, computers, software, middleware, video-conferencing, social networking, and other media applications and services enabling users to access, retrieve,

[1] The variance of the dependent variable is approximately 15.8, which is approximately twice larger than the mean (6.5), implying that the count data encompasses overdispersion.

store, transmit, and manipulate information in a digital form.[2]" According to MAFF (2021), 'smart agriculture' or 'smart farming' refers to the utilization of cutting-edge technologies such as robot, AI (Artificial Intelligence), IoT(Internet of things) in agriculture or farming management. Recent studies distinguished SF technologies generally as following types: recording and mapping technologies, which collect precise data for subsequent site-specific application; tractor GPS and connected tools that use real time kinetics to appropriately apply variable rates of inputs and accurately guide tractors; apps and farm management and information systems which integrate and connect with mobile devices for easier monitoring and management; and autonomously operating machines (e.g. weeding and harvesting robots (Fountas,2017; Knierim, 2019). In this study, the ICT&SF technologies adopted by Japanese agricultural corporations are tentatively identified as two types. One refers to the smart farming technologies (SFTs) contained ICT; the other type indicated some of general ICTs applied in SF.

The definition and adoption rates of each ICT&SF technology components are shown in Table 1. Involved three aspects of monitoring and collection of data, automatization and robotization of operation, as well as business management, a total of 21 ICT&SF technology categories are described in our research. The most frequently adopted technology component was financial management systems such as bookkeeping and accounting, with an adoption rate of 83.6%. Advertisement for companies and products was relatively frequently used technology component, being adopted by 126 corporations, at a percentage of 64.1%. Third frequently adopted technology component related to sales information management, with an adoption rate of 61.0%. By contrast, technologies with relatively low adoption rates included 'Automatic measurement of production harvesting', 'Automation of crop cultivation machine work/robot', 'Measurement of crop growth using drones and artificial satellites and, with the adoption rates of 8.2%, 7.7%, and 5.1% and respectively. This trend indicated similar to the statistics description in Nanseki (2021).

The independent variables in our count data modelling covered wide range of corporation attributes and representatives' characteristics, which were classified into following 17 groups: (1) corporate form; (2) eligible of farmland owner; (3) location of corporations; (4) age of corporations; (5) establishment background; (6)human capacity; (7) annual sales; (8) profit margin, (9) development stage of the corporations; (10) sales target for next 5 years; (11) profit target for next 5 years; (12) major crops; (13) self-evaluation on utilization of ICT&SF technology; (14) perceptions towards FTA participation of Japan; (15)age of representatives; (16) education background of representatives; (17) non-agricultural experience of

[2] http://aims.fao.org/information-and-communication-technologies-ict

representatives. The definition along with the unit and expected signs given in Table 2.

Result and discussion

Descriptive results

Distribution of ICT&SF technology adoption

Fig. 1 presents the distribution of the ICT&SF technology adoption intensity by Japanese agricultural corporations. The investigation gave evidence that 186 corporations out of 195 in the sample had adopted at least one ICT&SF technology components until 2019, indicating an overall adoption rate of 95.4%. By contrast, 4.6% of sampled corporations had implemented none of those technologies. The majority (82.1%) of corporations adopted 10 or less ICT&SF technologies, only 17.9% of the samples adopted 11 or more technologies. Moreover, the observed Japanese agricultural corporations adopted nearly 6.5 technologies on average.

Summary of the descriptive statistics

Table 3 depicts the summary of the descriptive statistics of all variables. It is demonstrated that, the majority (84.6%) of corporations are limited company and stock company. About 87.2% of the corporations are judicially qualified to own farmlands. There are nearly 24.6% of the sampled corporations are located in Kyushu and Okinawa regions, 23.6% corporations are in Tohoku region, whereas only around 1.5% corporations are from Hokkaido. The average age of sampled corporations is approximately at 18.4 years. For the background of establishment of these corporations, about 48.2% of samples are solely owned corporation established by one farmer; 25.6% of samples are joint corporations founded by several farmers. Regarding the human capital of corporations, the mean of board members is 3.5, and the number of regular employees of sampled corporations is approximately 11 on average. Nearly half of the agri-companies have a profit margin between 1% and 10%, while 20.0% of the companies have a financial deficit. As the aspect of development stage, about 41.5% of agricultural corporations are in a 'growing stage', compared to 16.4% and 5.6% in the stages of 'mature' and 'recession'. Focusing on the operating target, the largest proportion of companies as approximately 29.7%, targeted their sales to grow 1.5 times in the next five years; a total of 84.1% of the respondents targeted the profit margin of their corporations to increase 1%~20%, compared to 11.8% of samples with over 20% profit target in the next five years. Among the categories of major crops, the corporations with major products as 'Paddy rice' account for the largest proportion (17.4%), followed by 'Fruiter' (12.8%); the 'Beans and coarse cereals' accounted the least, only for 1.0%. About 9% of the agricultural companies are identified as a farm type of 'multiple crops farming'. According to the profile of corporate representatives, more than a half of the corporate representatives (55.4%) have an education level of high school, and 35.4% of representatives have graduated from the colleges. Only 3.1% of corporate representatives have obtained a postgraduate degree.

Empirical results

We apply the negative binomial model to identify the potential factors determining the technology adoption by agricultural corporations. We test two nonnested forms of the negative binomial model denoted NB1 (which is, a negative binomial model with constant dispersion) and NB2 (which is, a negative binomial model with no constant dispersion), and then compare the NB1 and NB2 estimates using AIC (Akaike' s information criterion) and BIC (Bayesian information criterion).

Table 2 displays the results of the negative binomial regression models. In addition to estimated parameters, the marginal effects of each explanatory variable on explained variable are also presented. The fitness of NB1 is better than NB2 (AIC/BIC of NB1 is lower than those of NB2). The test of likelihood ratio chi-square test in NB1 rejected the null hypothesis of 'variance =mean' (Indelta). The result of NB1 reveals that the indicators of corporation forms, number of board members, profit targets, main crops, self-evaluation, age and education background of representatives could be the determinants of ICT&SF technologies adoption by agricultural corporations in Japan. In specific, the marginal effect of *CFORM_3* on ICT&SF technologies implementation is -2.184, with a significant level of 5%, indicating that the agricultural cooperative corporations tend to adopt less technologies when compared to a benchmark as limited company. Regarding the factor of human capital, variable of *BM* is positive statistically significant at a 10% level, indicating that number of board members play a positive role in decision of ICT&SF technologies adoption in Japanese agricultural corporations. This result is consistent with the finding of Abdulai and Huffman (2005), which demonstrated that human capital has a positive impact on the decision to acquire information and to adapt a technology. From a perspective of corporations' profit goal, the marginal effect of TPROF_7 is -6.060 with a significant level of 10%. It shows that the corporations with 'no target' in next 5 years' profit were likely to use approximately 6 fewer ICT&SF technologies than those who targeted to keep financial balance in next 5 years. As for the major crops operated by an agricultural corporation, the corporations operating 'flowers and foliage plants' as major crops were likely use less technologies (marginal effect=-3.265, $P< 0.05$), compared to a benchmark major crop of 'paddy rice'. The self-evaluation of corporations has a positive impact on technology implementation of agricultural corporations. Moreover, from the estimated results of corporate representatives' characteristics, increasing age of the corporate representatives had a negative impact on the adoption intensity of technologies among the corporations (marginal effect= -0.425, $P< 0.1$). which in line with the result of Simmons et al. (2005), the older decision-makers are less enthusiastic about the technology adoption. As for the education background, the variables of *EDU_2* and *EDU_3* are positive statistically significant at 5% and 10% level respectively, indicating the representatives who graduated from specialized schools and vocational colleges are more likely to adopt ICT&SF technologies. This

result differs from the finding of Carrer et al., (2017), which demonstrated the education level of university has a positive effect on the likelihood of technology adoption in farm management. One of the possible explanations might be the representatives who graduated from specialized schools and vocational college have more opportunities for receiving specific agricultural acknowledgement and training lessons of farming skills, therefore they are more willing to adopt ICT&SF technologies.

Conclusions

Based on a national questionnaire survey of "Business Development and Innovation in Agricultural Corporation Management" in Japan, this study identified the determining factors in the decision of Japanese agricultural corporations on adoption of ICT&SF technology components. Within this context, the negative binomial models are employed to examine some related corporation attributes and representatives' characteristics, which potentially affect the intensity of technology components adoption by agricultural corporations.

The investigation gave evidence that 186 corporations out of 195 in the sample had adopted at least one ICT&SF technology components until 2019, indicating an overall adoption rate of 95.4%.

Among the 21 ICT&SF technologies, The most frequently adopted technology component was financial management systems such as bookkeeping and accounting, with an adoption rate of 83.6%, whereas the technology of 'Measurement of crop growth using drones and artificial satellites with the adoption rates shown a lowest adoption rate of 5.1%.As for the attributes of sampled corporation, majority (84.6%) of corporations are limited companies and stock companies, and 87.2% of the corporations are qualified to own farmlands. 17.2% of the corporation are with the major product of 'paddy rice', only 1.0% accounted for 'beans and coarse cereals' corporations. It is noticeable that for the profile of corporations' representatives, nearly half of the representatives are graduated from university.

The result obtained from the empirical models support that the indicators of corporation forms, human capital, profit targets, main crops, self-evaluation, age and education background of representatives could be the determinants of ICT&SF technologies adoption by agricultural corporations in Japan. Specifically, as for the corporation forms, the agricultural cooperative corporations tend to adopt less technologies when compared to a benchmark as limited company. From the human capital side, adoption intensity is associated positively with the number of board members. Regarding the profit targets, the corporations with 'no target' in next 5 years' profit were likely to use fewer ICT&SF technologies than those who targeted to keep financial balance in next 5 years. Compare to the corporation mainly operating paddy rice, the corporations operating 'flowers and foliage plants' as main crops were likely to use less technologies. Besides, the self-valuation of corporations has a positive impact on technology

implementation of agricultural corporations. Finally, in terms of the corporate representatives' characteristics, the age of the corporate representatives had a negative impact on a technology adoption. In the consideration of the education background, the representatives who graduated from a specialized school and a vocational college are more likely to adopt intensive ICT&SF technologies than those with an education level of the high school.

Author contributions

All listed authors discussed the results and contributed to the final manuscript. Mi Jie conceived of the original idea, performed the empirical computations, and drafted the manuscript. Nanseki Teruaki devised the project, designed the questionnaire, conducted the data collection, provided the data source, suggested the conceptual organization and data interpretation of this study, supervised the findings of this work. Chomei Yosuke assisted to data collection and contributed to editing and revising the manuscript. Uenishi Yoshihiro suggested the conceptual organization of this study, aided in interpreting the results and edited the manuscript. Nguyen Thi Ly advised the research design and to data interpretation, edited the manuscript. All authors reviewed the results and approved the final version of the manuscript.

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List of Tables

Table 1. Definition and adoption rates of ICT&SF technologies

Technology categories	Type [a]	Freq.	Adoption rates (%)
Technologies of data monitoring and collection			
1-Measurement of growing environment information of crops and livestock (temperature, water temperature, soil moisture, amount of solar radiation, etc.)	ICTs applied in SF	57	29.231
2-Measurement of biological information of crops and livestock (growth status, livestock estrus, body temperature, etc.)	SFTs contained ICT	52	26.667
3-Collecting work information from each field (recorded with a personal computer, smartphone, camera, GPS, etc.)	ICTs applied in SF	78	40.000
4-Automatic measurement of production harvesting (combined with sensor, etc.)	SFTs contained ICT	16	8.205
5-Automatic measurement of product quality (livestock milk / meat quality, crop sugar content / acidity, etc.)	SFTs contained ICT	19	9.744
6-Browsing farming information on smartphones (weather information, crop growth status, farm work content, etc.)	ICTs applied in SF	86	44.103
7-Measurement of crop growth using drones and artificial satellites (leaf color, pests, etc.)	ICTs applied in SF	10	5.128
Technologies of robotization and autonomously operating machines			
8-Automatic detection / notification of abnormal information (temperature / humidity / soil moisture, livestock estrus / body temperature, etc.)	SFTs contained ICTs	26	13.333
9-Automation of agricultural land irrigation and water supply (paddy pipelines, open waterways, upland fields, etc.)	SFTs contained ICTs	36	18.462
10-Agricultural machinery with operation assists function (straight-ahead assist function, etc.)	SFTs contained ICTs	18	9.375
11-Automatic environmental controls of greenhouses and barns (temperature, humidity, soil moisture, CO2 concentration, etc.)	SFTs contained ICTs	40	20.513
12-Livestock feeding, manure cleaning, milking automation, robots	SFTs contained ICTs	19	9.744
13-Automation of crop cultivation machine work/robot (plowing, fertilization / control (including drone), harvesting, etc.)	SFTs contained ICTs	15	7.692
14-Automatic sorting of harvested products (weight / shape sorting, color sorting, sugar content sorting, etc.)	SFTs contained ICTs	44	22.564
Technologies of business management			
15-Management of production record information (including data analysis such as tabulation and graphing)	ICTs applied in SF	106	54.359
16-Providing production information to business	ICTs applied in SF	83	42.564

partners and consumers (product quality, production history, etc.)			
17-Sales information management (including customer management and internet sales)	ICTs applied in SF	119	61.026
18-Inventory management of materials such as pesticides and fertilizers (recorded with a personal computer, smartphone, etc.)		87	44.615
19-Financial management systems such as bookkeeping and accounting (settlement, management diagnosis, payroll, etc.)	ICTs applied in SF	163	83.590
20-Planning of business strategy and creation of business plan (simulation on PC, etc.)	ICTs applied in SF	76	38.974
21-Advertisement for companies and products (provided information on homepage, etc.)	ICTs applied in SF	126	64.615

Note: [a] the types of technology categories are tentative one. The ICTs and SFTs are broad concepts, and they intersect with each other. With the development of each technology categories, there are some possibilities that the types would be updated.

Table 2. Definition of the variables in estimation

Variables Name	Definition	Unit
TECH (dependent)	Number of ICT&SF technologies adopted (Values ranging from 0 to 21)	Number
1. Corporate form (+/-)		
CFORM_1	1 if the corporation is limited company; 0 otherwise	Dummies
CFORM_2	1 if the corporation is stock company; 0 otherwise	
CFORM_3	1 if the corporation is agricultural cooperative corporation; 0 otherwise	
CFORM_4	1 if the corporation form is others; 0 otherwise	
2. Eligible of farmland owner (+)		
FARML	1 if a corporation is judicially qualified to own farmland; 0 otherwise	Dummy
3. Location of corporations (+/-)		
R_HKD	1 if the corporation located in Hokkaido; 0 otherwise	Dummies
R_TH	1 if the corporation located in Tohoku; 0 otherwise	
R_KT	1 if the corporation located in Kanto; 0 otherwise	
R_HR	1 if the corporation located in Hokuriku; 0 otherwise	
R_KKTK	1 if the corporation located in Kinki Tokai; 0 otherwise	
R_CHSK	1 if the corporation located in Chugoku and Shikoku; 0 otherwise	
R_KSON	1 if the corporation located in Kyushu and Okinawa; 0 otherwise	
4. Age of corporations (+/-)		
AGE_C	2019- establishment year	Year
5. Establishment background (+/-)		
ESTAB_1	1 if a farmer established a solely owned corporation; 0 otherwise	Dummies
ESTAB_2	1 if a farmer established a joint corporation with other members; 0 otherwise	
ESTAB_3	1 if a Farmer has established corporations in collaboration with non-farmers and companies from other industries; 0 otherwise	
ESTAB_4	1 if a non-farmer entered agriculture as individuals and established a corporation; 0 otherwise	
ESTAB_5	1 if the company's main business is non-agriculture, but they have entered agriculture as a new business; 0 otherwise	
ESTAB_6	1 if a corporation parent/main company or group company has established a new corporation and entered agriculture; 0 otherwise	
ESTAB_7	1 if the establishment background of a corporation is others; 0 otherwise	
6. Human capital (+)		
BM	The total number of board members	Persons
RE	The total number of regular employees	
7. Annual sales (+)		
SALE	Categorical variable of corporations' annual sales: 1= less than 30 million Yen; 2= 30~50 million Yen; 3=50~100 million Yen; 4= 100~300 million Yen; 5= 300-500 million Yen; 6= 500~1000 million Yen; 7=1000~1500 million Yen; 8=1500~2000 million Yen; 9= more than 2000 million Yen	Category
8. Profit margin (+)		
PROF_1	1 if profit margin of a corporation is 0% (break-even); 0 otherwise	Dummies
PROF_2	1 if profit margin of a corporation is 1%~5%; 0 otherwise	
PROF_3	1 if profit margin of a corporation is 5%~10%; 0 otherwise	
PROF_4	1 if profit margin of a corporation is 10%~15%; 0 otherwise	

PROF_5	1 if profit margin of a corporation is 15%~20%; 0 otherwise	
PROF_6	1 if profit margin of a corporation is more than 20%; 0 otherwise	
PROF_7	1 if the deficit; 0 otherwise	
9. Development stage of the corporations (+/-)		
STAGE_1	1 if development stage is 'Starting'; 0 otherwise	
STAGE_2	1 if development stage is 'Growing'; 0 otherwise	
STAGE_3	1 if development stage is 'Mature'; 0 otherwise	
STAGE_4	1 if development stage is 'recession' ;0 otherwise	
STAGE_5	1 if development stage is second period of 'starting'; 0 otherwise	Dummies
STAGE_6	1 if development stage is second period of 'growing'; 0 otherwise	
STAGE_7	1 if development stage is second period of 'mature'; 0 otherwise	
STAGE_8	1 if development stage is second period 'recession'; 0 otherwise	
STAGE_9	1 if others	
10. Sales target for next 5 years (+)		
TSALE_1	1 if the target sales in next 5 years is 'maintain'; 0 otherwise	
TSALE_2	1 if the target sales in next 5 years is '1.2 times'; 0 otherwise	
TSALE_3	1 if the target sales in next 5 years is '1.5 times'; 0 otherwise	
TSALE_4	1 if the target sales in next 5 years is '1.8 times'; 0 otherwise	
TSALE_5	1 if the target sales in next 5 years is '2.0 times'; 0 otherwise	Dummies
TSALE_6	1 if the target sales in next 5 years is '2.0~3.0times'; 0 otherwise	
TSALE_7	1 if the target sales in next 5 years is 'over 3 times'; 0 otherwise	
TSALE_8	1 if the target sales in next 5 years is 'decrease'; 0 otherwise	
TSALE_9	1 if no target; 0 otherwise	
11. Profit target for next 5 years (+)		
TPROF_1	1 if the profit margin in next 5 years is '0%'; 0 otherwise	
TPROF_2	1 if the profit margin in next 5 years is '1%~5%'; 0 otherwise	
TPROF_3	1 if the profit margin in next 5 years is '5%~10%'; 0 otherwise	
TPROF_4	1 if the profit margin in next 5 years is '10%~15%';0 otherwise	Dummies
TPROF_5	1 if the profit margin in next 5 years is '15%~20%';0 otherwise	
TPROF_6	1 if the profit margin in next 5 years is 'over than 20%'; 0 otherwise	
TPROF_7	1 if 'no target' '; 0 otherwise	
12. Major product [b] (+/-)		
PROD_1	1 if the major product is 'Paddy rice'; 0 otherwise	
PROD _2	1 if the major product is 'Wheat'; 0 otherwise	
PROD _3	1 if the major product is 'Beans and coarse cereals'; 0 otherwise	
PROD _4	1 if the major product is 'Open ground vegetable';0 otherwise	
PROD _5	1 if the major product is 'House vegetable'; 0 otherwise	
PROD _6	1 if the major product is 'Flowers and foliage plants'; 0 otherwise	
PROD _7	1 if the major product p is 'Fruiter'; 0 otherwise	Dummies
PROD _8	1 if the major product is 'Mushroom'; 0 otherwise	
PROD _9	1 if the major product is 'Dairy'; 0 otherwise	
PROD _10	1 if the major product is 'Beef cattle'; 0 otherwise	
PROD _11	1 if the major product is 'Swine'; 0 otherwise	
PROD _12	1 if the major product is 'Poultry (meat/ eggs)'; 0 otherwise	
PROD _13	1 if the major product is 'Others'; 0 otherwise	
PROD _14	1 if the is 'multiple crops farming'; 0 otherwise	
13. Self-evaluation on utilization of ICT&SF technology (+)		
SELF_U	1=Weaker than others; 2=Slightly weaker than others; 3= Neither weaker nor stronger than others; 4 = Slightly stronger than others; 5=Stronger than others	Likert scale

14. Perceptions towards FTA participation of Japan (+)		
FTA	Respondents' perception towards the FTA participation of Japan 1=big crisis; 2=crisis; 3= neutral; 4=chance; 5=big chance	Likert scale
15. Age of representatives (+/-)		
AGE_R	Value ranging from 1~7: 1=10~20 years old; 2 = 20-30 years old; 3 = 30-40 years old; 4 = 40-50 years old; 5 = 50-60 years old; 6 = 60-70 years old; 7=over than 70 years old	Category
16. Education background of representatives (+)		
EDU_1	1 if the representative graduated high school; 0 otherwise	Dummies
EDU_2	1 if the representative graduated from vocational school; 0 otherwise	
EDU_3	1 if the representative graduated from an educational institution; 0 otherwise	
EDU_4	1 if the representative graduated from a junior college; 0 otherwise	
EDU_5	1 if the representative graduated from a university; 0 otherwise	
EDU_6	1 if the representative graduated from a graduate school; 0 otherwise	
EDU_7	1 if others	
17. Non-agricultural experience of representatives (+/-)		
NAGRI	Values range from 1 ~ 6: 1= None; 2=1~5 years; 3 = 5-10 years; 4 = 10-15 years; 5 = 15-20 years; 6 = 20-25 years 7= more than 21 years	Category

Source: Nanseki (2021)

Note: (1) [b] Major crop of an agricultural corporation is classified as the crop accounted for more than 60% of a corporation's annual sales; (2) Symbols in the parentheses denote the expected signs of each category of independent variables.

Table 3. Result of descriptive statistics

Variables Name	Means	Std. dev.	Min	Max	Variables Name	Means	Std. dev.	Min	Max
TECH(dependent)	6.544	3.976	0	21	**10. Sales target for next 5 years**				
1.Corporate form					*TSALE_1*	0.118	0.323	0	1
CFORM_1	0.395	0.490	0	1	*TSALE_2*	0.282	0.451	0	1
CFORM_2	0.451	0.499	0	1	*TSALE_3*	0.297	0.458	0	1
CFORM_3	0.138	0.346	0	1	*TSALE_4*	0.036	0.187	0	1
CFORM_4	0.015	0.123	0	1	*TSALE_5*	0.133	0.341	0	1
2. Eligible of farmland owner					*TSALE_6*	0.062	0.241	0	1
FARML	0.872	0.335	0	1	*TSALE_7*	0.051	0.221	0	1
3. Location of corporations					*TSALE_8*	0.005	0.072	0	1
R_HKD	0.015	0.123	0	1	*TSALE_9*	0.000	0.000	0	0
R_TH	0.236	0.426	0	1	**11. Profit target for next 5 years**				
R_KT	0.128	0.335	0	1	*TPROF_1*	0.036	0.187	0	1
R_HR	0.092	0.290	0	1	*TPROF_2*	0.205	0.405	0	1
R_KKTK	0.138	0.346	0	1	*TPROF_3*	0.333	0.473	0	1
R_CHSK	0.138	0.346	0	1	*TPROF_4*	0.149	0.357	0	1
R_KSON	0.246	0.432	0	1	*TPROF_5*	0.118	0.323	0	1
4. Age of corporations					*TPROF_6*	0.118	0.323	0	1
AGE_C	18.436	12.455	1	76	*TPROF_7*	0.021	0.142	0	1
5. Establishment background					**12. Major crops**				
ESTAB_1	0.482	0.501	0	1	*CROP_1*	0.174	0.380	0	1
ESTAB_2	0.256	0.438	0	1	*CROP_2*	0.000	0.000	0	0
ESTAB_3	0.041	0.199	0	1	*CROP_3*	0.010	0.101	0	1
ESTAB_4	0.056	0.231	0	1	*CROP_4*	0.092	0.290	0	1
ESTAB_5	0.046	0.210	0	1	*CROP_5*	0.113	0.317	0	1
ESTAB_6	0.056	0.231	0	1	*CROP_6*	0.036	0.187	0	1
ESTAB_7	0.067	0.250	0	1	*CROP_7*	0.128	0.335	0	1
6. Human capital					*CROP_8*	0.031	0.173	0	1
BM	3.544	2.392	1	20	*CROP_9*	0.021	0.142	0	1
RE	10.615	21.363	0	238	*CROP_10*	0.046	0.210	0	1
7. Annual sales					*CROP_11*	0.041	0.199	0	1
SALE	3.708	1.718	1	9	*CROP_12*	0.046	0.210	0	1
8. Profit margin					*CROP_13*	0.103	0.304	0	1
PROF_1	0.082	0.275	0	1	*CROP_14*	0.092	0.290	0	1
PROF_2	0.313	0.465	0	1	**13. Self-evaluation**				
PROF_3	0.185	0.389	0	1	*SELF_U*	2.610	0.980	1	5
PROF_4	0.097	0.297	0	1	**14. Perceptions towards FTA participation of Japan**				
PROF_5	0.067	0.250	0	1	*FTA*	2.882	1.006	1	5
PROF_6	0.026	0.158	0	1	**15. Age of representatives**				
PROF_7	0.200	0.401	0	1	*AGE_R*	5.082	1.181	2	7
9. Development stage of the corporations					**16. Education background of representatives**				
STAGE_1	0.067	0.250	0	1	*EDU_1*	0.554	0.498	0	1
STAGE_2	0.415	0.494	0	1	*EDU_2*	0.077	0.267	0	1
STAGE_3	0.164	0.371	0	1	*EDU_3*	0.138	0.346	0	1
STAGE_4	0.056	0.231	0	1	*EDU_4*	0.062	0.241	0	1
STAGE_5	0.159	0.367	0	1	*EDU_5*	0.354	0.479	0	1
STAGE_6	0.103	0.304	0	1	*EDU_6*	0.031	0.173	0	1
STAGE_7	0.026	0.158	0	1	*EDU_7*	0.026	0.158	0	1
STAGE_8	0.005	0.072	0	1	**17. Non-agricultural experience of representatives**				
STAGE_9	0.005	0.072	0	1	*NAGRI*	3.164	1.983	0	6

Note: N=195

Table 4. Result of Negative Binomial Regression Model

	NB2		NB1	
	Parameter	Marginal effect	Parameter	Marginal effect
1.Corporate form (Benchmark: *CFORM_1*)				
CFORM_2	0.002	0.015	-0.001	-0.004
CFORM_3	-0.327**	-2.141**	-0.334**	-2.184 **
CFORM_4	-0.233	-1.523	-0.249	-1.627
2. Eligible of farmland owner				
FARML	0.184	1.203	0.195	1.274
3. Location of corporations (Benchmark: *R_HKD*)				
R_TH	-0.303	-1.983	-0.292	-1.908
R_KT	-0.274	-1.795	-0.263	-1.721
R_HR	-0.207	-1.355	-0.203	-1.328
R_KKTK	0.084	0.547	0.108	0.704
R_CHSK	-0.284	-1.856	-0.276	-1.808
R_KSON	-0.282	-1.845	-0.276	-1.808
4. Age of corporations				
AGE_C	0.003	0.018	0.003	0.017
5. Establishment background (Benchmark: *ESTAB_1*)				
ESTAB_2	0.017	0.112	0.025	0.161
ESTAB_3	0.181	1.182	0.182	1.193
ESTAB_4	0.193	1.260	0.2	1.309
ESTAB_5	0.152	0.997	0.162	1.063
ESTAB_6	0.137	0.895	0.146	0.953
ESTAB_7	-0.210	-1.375	-0.189	-1.239
6. Human capital				
BM	0.042**	0.273**	0.041*	0.270*
RE	0.000	-0.003	0.000	-0.003
7. Annual sales				
SALE	-0.024	-0.155	-0.024	-0.157
8. Profit margin (Benchmark: *PROF_1*)				
PROF_2	0.085	0.559	0.084	0.547
PROF_3	0.002	0.015	-0.010	-0.065
PROF_4	0.118	0.773	0.129	0.842
PROF_5	-0.022	-0.146	-0.011	-0.075
PROF_6	-0.179	-1.174	-0.168	-1.098
PROF_7	0.130	0.852	0.130	0.849
9. Development stage of the corporations (Benchmark: *STAGE _1*)				
STAGE_2	0.185	1.211	0.202	1.321
STAGE_3	0.241	1.574	0.261	1.710
STAGE_4	0.013	0.082	0.042	0.274
STAGE_5	0.227	1.486	0.252	1.648
STAGE_6	0.313	2.050	0.331	2.166
STAGE_7	0.223	1.461	0.215	1.407
STAGE_8	-29.206	-191.118	-14.031	-91.810
STAGE_9	-0.110	-0.721	-0.065	-0.427
10. Sales target for next 5 years (Benchmark: *TSALE _1*)				
TSALE_2	0.140	0.919	0.149	0.978
TSALE_3	0.037	0.242	0.046	0.298
TSALE_4	0.283	1.853	0.313	2.045
TSALE_5	-0.052	-0.342	-0.043	-0.281

TSALE_6	0.023	0.147	0.042	0.275
TSALE_7	0.116	0.757	0.126	0.823
TSALE_8	-0.167	-1.092	-0.101	-0.659
TSALE_9	(omitted)	0.000	(omitted)	0.000
11. Profit target for next 5 years (Benchmark: *TPROF_1*)				
TPROF_2	0.077	0.505	0.095	0.622
TPROF_3	0.199	1.301	0.203	1.328
TPROF_4	0.086	0.560	0.092	0.603
TPROF_5	0.279	1.828	0.279	1.828
TPROF_6	0.182	1.193	0.192	1.257
TPROF_7	-0.930**	-6.089**	-0.926*	-6.060*
12. Major crops (Benchmark: *CROP_1*)				
CROP_2	(omitted)	0.000	(omitted)	0.000
CROP_3	-0.006	-0.042	-0.034	-0.220
CROP_4	-0.023	-0.150	-0.012	-0.080
CROP_5	-0.059	-0.388	-0.065	-0.428
CROP_6	-0.473**	-3.098**	-0.499**	-3.265**
CROP_7	-0.164	-1.074	-0.155	-1.011
CROP_8	-0.299	-1.954	-0.279	-1.825
CROP_9	-0.150	-0.982	-0.140	-0.916
CROP_10	-0.253	-1.655	-0.240	-1.572
CROP_11	0.227	1.488	0.257	1.681
CROP_12	0.207	1.354	0.218	1.425
CROP_13	-0.201	-1.315	-0.214	-1.397
CROP_14	-0.069	-0.452	-0.058	-0.380
13. Self-evaluation				
SELF_U	0.326***	2.135***	0.328***	2.146***
14. Perceptions towards FTA participation of Japan				
FTA	0.042	0.277	0.045	0.293
15. Age of representatives				
AGE_R	-0.066**	-0.432**	-0.065*	-0.425*
16. Education background of representatives				
EDU_2	0.293**	1.920**	0.298**	1.950**
EDU_3	0.247**	1.619**	0.246*	1.613*
EDU_4	-0.196	-1.285	-0.214	-1.401
EDU_5	-0.020	-0.129	-0.029	-0.188
EDU_6	-0.250	-1.633	-0.240	-1.567
EDU_7	0.067	0.440	0.075	0.492
17. Non-agricultural experience of representatives				
NAGRI	0.005	0.031	0.006	0.038
_cons	0.713		0.641	
N	195		195	

Pseudo-R2	0.1457	0.1479
Log Likelihood	-460.277	-459.061
lnalpha	-18.048	
lndelta		-1.716**
AIC	1062.553	1060.122
BIC	1294.936	1292.505

Note: (1) ***, **, * denote statistically significance level of 1%, 5%, 10% respectively; (2) The parameter here can be interpreted as semi-elasticity; marginal effect is calculated at the mean of the dependent variable (Paxton et al., 2011)

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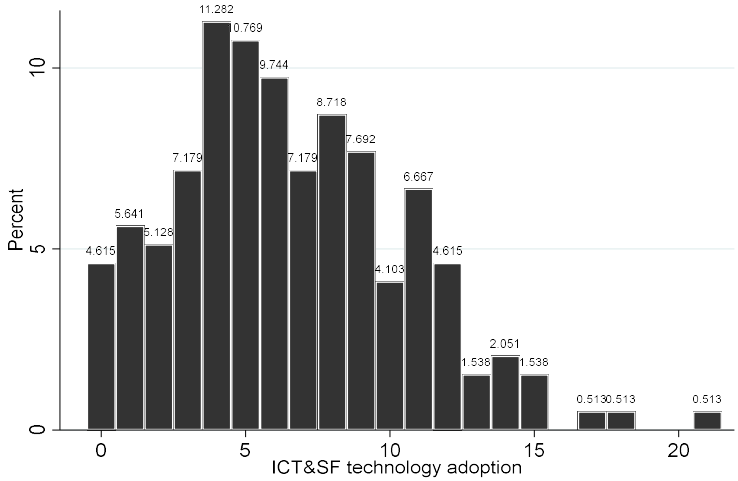

Fig. 1. Distribution of technology adoption intensity of agricultural corporations

(Source: Questionnaire Survey on Business Development and Innovation in Agricultural Corporation Management in 2019)