social sciences

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Determinants of Decision-Makers' Attitudes toward Industry 4.0 Adaptation

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Received: 12 April 2019; Accepted: 28 April 2019; Published: 6 May 2019

Abstract: Industry 4.0 could drastically change not only firms' production sites, organization, operation, and marketing but also industrial competition rules. This study aims at investigating a real situation of firms' willingness to adapt to Industry 4.0 and revealing the determinants of decision-makers' attitudes toward Industry 4.0 adaptation, as well as factors that inhibit adaptation. The study, using statistical analysis and questionnaire survey data for quantitative observation, finds that firms required the following: fostering the positive attitude of decision-makers toward adapting Industry 4.0, enhancing decision-makers' acquisition of appropriate knowledge, and complementing lack of resources such as skilled workers. Moreover, firms applying to adapt to Industry 4.0 as well as outsiders must participate in promoting it among manufacturing firms.

Keywords: Industry 4.0; decision-maker; organizational inertia; information systems

1. Introduction

Industry 4.0, recognized as the Fourth Industrial Revolution, is heralding drastic changes in manufacturing production sites and is required to survive the next-generation of industrial manufacturing. Industry 4.0 is realized by a combination of various state-of-the-art digital technologies utilized in construction, procurement, product design and development, manufacturing, logistics, and marketing and services and is aimed at increasing efficiency of production and cost reduction. Increasing the level of digitalization, automation, and virtualization in production sites leads to achieving smart manufacturing (Schumacher et al. 2016), namely, a smart factory.

In a smart factory, the internet connects facilities and automation. Production status and inventory information are accessed in real-time for detecting and removing unnecessary processes or bottlenecks, remote monitoring, and predictive maintenance. Firms are also linked with suppliers and customers to improve the efficiency of the supply chain (Roblek et al. 2016). Artificial intelligence (AI) with sensors detects degrading performance automatically and restores machine and equipment abnormality. AI also analyzes collected marketing data for demand prediction and inventory management. These technologies are combined with high-tech machines: multifunctional robots, 3-D printers, and automated conveyor systems.

Not only mass-production but also partial small-scale production has gone digital. The complex and delicate works of craftsmen, which were once difficult to automate to improve the speed of product development and trial production, has benefitted from automated manufacturing by the robots, shortening production lead time to match to the need of customers.

However, many firms, especially small- and medium-sized, have delayed in adapting to Industry 4.0. Currently, information on how these technologies can be applied to firms' established manufacturing sites and the benefit to firms is inadequate for making an informed decision to adapt to Industry 4.0. Many firms hesitate to adapt to Industry 4.0 because they do not adequately understand how their operation and organization could be changed.

Few studies investigate firms' awareness about adapting to Industry 4.0. Although national policies in developed countries push progress forward by spreading Industry 4.0 among firms, they do not consider the reality of firms' awareness about it. This study investigates a real situation of firms' willingness to adapt to Industry 4.0 and the factors that inhibit firms from doing so. We use the data collected from Japanese manufacturers using a questionnaire survey for statistical analysis to reveal the determinants of decision-makers' attitudes toward Industry 4.0 adaptation. We indicate firms' internal and environmental approaches and suggest firm- and national-level policies to promote Industry 4.0 adaptation.

2. Literature Review

2.1. The Present State of Industry 4.0 and Firms' Adaptation

The German government first proposed its national high-technology strategy using the term Industry 4.0 (Kagermann et al. 2013; Lasi et al. 2014; Strange and Zucchella 2017; Ślusarczyk 2018). Similar concepts have also been developed such as the Nouvelle France Industrielle in France, Produktion 2030 in Sweden, Fabbrica Intelligente in Italy, Made Different in Belgium-Holland, Industria Conectada 4.0 in Spain, Produktion der Zukunft in Austria (Ślusarczyk 2018), the Industry Connected 4.0 in the USA, the Internet Plus or Made in China 2025, and Manufacturing Innovation 3.0 in South Korea (Kiel et al. 2017). In Japan, the government proposed the concept of connected industries and challenged many manufacturing firms to adapt to Industry 4.0 and establish smart factories. Similar ideas of this concept occur under names such as Integrated Industry, Smart Industry, Smart Manufacturing, Intelligent Manufacturing, and 4.0 Industrial Revolution, among others (Ślusarczyk 2018). As mentioned above, various terminology relating to the concept of Industry 4.0 emerged and the meaning and objective of each term overlap.

Industry 4.0 combines the strengths of optimized industrial manufacturing with cutting-edge internet technologies (Schmidt et al. 2015). It is characterized by smart manufacturing and smart factories. Various technological concepts compose the base of Industry 4.0, such as the Internet of Things (IoT), cyber-physical system (CPS), AI, embedded actuators and sensors, network of microcomputers, machines linked to the value chain, and Internet of Services (IoS) (Schmidt et al. 2015; Roblek et al. 2016; Shamim et al. 2016; Kiel et al. 2017; Strange and Zucchella 2017). These technologies enable products to be integrated into intertwined digital and physical processes (Schmidt et al. 2015). Combining these technologies, full automation, and digitalization processes minimize human interventions (Shamim et al. 2016) and enhance efficiency and cost-cutting in the manufacturing process and services (Roblek et al. 2016).

Cloud-computing and real-time evaluation of bid data collected from manufacturing to the market is used for digital simulations. This increases efficiency and flexibility in production for optimizing costs and quality to enable a higher availability of production facilities, mass customization, and production time improvement (Schmidt et al. 2015; Strange and Zucchella 2017; Kiel et al. 2017). Products integrated with cloud computing in the field can provide data that enable predictive maintenance and give information about optimization possibilities in production (Schmidt et al. 2015).

Connected and interactive manufacturing sites and workflows by Industry 4.0 lead to a highly efficient and comprehensive supply chain (Roblek et al. 2016; Shamim et al. 2016) to decrease lead times and time-to-market (Kiel et al. 2017). Additionally, firms will be able to monitor emerging trends and opportunities without the need to make substantial resource commitments (Strange and Zucchella 2017). Connected and interactive smart factories and market information enable predictive analytics, highly differentiated products, and a well-coordinated combination of products and services (Schmidt et al. 2015; Shamim et al. 2016).

Although adapting to Industry 4.0 creates a competitive advantage for firms (Kiel et al. 2017) and has made big impacts in many industries in competition and corporate strategies, adaptation by firms is still in the early stages (Schmidt et al. 2015; Roblek et al. 2016; Strange and Zucchella 2017).

While many firms have already gained the benefits of Industry 4.0 adaptation, most firms in industries hesitate to adapt to it or have still not grasped its importance for future competition.

One reason most firms hesitate to adapt to Industry 4.0 is that they fear the drastic change that state-of-the-art technologies will introduce into their operations and organization. Industry 4.0 could change not only supply chains, business models, and business processes, but also organizations (Kiel et al. 2017). Additionally, because Industry 4.0 has not developed adequately, a conclusive evaluation of profitability by firms remains unclear (Kiel et al. 2017). There is a manufacturer's dilemma as to whether they can commit to Industry 4.0, considering the investment required and the unperceived benefits (Sanders et al. 2016).

2.2. Adapting to Industry 4.0

As industrial competition intensifies due to the development of information technology (IT), firms need to apply state-of-the-art IT and computers to their production site and business models. Adapting to state-of-the-art IT for firms and its benefits and effects on competition are the main issues in information management literature. Here, we review the literature discussing the benefits and difficulties firms face in adopting new information systems. We, then, associate the conceptual results to the situation of Industry 4.0 and derive the hypothesis for this study.

Advanced IT and its systems provide firms with an opportunity to improve their efficiency and effectiveness in business activities and gain competitive advantage (Porter and Millar 1985) by gaining access to more sophisticated solutions for enterprise resource planning or customer relationship management (Chibelushi and Costello 2009; Lewis and Cockrill 2002). Moreover, IT has the potential to reduce coordination costs and the transaction risks associated with explicit coordination and cooperation both within the firm and in relationships with customers and other firms (Clemons and Row 1992). IT alone has not produced sustainable performance advantages in firms, but that some firms have gained advantages by using IT to leverage intangible costs shows that IT adaptation is not an alternative but an imperative for future business success (Daniel and Grimshaw 2002; Tan et al. 2010).

While IT adaptation presents many merits and benefits to firms, it requires firms to transform established business models. It takes expenses, time, and effort to change operational and organizational routines, which (accompanied by introducing IT experts) changes management rules within and outside the organization. Additionally, the initial investment in introducing information systems and its administrative cost could be a reason firms fail to adapt. Most firms are sensitive to the costs needed to adapt to new information systems, so they are reluctant to invest without a clear identification of potential benefits (Lewis and Cockrill 2002; Simmons et al. 2008). Moreover, to achieve high-performance using information systems, IT must be integrated with existing human and business resources such as flexible culture, strategic planning, IT integration, and supplier relationships, to focus on strengthening the organization's cultural, structural, and systems infrastructures (Thomas and Dent-Micallef 1997). Therefore, IT investments are accompanied by various drastic organizational changes, where significant organizational dynamic capabilities and appropriate strategic processes influence firm performance (Sambamurthy et al. 2003; Sher and Lee 2004).

In new information system adaptation, a decision-maker's attitude is a critical factor (Bharati and Chaudhury 2006; Higon 2012, Mills and Pawson 2012). Decision-makers with entrepreneurial alertness and strategic foresight can anticipate the opportunities and business value in information technologies (Sambamurthy et al. 2003). A lack of positive perceptions of value in information system adoption, weighted toward negative perceptions regarding costs and a lack of resources, results in a failure to see the strategic fit of these new information system applications with their business model (Jones et al. 2014). Firms with positive attitudes toward IT adopted and utilized IT more effectively (Ndubisi and Jantan 2003; MacGregor and Vrazalic 2005; Lockett and Brown 2006). If firms find more value in new information systems than established manual systems, where IT is easy to use and understand and is consistent with the needs of the adopting business, then there is a greater chance that a favorable attitude toward the innovation will be formed (Thong 1999).

However, decision-makers cannot always make rational estimations about benefits and risks to make an informed judgment on whether to introduce a new information system into the respective organization. There are psychological reasons for their negative attitudes toward adapting Industry 4.0. In adapting organizational structures to changing environments, inertial pressures on organizations militate against adapting to change (Hannan and Freeman 1984). Such organizational inertia could interrupt an organization's flexible change, leading to failure in adapting to a new environment and reducing the chances of survival. Organizational inertia is in two distinct patterns characterizing firm behavior: failure to change resource investment patterns and failure to change organizational processes that use those resources (Gilbert 2005). Established organizational routines lead to internal inertial pressures of the status quo toward outside threats and firms obedient to the routine. Such organizational inflexibility could be a crucial factor contributing to failure, delay, and hesitation in ascertaining Industry 4.0 adaptation benefits.

3. Hypothesis Building

As shown in the literature, the attitudes of firms' principal decision-makers affect the Industry 4.0 adaptation. In this study, we aim to reveal the factors affecting firms' attitudes toward Industry 4.0 adaptation through statistical analysis using data from a questionnaire survey. Next, by referencing prior studies, hypotheses were built to test various factors which could have an effect in improving or impairing attitudes toward Industry 4.0 adaptation.

Firm size and performance could be considered as one of the factors. Adapting to Industry 4.0 requires firms to introduce new information systems and infrastructures such as machines, facilities, and applied devices. Thus, a huge initial cost will be incurred. Additionally, adapting to Industry 4.0 does not necessarily ensure that firms can gain enough benefits from it. Firms with adequate financial resources could have the potential to invest in Industry 4.0 and satisfy the initial investment and administrative cost despite the risk of failure.

Firms' size is a significant factor in determining information system adoption (Bengtsson et al. 2007), and there is a significant discriminator between adopters and nonadopters of information systems among the firms (Thong 1999). It can be said that the larger the firm size, the higher the likelihood of firms adapting to Industry 4.0.

Hypothesis 1. *The bigger the firm's business size, the more likely the firm has already adapted to or plans to adapt to Industry 4.0.*

Likewise, decision-makers are willing to take risks and become aggressively invested in the future when the firm's performance is well. The same situation also applies to the investment Industry 4.0. Therefore, similar to Hypothesis 1, the following is also assumed:

Hypothesis 2. *The more the firm performs well, the more likely the firm has already adapted to or plans to adapt to Industry 4.0.*

Adapting to Industry 4.0 could lead to drastic changes in organizational operations and relationships with other firms and customers. Additionally, there are adaptation costs and risks of failure. Decision-makers' innovativeness and information system knowledge are positively associated with the decision to adopt new information systems (Thong 1999). If decision-makers are self-aware of their affinity to innovation and are willing to take the risk of introducing new information systems, it will be relatively easy to adapt to Industry 4.0.

Hypothesis 3. *The more the firm is characterized by an innovative culture, the more likely the firm has already adapted to or plans to adapt to Industry 4.0.*

The lack of a skilled workforce is a critical factor that affects Industry 4.0 adaptation (Shamim et al. 2016). Introducing a new information system to the firms means there will be more demand for skilled workers capable of planning, monitoring, and supervising manufacturing processes and facilities (Stock and Seliger 2016). Therefore, if firms' decision-makers recognize that they lack such experts, they delay or abandon Industry 4.0 adaptation.

Hypothesis 4. *The more the firm thinks it has adequate experts, the more likely the firm has already adapted to or plans to adapt to Industry 4.0.*

Many executives and managers cannot keep up with Industry 4.0 and related technology developments and, thus, are unable to understand it. This is even more often the case in non-IT-related industries even though the range of knowledge decision-makers possess vary among firms. Firms with decision-makers and employees who are knowledgeable about Industry 4.0 and related technologies are likely to adopt it. Thus, employees' knowledge about information systems is the most significant discriminator between adopters and nonadopters of information systems (Thong 1999). Decision-makers with the appropriate knowledge can appreciate the benefits of adapting Industry 4.0. This means that firms with more knowledge can smoothly adapt to Industry 4.0.

Hypothesis 5. *The more knowledge the firm has, the more likely the firm has already adapted to or plans to adapt to Industry 4.0.*

Additionally, given that decision-makers' innovativeness or a lack of experts could affect firms' adaptation to Industry 4.0, it is expected that if the principal decision-makers of the firms possess more related knowledge, the effect of these factors on Industry 4.0 adaptation could be stronger.

Hypothesis 6. *The effect of Hypothesis 3 will be strong if decision-makers' knowledge is high.*

Hypothesis 7. *The effect of Hypothesis 4 will be strong if decision-makers' knowledge is high.*

4. Materials and Methods

The data used in this study are obtained from a survey carried out by the government of Seto City in Aichi prefecture, Japan. This city is planning to promote adaptation to Industry 4.0 via firms located within it and offers services that solve human resource shortage by developing the information industry. Based on this plan, this survey aims to reveal the determinants of firms' attitudes toward adaptation to Industry 4.0. This study, using the dataset, tests the above hypotheses and specifies the determinants of decision-makers' attitudes. It suggests methods that lead to positive attitudes in promoting Industry 4.0 understanding and adaptation.

This survey is based on questionnaires distributed mainly to manufacturers in Japan. The period of questionnaire distribution and collection is from August 2017 to May 2018; answers were obtained via post. Questionnaires were distributed to 10,000 firms, 3000 in Aichi Prefecture, 3000 in Gifu, Mie, and Shizuoka Prefecture, 3000 in Tokyo and Kanagawa Prefecture, and 1000 firms in Osaka. Overall, 1062 questionnaires were distributed (response rate was 10.62). The respondents were owners and managers of firms.

The questionnaire includes both multiple-choice and description-type questions, and questions scaled by a five-point Likert scale. The questionnaire asked about firms' current conditions and characteristics, investments, and adaptation plans regarding Industry 4.0, and the needs of experts skilled in Industry 4.0 operations, among others. There are 29 items on the questionnaire. Table 1 shows the list of variables used in this study, including the minimum, maximum, average, and standard deviation. Table 2 shows the correlation matrix of each variable used in the analysis.

Table 1. The list of variables used in the statistical analysis.

Variables (Use)	Questions and Corresponding Answers	Min.	Max.	Avg.	S.D.
Firm has already adapted Industry 4.0 (Dependent variable)	Q: Does your company work on something for Industry 4.0? A: Yes, it does.	0	1	0.07	0.25
Firm plans to adapt Industry 4.0 (Dependent variable)	Q: Same question as above. A: No, but it plans to in the near future.	0	1	0.19	0.39
Firm has no plans to adapt Industry 4.0 (Dependent variable)	Q: Same question as above. A: No, it has no plans to work on it.	0	1	0.81	0.39
Firm size (Variable to test Hypothesis 1)	Sales (million)	1	28,403,118	65,871.16	1,119,368.86
Performance (Variable to test Hypothesis 2)	Q: How well is your firm's current business performance? A: Five-point Likert scale (1. Very bad ~ 5. Very well)	1	5	2.96	0.9
Innovative culture (Variable to test Hypothesis 3)	Q: Your company has an innovative culture. A: Five-point Likert scale (1. Strongly disagree ~ 5. Strongly agree)	1	5	3.5	1.06
Lack of experts (Variable to test Hypothesis 4)	Q: Does your company lack employees knowledgeable in IT areas such as AI? A: Five-point Likert scale (1. We have too many ~ 5. We are too lacking) They are coded as dummy variables as 4 and 5 = 1, 1, 2, and 3 = 0.	0	5	4.47	0.81
Knowledge (Variable to test Hypothesis 5, 6, and 7 as interaction term)	Q: "Do you know the following? 1. Industry 4.0. 2. AI, 3. IoT, 4. ICT (multiple-choice) A principal component variable made by factor analysis is used.	−1.3	1.5	0	1

Source: Data analysis.

Table 2. Correlation matrix of variables.

		1	2	3	4	5	6	7	8
1	Firm has already adapted to Industry 4.0	1	−0.102 ***	−0.551 ***	0.194 ***	0.096 ***	0.195 ***	−0.100 **	0.154 ***
2	Firm plans to adapt to Industry 4.0	−0.102 ***	1	−0.775 ***	−0.021	0.019	0.144 ***	0.068	0.174 ***
3	Firm has no plans to adapt to Industry 4.0	−0.551 ***	−0.775 ***	1	−0.104 **	−0.077 **	−0.245 ***	0.007	−0.244 ***
4	Firm size	0.194 ***	−0.021	−0.104 **	1	−0.049	0.064 *	−0.033	0.074 *
5	Performance	0.096 ***	0.019	−0.077 **	−0.049	1	0.203 ***	−0.070 *	0.038
6	Innovative culture	0.195 ***	0.144 ***	−0.245 ***	0.064 *	0.203 ***	1	−0.102 **	0.125 ***
7	Lack of experts	−0.100 **	0.068	0.007	−0.033	−0.070 *	−0.102 **	1	0.155 ***
8	Knowledge	0.154 ***	0.174 ***	−0.244 ***	0.07 *	0.038	0.125 ***	0.155 ***	1

Note: Two-sided test and *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Source: Data analysis.

In the regression analysis, dummy variables from the question: "Does your company work on something for Industry 4.0?" are used as dependent variables. Thus, this study employs a binomial logistic regression analysis. Hence, using dummy variables of answers as dependent variables ("Yes it does," "No, but it plans to in the near future," and "No, it has no plans to work on it"), the study was broadly classified into three analyses. Some analysis models were tested with three classified dependent variables respectively to find the effects of each independent variable.

Thus, to measure a firm owner's knowledge about Industry 4.0 and related technologies, we employed the item of multiple-choice questions: "Do you know the following? 1. Industry 4.0. 2. AI, 3. IoT, 4. ICT. One factor is extracted from these four dummy variables using factor analysis with varimax rotation. A principal component variable made by this analysis is used as a proxy variable of "Knowledge."

Table 3 shows a distribution of answers about "Adaptation to Industry 4.0". The firms which had already adapted to Industry 4.0 account for 5.9% and the firms which plan to adapt to Industry 4.0 is 11.0% of the whole sample. It shows that less than 20% of the firms' have positive attitudes to adaptation to Industry 4.0. However, 71.2% of firms have no adaptation plans; most firms hesitate or refuse to adapt to Industry 4.0. They do not consider adapting to Industry 4.0 because few firms precisely understand and estimate how Industry 4.0 can change a firm's production, operation, and organization.

Table 3. The distribution of answers in "Adaptation to Industry 4.0".

Adaptation to Industry 4.0	N	%
Firm has already adapted to Industry 4.0	63	5.9
Firm plans to adapt to Industry 4.0	117	11
Firm has no plans to adapt to Industry 4.0	756	71.2
No answer	126	11.9
Total	1062	100

Source: Questionnaire survey.

5. Analysis Results

Table 4 shows the result of the regression analysis. Initially, in all the models, the statistical effects of the variable, "Firm size", is not shown in all models. Therefore, hypothesis 1 is rejected. This result shows that there are no relationships between firms adapting to Industry 4.0 and firm size. Thus, it is difficult to objectively determine that larger firms tend to adapt to Industry 4.0 and small- and medium-sized firms have less capacity to adapt to Industry 4.0.

However, the "Performance" effect on "Firm has adapted to Industry 4.0" was significant and positive. This shows that Hypothesis 2 is supported. Regardless of the firm's size, the decision-makers who feel their firm performs well have positive attitudes toward Industry 4.0 adaptation. Additionally, this variable has a significantly negative effect on "Firm plans to adapt to Industry 4.0." It means that if decision-makers recognize their firm's financial and sales conditions are not desirable, no matter how they intend to adapt to Industry 4.0 they can no longer resolve to adapt. Meanwhile, this variable has no statistical effect on "Firm has no plans to adapt to Industry 4.0." If firms cannot precisely understand and estimate how they can benefit from adapting to Industry 4.0 in the future and how Industry 4.0 can impact on their performance and organization, they are unlikely to possess the willingness to adapt.

"Innovative culture" strongly affects all corresponding models. Concerning "Firm has adapted to Industry 4.0" and "Firm plans to adapt to Industry 4.0", the "Innovative culture" variable has positive effects on them. Thus, Hypothesis 3 is supported. If the decision-makers are aware that their firms possess an innovative culture, such firms tolerate investment risks in introducing new information systems to change their organization and operations. Such tolerance lowers the adaptation barrier to Industry 4.0. Additionally, this variable has a negative effect on "Firm has no plans to adapt to Industry 4.0"; the converse of Hypothesis 3 is also supported. A conservative culture inhibits firms' adaptation to Industry 4.0.

Table 4. The results of the binomial logistic regression.

	Firm Has Already Adapted Industry 4.0			Firm Plans to Adapt Industry 4.0			Firm Has No Plans to Adapt Industry 4.0		
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
	β	β	β	β	β	β	β	β	β
Firm size	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Performance	0.385 ** (0.223)	0.379 * (0.224)	0.394 * (0.223)	−0.279 * (0.148)	−0.278 ** (0.149)	−0.267 * (0.149)	0.080 (0.132)	0.083 (0.132)	0.070 (0.133)
Innovative culture	0.615 ** (0.239)	0.498 * (0.281)	0.580 ** (0.238)	0.315 ** (0.134)	0.328 * (0.169)	0.306 ** (0.135)	−0.437 *** (0.124)	−0.398 *** (0.152)	−0.423 (0.125)
Lack of experts	−0.628 *** (0.213)	−0.650 *** (0.215)	−0.818 *** (0.282)	0.270 (0.192)	0.272 (0.193)	0.111 (0.207)	0.094 (0.150)	0.100 (0.151)	0.252 (0.169)
Knowledge	0.478 ** (0.221)	−0.323 (1.133)	−0.576 (0.983)	0.485*** (0.155)	0.554 (0.595)	−1.622 * (0.960)	−0.565 *** (0.137)	−0.329 (0.555)	0.996 (0.739)
Innovative culture × Knowledge		0.193 (0.269)			−0.018 (0.151)			−0.061 (0.140)	
Lack of experts × Knowledge			0.267 (0.247)			0.468 *** (0.212)		(0.140)	−0.359 (0.168)
Constant	−3.619 *** (1.403)	−3.037 ** (1.591)	−2.796 ** (1.573)	−3.230 *** (1.115)	−3.289 *** (1.217)	−2.576 ** (1.162)	2.222 ** (0.906)	2.031 ** (1.003)	1.557 (0.960)
N Nagelkerke R^2	1062 0.226	1062 0.228	1062 0.232	1062 0.088	1062 0.088	1062 0.106	1062 0.138	1062 0.139	1062 0.153

Note: Standard errors are in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Source: Data analysis.

"Lack of experts" has a strong and negative effect on "Firm has adapted to Industry 4.0" in all corresponding models, and, thus, supports Hypothesis 4. If there are experts and skilled workers with knowledge and skills on Industry 4.0 and related technologies in the firms, then appreciating the necessity of adapting to Industry 4.0 by principal decision-makers could induce progress. Additionally, it could deploy experts to operate and manage new information systems after the adaptation. Therefore, firms with adequate experts smoothly adapt to Industry 4.0. However, in all the models where the dependent variable is "Firm has no plans to adapt to Industry 4.0", the statistical effect of "Lack of experts" is not apparent. This result shows that the converse of Hypothesis 4 is not supported. It means that the factor which discourages the willingness to adapt to Industry 4.0 is not the lack of expert resources but, rather, the decision-maker's attitude and knowledge concerning Industry 4.0 adaptation.

The statistical effects of "Knowledge" are shown in all the models except models 2, 3, 5, 8, and 9 which test the interaction terms. There is a positive effect on "Firm has adapted to Industry 4.0" and "Firm plans to adapt to Industry 4.0" in model 1 and 4, but there is a negative effect on "Firm has no plans to adapt to Industry 4.0" in model 7. Therefore, Hypothesis 6 and the converse of it is supported. The firm with knowledge about Industry 4.0 and related technologies can estimate how this system will change its production, operation, and organization, and bring benefits to the firm. Such firms have already adapted to Industry 4.0 or have positive attitudes toward adapting to Industry 4.0. However, firms lacking corresponding knowledge have negative attitudes toward adapting to Industry 4.0. This result shows that the firm which does not acquire knowledge and understand Industry 4.0 would delay in adapting.

Next, the effect of the interaction terms of each of the two variables on "Knowledge" is observed. The interaction term of "Innovative culture" and "Knowledge" has no statistical effect on dependent variables in the corresponding models of 2, 5, and 8. Therefore, Hypothesis 6 is rejected. This result shows that the positive attitude toward adapting to Industry 4.0 which the innovative firm possesses dependents more on a decision-maker's policy about investment and resource-allocation than their IT knowledge.

The interaction terms of "Lack of experts" and "Knowledge" have strong and positive effects on dependent variables in model 6 and 9. Meanwhile, only the "Lack of experts" variable has no statistical effect on "Firm plans to adapt to Industry 4.0", where its interaction effect on "Knowledge" is apparent. It means, out of the firms with knowledge about Industry 4.0, there are firms with positive attitudes to adapt to Industry 4.0 but hesitate because they do not possess adequate experts required. Therefore, the lack of experts is a critical factor for firms in adapting to Industry 4.0. Likewise, while only the "Lack of experts" variable has no statistical effect on "Firm has no plans to adapt to Industry 4.0", the interaction of "Lack of experts" and "Knowledge" have strong and negative effects. It shows that firms with knowledge about Industry 4.0 and related technologies do not choose to adapt to Industry 4.0 if they lack the human resources required to adapt to Industry 4.0. Firms possessing appropriate knowledge about Industry 4.0 can deeply estimate their resource capacity to adapt to Industry 4.0. If such firms recognize that they lack experts, they may become cautious about adapting to Industry 4.0. These results show that Hypothesis 7 is rejected and its converse is supported.

6. Additional Analysis for a Detailed Qualitative Observation

Given the above, to reveal more details concerning each firm's policy and thinking on the determinants of adaptation to Industry 4.0, we now examine the distribution of the respondent choices by each of the three samples: firm has already adapted to Industry 4.0, firm plans to adapt to Industry 4.0, and firm has no plans to adapt to Industry 4.0. Table 5 shows the distribution of the choices in six questions, two of which are corresponding to each of the three groups firms.

Table 5. The distribution of respondent choices in six questions under three groups of firms.

Achievement by adapting to Industry 4.0	N	%	Problem to solve in managing Industry 4.0	N	%
Sales increase	11	17.5	Lack of experts	38	60.3
Profit increase	9	14.3	Lack of funds	7	11.1
Cost cutting	33	52.4	Plant locations	2	3.2
Productivity increase	48	76.2	Collaborations with other firms	6	9.5
Quality increase	33	52.4	Difficulty of work digitization	18	28.6
Development speed increase	14	22.2	Others	6	9.5
New business development	3	4.8			
Good customer relations	18	28.6			
Get new customers	7	11.1			
Others	2	3.2			
Total	63		Total	63	
Expectation of adapting to Industry 4.0	**N**	**%**	**Cooperative partner in adapting to Industry 4.0**	**N**	**%**
Sales increase	30	25.6	No partner (self-owned)	29	24.8
Profit increase	45	38.5	System service company	73	62.4
Cost cutting	70	59.8	Facility maintenance company	49	41.9
Productivity increase	89	76.1	Industry 4.0 promotion consultant group	10	8.5
Quality increase	56	47.9	Customers	27	23.1
Development speed increase	23	19.7	Others	6	5.1
New business development	17	14.5	No idea	2	1.7
Good customer relations	26	22.2			
Get new customers	18	15.4			
Others	2	1.7			
Total	117		Total	117	
The reason not to adapt to Industry 4.0	**N**	**%**	**Interest in Industry 4.0**	**N**	**%**
Lack of experts	223	29.5	Very interested	62	8.2
Lack of funds	79	10.4	interested	165	21.8
Plant locations	16	2.1	Not very interested	259	34.3
Collaborations with other firms	25	3.3	Not interested	99	13.1
Difficulty of work digitization	198	26.2	No idea	149	19.7
No idea	135	17.9	No answer	22	2.9
No benefits in adapting to Industry 4.0	342	45.2			
Others	79	10.4			
Total	756		Total	756	

Source: Questionnaire survey.

For the group described by "firm has already adapted to Industry 4.0", the multiple-choice question (multiple answers possible), "what kind of results does your firm achieve by adapting to Industry 4.0 in your production sites?", is examined. This result is in Table 5 under "Achievement by adapting Industry 4.0." It shows that firms benefit from productivity improvement by adapting to Industry 4.0 in areas such as "Quality increase" and "Productivity increase." Several firms also benefit from the secondary effects of adapting to Industry 4.0 in areas such as "Development speed increase," "Good customer relations," and "Sales increase."

Additionally, for the same group of firms, the multiple-choice question (multiple answers possible), "what is the problem to be solved for your firm in adapting to Industry 4.0", was examined. This result is presented under "Problem to solve in managing Industry 4.0" in Table 5. From this table, "Lack of experts" is the most notable problem for firms. Moreover, firms constantly need human resources possessing highly specialized knowledge and skills for operating and maintaining new and advanced information systems and equipment. "Difficulty of work digitization" is also a major problem for many firms. Many firms doubt how established production sites and operations could be made efficient by applying current level technologies of industry 4.0. Some firms indicated "Lack of funds" and "Collaborations with other firms" as the problems to be solved. After adapting to Industry 4.0, some firms either lack funds to maintain the operations or lose sight of the necessity to collaborate with customers or suppliers in information systems.

Next, for the group described by "firm plans to adapt to Industry 4.0", two questions are examined. Initially, the multiple-choice question (multiple answers possible), "Why does your firm need to adapt to Industry 4.0 in your production sites?", is asked and its result is presented in Table 5 under "Expectation of adapting to Industry 4.0." As shown by "Quality increase," "Production increase," and "Cost cutting," many firms would like to achieve high quality and productivity by adapting to Industry 4.0. Firms with positive attitudes toward Industry 4.0 adaptation expect the achievements that those who have already adapted to Industry 4.0 enjoy. However, many firms also expect other secondary effects such as "Sales increase," "Good customer relations," and "Development speed increase."

Another question for this group under "firm plans to adapt to Industry 4.0" is: "who becomes your important cooperative partner in adapting to Industry 4.0?" This is also a multiple-choice question (multiple answers possible). As shown in Table 5, "System service company," "Facility maintenance company," "No partner (self-owned)," "Customers," and "Industry 4.0 promotion consultant group" are frequently in this order. This result expresses that most of the firms in non-related IT industries are conscious of a shortage of teaching and training skills for IT experts in their organization. This is also supported by the result where firms may focus less on developing IT experts by in-firm training.

Moreover, for the group under "firm has no plans to adapt to Industry 4.0", two questions are examined. The first question, "Why is your firm not adapted to Industry 4.0?", is answered as a multiple choice question (multiple answers possible) and its distribution result is shown in Table 5. The most frequent answer is "No benefits in adapting to Industry 4.0." Currently, firms which have adapted to Industry 4.0 are in the minority. Thus, information about how their profitability increases and how their operation and organization changes are scarce and the merit of adapting to Industry 4.0 is not well known by other firms. Due to such information scarcity, most firm decision-makers have difficulty in understanding Industry 4.0, what to expect about its benefits, and how the firm's operation and organization will be changed by adapting it. The "No idea" answer is comparatively frequent and reflects decision-makers in such a situation.

The second most common answer is "Lack of experts." It can be assumed that there are many firms which cannot decide an Industry 4.0 adaptation due to the lack of skilled workers who possess knowledge about Industry 4.0 and related technologies and skills of managing and operating new information systems. Additionally, many firms also forecast that they would experience "Difficulty of work digitization" in adapting to Industry 4.0. In the situation where the beneficial potential of Industry 4.0 is unknown, many firms cannot judge the degree to which their operation can apply to Industry 4.0 in consideration of their own established production style and products. "Are you

interested in Industry 4.0?" was presented to the same group, and its result is shown in Table 5. Out of the firms which do not plan to adapt to Industry 4.0, the firms who answered "very interested" or "interested" comprised 30% of the group, while the firms who answered "not very interested" or "not interested" comprised 47.4%, about half the group. There is a possibility that such firms consider Industry 4.0 as none of their business. The firms not interested in Industry 4.0 possibly do not collect information about Industry 4.0 and, thus, will not understand the benefits this technology brings to the firm. However, the firms who answered "No idea" comprise 19.7% of the group. From these results, it is conceivable that firms which do not plan to adapt to Industry 4.0 lack knowledge and information about Industry 4.0. It is important to enhance the knowledge level of firm decision-makers concerning Industry 4.0 to promote adaptation among the firms.

The description under "Others" presents the question: "Why is your firm not adapted to Industry 4.0?" The comments by the firms are presented in Table 6. Many firms under "firm has no plans to adapt to Industry 4.0" think that it is difficult to let their established production be digitized and adapt to Industry 4.0. Many decision-makers anticipate that build-to-order production systems, small-scale with multi-item productions, and manual operation of a skilled craftsman cannot be digitized and do not fit in Industry 4.0.

Table 6. Comments of decision-makers who have negative attitudes toward Industry 4.0 adaptation.

The Reason not to Adapt to Industry 4.0 ("Others" Description)	N
There is a difficulty in adapting to Industry 4.0 in our production site (Build-to-order production system, small-scale with multi-item production, and manual operations by skilled workers does not fit in a digitized operation)	57
I do not think or understand that adapting to Industry 4.0 have merit or benefit for our firm	12
I still cannot concretely imagine or understand Industry 4.0 and how our firm would change by adapting to it.	8
Our firm's operation system has been established and cannot be changed; We have no intention to change our current operation.	7
Since workers in the production line are aging, the attitude toward adapting to Industry 4.0 is negative.	6
I do not understand enough about Industry 4.0 and its effects on our firm.	5
Since employee's knowledge and skills are lacking, it is practically difficult to adapt to Industry 4.0.	5
Due to the shortage of funds and human resources, it is practically difficult to adapt to Industry 4.0.	4
Our firm has other problems to be solved before adapting to Industry 4.0.	3
Our firm's policy about information system adaptation follows the parent company.	2
Our firm does not need to adapt to Industry 4.0 at the moment.	2
A variety of considerable products in development would be lost by adapting to Industry 4.0 in the production line.	1
We will adapt to Industry 4.0 after it is completely established.	1
It is difficult for our firm to adapt to Industry 4.0 at a moment.	1
Our firm needs more experts to manipulate advanced information system.	1

Source: Questionnaire survey.

Other frequent comments, "I do not think or understand that adapting to Industry 4.0 have merit or benefit for our firm" and "I still cannot concretely imagine or understand Industry 4.0 and how our firm would change by adapting to it", are resonate with decision-makers. Society's recognition of Industry 4.0 has still not progressed, and many firms do not foresee Industry 4.0's value in the future.

Additionally, as shown in the comments of Table 6, the shortage of experts and funds are critical factors for some firms in adapting to Industry 4.0. Lack of required resources in adaptation to Industry 4.0 diminish decision-makers' positive attitudes toward it. As shown in some comments such as "our firm's operation system has been established and cannot be changed; we have no intention to change

our current operation" and "it is difficult for our firm to adapt to Industry 4.0 at the moment", there are some firms which fear drastic change in their established production line, operation, and organization. Many decision-makers of the firms are likely to feel the inertial pressures to keep the status quo of operation and organization and refuse change.

7. Discussion

7.1. Inhibition Factors for Firms in Adapting to Industry 4.0

Firms which have already adapted to Industry 4.0 in their manufacturing agree that it brings a variety of benefits such as quality improvement, productivity improvement, and cost-cutting, among others. While there are Industry 4.0 adaptation success stories, most firms hesitate to adapt to Industry 4.0 for various reasons.

In light of the regression analysis results and the additional investigation about items answered by firms unwilling to adapt to Industry 4.0, two factors inhibiting firms from adapting to Industry 4.0 could be observed. One is the lack of resources for adapting to Industry 4.0: knowledge, experts, and funds. Another is the decision-maker's psychological factor which leads to their hesitation to adapt to Industry 4.0: bias and inertia toward organizational change.

The former inhibiting factor (the lack of resources required in adapting Industry 4.0) could be excluded by compensating firms with corresponding resources outsourced or developed from inside the organization. If firms suffer from a shortage of experts, they must outsource experts or educate employees via in-firm training. If the owners or managers do not possess enough knowledge of and have a poor understanding of Industry 4.0, they can make exertions to acquire knowledge by collecting information and receiving education and training. Concerning the shortage of funds for investment in introducing new information systems, firms can raise funds by borrowing from banks or distributing budgets from their other planning expense.

The latter inhibiting factor, however, is comparatively difficult to overcome and presumably takes time to be excluded because it is rooted in a decision-maker's psychology and thinking. Some examples of decision-maker bias about adapting Industry 4.0 are obvious in their comments in Table 6; they think their production does not fit in Industry 4.0. However, technologies related to Industry 4.0 cover various production systems including build-to-order production system, small-scale with multi-item production, and even a craftsman's production. Additionally, they do not understand the benefits of Industry 4.0 and are not willing to adapt to Industry 4.0. Without collecting information and acquiring knowledge about Industry 4.0, they have a bias which could lead to underestimating the benefits therein; they tend to maintain the status quo and stick to established operations, avoiding change. Such psychological dispositions toward adapting to new information systems lead to organizational inertia and inhibit firms' positive attitudes toward adapting to Industry 4.0.

Past experiences could contribute to the preconception against change and inhibit decision-makers from making rational decisions. While firms' core capabilities provide a competitive advantage, they are not easy to change because they reflect accumulated behaviors and beliefs based on early corporate successes, firm institution, values, and culture (Leonard-Barton 1992). In the comments in Table 6, some firms note that their operation system has been established and cannot be changed; thus, they have no intention to change their current operations. Hence, in responding to environmental changes, firms tend to maintain the status quo by not renewing or replacing existing core capabilities. This may hinder a firm's innovative activities. When decision-makers decide on resource allocation, they sometimes overestimate their established way of thinking and policy, and their viewpoints and concepts, accordingly, become narrow to specific solutions for problem solving. Decision-makers typically have specific blind spots, and it leads to a variety of specific judgmental mistakes (Zajac and Bazerman 1991). Firms tend to hesitate to invest in the acquisition of resources which likely violate the firm's established operations, identity, traditions, and cultural norms and values. The existing power of top management and key decision-makers affect the resource-allocation of the firm (Oliver 1997). Their bias and

narrowing views encourage their organization to stick to their established operations and avoid introducing new information systems. Such a condition lead to organizational inertia.

7.2. Internal and Environmental Approaches to Diffusing Industrial 4.0 among the Firms

These two factors, which are due to resource shortage and decision-maker bias and inertia, could be excluded by combining two types of approaches: internal organizational approach and environmental approach.

There are several internal approaches for changing a decision-maker's thinking and compensating for the shortage of resources to promote Industry 4.0 adaption. First, increasing decision-makers' knowledge about Industry 4.0 and how it could change and improve the effectiveness of firms' operations could enhance Industry 4.0 adaptation. As shown in our analysis, firms with an innovative culture and adequate knowledge about Industry 4.0 and related technologies have positive attitudes in toward Industry 4.0. Many decision-makers cannot concretely imagine and understand Industry 4.0 and how their firm would change and benefit from adapting Industry 4.0. These knowledge deficiencies, in turn, raise the barrier to information system adoption (Attewell 1992). Thus, to solve it, acquiring appropriate knowledge about Industry 4.0 could overcome bias and organizational inertia. This can lead to favorable attitudes, change of thought and policy, and increasing motivation toward investing in Industry 4.0 adaptation. Furthermore, knowledge about Industry 4.0 and related technologies could enhance a firm's innovative culture because decision-makers with the appropriate knowledge could estimate possibilities of applying various information systems and balancing between benefits and costs.

Concerning internal approaches for acquiring appropriate knowledge, decision-makers have to possess positive attitudes by collecting information from firms in the same industry, information system developers, vendors, consultants, customers, and suppliers who have adapted to Industry 4.0. Even if their benefits might not be easily quantifiable, firms must have a relationship with vendors and consultants to leverage their expertise and recognize the rationale for investing in information technologies (Sambamurthy et al. 2003).

Merely complementing a decision-maker's knowledge is not enough for firms to adapt to Industry 4.0. From the regression analysis results of the interaction terms, dissolving human resource shortage by acquiring a skilled workforce to operate information systems is a critical factor for adapting Industry 4.0 (Shamim et al. 2016). Given the comments by decision-makers in Table 6, the shortage of employee's knowledge and skills lead to practical difficulties in introducing and operating advanced information systems. Moreover, especially in the small- and medium-sized firms, aging employees can affect the introduction of new information systems (Shamim et al. 2016) since the attitude of such employees toward IT knowledge and skills is negative, as Table 6 indicates. An in-firm training system is one of the effective means to transfer knowledge to workers and improve their attitudes to foster the values of adaptation and operational change (Bruque and Moyano 2007). While changing employees' thinking about new information systems, firms can aggressively employ experts to improve organizational attitudes toward Industry 4.0 and its adaptation for future benefits.

The third effective internal approach to enhance Industry 4.0 adaptation is compensating for funds required in introducing new information systems, as revealed in decision-makers' comments. Not only the shortage of human resource but also the shortage of funds is a critical reason firms hesitate to invest in Industry 4.0 adaptation. Given that firms are required to receive a return on any potential investment in the short term while minimizing associated risks, financial resource availability appears to be particularly critical (Jones et al. 2014). As the regression analysis shows, Industry 4.0 adaptation is not related to a firm's size; it is related to firm performance recognition by decision-makers. This result shows that increasing firm sales and performance is one of the critical factors for improving a decision-maker's motivation to invest in introducing new information systems.

7.3. Environmental Approaches to Diffusing Industrial 4.0 among Firms

Merely employing internal approaches to solving firms' resource shortage and changing the awareness of decision-makers is not enough. To effectively improve Industry 4.0 adaptation and the corresponding understanding and knowledge of it, outsiders (such as governments and local governments, developers and vendors of information systems and equipment, IT consultants, and customers and suppliers) must approach firms in various ways.

One of the concrete external approaches by outsiders is the development of decision-makers' understanding and knowledge of Industry 4.0 and its benefits for firms. Many decision-makers have negative attitudes toward adapting to new information systems they have never used because of bias and a narrow viewpoint. Thus, they cannot objectively evaluate how such technologies change their organization and operation, and the degree to which they will benefit from the adaptation. Most firms are not maximizing the potential of information systems for organizational transformation (Loebbecke and Schäfer 2001; Lewis and Cockrill 2002). Therefore, decision-makers need to be coached and mentored in developing information system while developing knowledge and skills (Simmons et al. 2008).

Governments and local governments are outsiders whose policies and programs could hugely influence firms' strategic policies and thinking on information system adaptation (Simmons et al. 2008; Jones et al. 2014). Education for the decision-makers of firms held by public institutions could help managers understand Industry 4.0 and eventually promote its adaptation. If the government is unable to develop decision-makers' positive strategic responses by themselves, government-sponsored advisers or consultants will need to investigate the attitudes required by decision-makers for Industry 4.0 adaptation, particularly within the framework of business sustainability (Jones et al. 2014).

Cooperating with other firms such as customers, suppliers, developers and vendors of information systems and system consultants to adapt to Industry 4.0 is also effective for firms to acquire appropriate knowledge and understanding. In particular, customers' disposition on information system adaptation can influence respective firms' perception of value and decision in adaptation (Beckinsale et al. 2011; Fillis and Wagner 2005; Jones et al. 2014). As shown in Table 6, many firms would follow their parent company or customers in introducing new information systems because they do not want to lose established fiduciary relationships and connections with them. New information systems introduced to firms need to be compatible with customer and parent company expectations for fast product and information exchange. Customers, suppliers, and parent companies could have a critical influence on decision-makers' attitudes toward Industry 4.0 adaptation; thus, comprehensive cooperation among them in introducing new information systems can be realized.

If firms have no partner for consultation for introducing new information systems, they should request assistance from system developers, vendors, and consultants. Before adaptation, firms can arrange for managers or workers who are to lead the change to have "technological stays" in advanced firms or public institutions (Bruque and Moyano 2007). Additionally, for promoting Industry 4.0, governments or local governments must help firms to find partners to assist in Industry 4.0 adaptation.

Moreover, the shortage of human resources possessing knowledge and skills required for Industry 4.0 adaptation is a critical problem for most firms; the effects of in-firm education and training to develop experts knowledgeable in Industry 4.0 is limited because most firms have no experience in operating Industry 4.0 and related technologies and equipment. They lack the know-how to educate and train experts with such skills. Therefore, such firms should outsource experts from universities, colleges, professional schools, system developers and vendors, and employment mediation support service. It is also effective when governments and local governments support firms to find partners or experts to offer expertise; they could connect firms with appropriate institutions for expertise.

Finally, to compensate for firms' fund shortage regarding Industry 4.0 adaptation, financial support by governments or local governments can prove to be effective. Introducing various corresponding systems, purchasing equipment and devices, searching for partners, and employing experts are costly

for firms. It is a critical problem to hinder Industry 4.0 adaptation. Official financial support from governments could reduce the cost to firms and promote Industry 4.0 adaptation across the country.

8. Conclusions

Given the intense production and competition worldwide, firms should keep pace with rapid technological developments to increase productivity. The emergence of Industry 4.0 could drastically change not only a firm's production sites, organization, operation, and marketing but also competition rules in the industry. Soon, it could differentiate between Industry 4.0 adapters and non-adapters in competitive advantages and, even, change the leader of the industry.

Fostering decision-makers' positive attitudes, enhancing decision-makers' acquisition of appropriate knowledge, and complementing the lack of resources such as skilled workers are required for firms to adapt to Industry 4.0. Thus, to promote Industry 4.0 adaptation among the firms, both internal and environmental approaches are needed. Outsiders must also participate in promoting adaptation among the manufacturing firms along with firms that would apply to adapt to Industry 4.0.

This study demonstrates the determinants of the decision-maker's attitudes toward Industry 4.0 adaptation and the factors that inhibit firms' adaptation. Due to the inadequate knowledge and experience of decision-makers, there is a bias that leads to maintaining the status-quo of operations and hesitating to introduce new information systems. Thus, to exclude inhibiting factors and since the effects of in-firm self-supporting efforts are limited, not only is a change in decision-makers' attitudes required but, also, outsiders' commitment to firms.

It is empirically shown that the lack of knowledge of technological developments leads to decision-maker bias and inertia, and it delays their understanding of Industry 4.0. In the developing stages of technology, few firms have adapted to it, and most firms cannot appropriately estimate the benefits of it. Without collecting corresponding information and acquiring the required knowledge, they cannot adequately understand it. Overcoming bias and inertia is much more difficult and time-consuming than compensating for a shortage of resources.

This study has scope for future research. First, while the analysis results clearly reflect a part of decision-makers' attitudes and policies toward adapting to Industry 4.0, their attitudes and policies could change in the next few years. Industry 4.0 is still in the early stage of development and is undergoing rapid growth. The possibilities of usefulness and applicability to various types of manufacturing processes and products will widen in the future. As the technologies related to Industry 4.0 and the benefits of them for the firms come to be more notable and understood by firms, many firms may apply to adapt to Industry 4.0. Thus, to track this change in attitude toward Industry 4.0 and its adaptation, investigations must be conducted continuously and regularly with appropriate support measures, planning fitting for the situation, and timing that corresponds to firms' current attitudes and knowledge.

Secondly, more in-firm and outside support measures should be concretely designed, and the demands for estimating the benefits of the measures required for implementation should be investigated. Government support guidelines for firms and other outsiders to promote the diffusion of Industry 4.0 is one of the effective approaches to cope with its adaptation. Questionnaire surveys of decision-makers' attitudes need to continue in academia to offer information on the needs and demands of firms to support them in adapting to Industry 4.0.

Funding: This research received no external funding.

Acknowledgments: The author thanks for Motonary Yamada, Makoto Shimizu, Kazuaki Maeda, Heasun Ham for their advice and suggestions. The author also thanks for two anonymous reviewers and the editors for helpful comments on a previous version of this paper. Thanks are also due to the government of Seto City in Aichi prefecture to share a survey data.

Conflicts of Interest: The author declares no conflict of interest.

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