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**Research Report**

## Smart Policies for Smart Factories

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## Smart Policies for Smart Factories\*

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**“Smart factories have been found to enhance the productivity of the overall production process, proving to be an appropriate policy as a key strategy for domestic manufacturing innovation. However, to maintain its effectiveness even when the scale and recipients of policy support are expanded, there should be improvements in the policy details and action plans. Above all, making factories smart requires not only the adoption of relevant technologies, but also proper management practices and organizational operations necessary to utilize the new technologies. The government should place the policy priority on helping firms to align workers’ incentives with the technological change. It is also necessary to smartize the governance system of the overall manufacturing innovation strategy which include smart factories.”**

### I. Issues

In an effort to tackle the slowing growth in the wake of the global financial crisis, major countries are actively implementing industrial policies to revive the manufacturing sector. There has been a sweeping movement to vigorously apply recent technological changes—dubbed the Fourth Industrial Revolution—to production sites. Prime examples include Germany's Industrie 4.0, Korea's Manufacturing Industry Innovation 3.0, Japan's Revitalization Strategy and China's Made in China 2025. Based on digitization, all share the common goal of high value-added and enhancing the efficiency and flexibility of production.

The scale of the smart factory fostering policy, a key element of Korea's manufacturing innovation strategy, is gradually expanding. It is time to check the effectiveness of the policy.

\* Rewritten from Kim, Minho, Sunghoon Chung, and Changkeun Lee, *Smart Factory: Economic Impact and Policy Implications*, Research Monograph 2019-01, Korea Development Institute, 2019 (in Korean).

An actual realization of this paradigm is the smart factory. For Korea, the fostering of smart factories has become a crucial industrial policy. Indeed, from 2014, the government stepped up its efforts to promote smart factories and over the next five years, allocated 413.6 billion won for their provision. In 2019, a total of 1 trillion won was earmarked for relevant projects including those to supply, through which the government set the goal of building 30,000 smart factories by 2022.

However, there are concerns that the policy is similar to the SME IT Support Project which was implemented in the early 2000s, and also targeted 30,000 firms. Despite the concerted efforts made at the time to encourage SMEs to adopt the Enterprise Resource Planning (ERP) software, there were numerous cases in which the software was not being properly utilized.<sup>1)</sup> To ensure the effectiveness of the policy even when it is expanded, a good understanding of the economic effects of smart factories and the drivers are first needed.

This study conducts a detailed survey of approximately 1,000 manufacturing plants to measure their level of *smartness*—otherwise known as smartization—and analyzes how the changes in smartization affect the performance and employment of their factories. Additionally, factors that determine factory smartization are identified, and emphasis has been placed on the fact that factories do not automatically become smart through the adoption of technology. Finally, the conclusion presents measures to enhance the efficiency of government policies that are related to smart factories.

## II. Concept of a Smart Factory and Measuring the Level of Smartization

Smart factories, just as in their name, refer to factories that operate in a smart way. Then, what does it mean to be smart? From a technical point of view, smart factories are those that have undergone the “digitization and networking of all processes, products and resources.”<sup>2)</sup> According to this definition, a smart factory has the ability to share all of the information generated in the factory with its members (workers, machinery, parts, etc.) and apply it to the production process. And despite the common perception that factories are simple organizations wherein workers and machines only execute set tasks, smart factories endeavor to become organizations that have freethinking and freely deciding members.

Take Nobilia, a German kitchen furniture manufacturer, for example. The company’s factory automatically orders, processes and assembles the parts necessary for production through information technology (IT) and operational technology (OT). It also digitizes the information generated during the process and reflects them in the decision-making. For instance, the location of holes needed to assemble furniture is recorded and managed in the data warehouse (DW), and the information (motor power, vibration, etc.) generated during the drilling is input into the production management system (MES) and used to optimize the production process. In addition, every part is tagged with electronic tags (RFID) or barcodes, making it possible to

1) No comprehensive evaluations have been conducted on the project, making it difficult to measure the exact rate of software use, but there are survey results and case studies available on some beneficiaries (National Human Resources Development Institute, 2006).

2) This definition is from the presentation delivered by professor Detlef Zühlke—who created the concept of smart factory for the first time—in ‘Korea-Germany Smart Factory Forum’ held at Hannover Messe 2018 in April 2018. Refer to Kagermann *et al.* (2013) and Radziwon *et al.*(2014) for further details and various perspectives and definitions of smart factory.

This study provides policy implications by measuring the level of smartness at the factory-level, analyzing economic effects from enhanced smartization, and examining factors that can facilitate the smartization.

Smart factory is a factory in which workers and equipment exchange information and thus can make better decisions.

locate any part during production and to identify which part caused a defect even after delivery. This production method is a key component of Nobilia's success in becoming Europe's largest kitchen furniture company with just two factories.<sup>3)</sup>

With the help of state-of-the-art technology such as AI and IoT, smart factories are continually evolving to make better decisions by networking not only the workers but also equipment and parts. These technologies, however, are not essential to the realization of a smart factory. A factory could still be regarded as smart so long as the information, which could even be gathered manually is shared and utilized to optimize the production process. Toyota factories are smart in this sense—they have utilized a lean method called *Kanban* since the 1960s which minimizes waste by enabling workers to exchange necessary information.<sup>4)</sup> Of course, using technology to exchange digitized information can be faster and more accurate, but it should be noted that technology does not automatically make a factory smart, it is merely a tool that helps a factory become smarter.

In this context, although the term 'smart factory' is commonly used, there is no clear criteria by which we can tell whether a factory is smart we can only gauge how smart a factory is. Therefore, rather than just keeping a tally of how many smart factories there are and how many are needed in the future, more practical policies are needed to encourage voluntary smartization based on an understanding of the mechanisms through which factories become smarter.

Proper definitions for the levels of smartization must first be established and the actual level must be measured accordingly. To that end, this study defines the smartization level by the two most essential characteristics of all smart factories: (i) how tightly a factory's production activities are interconnected (system interconnection or SI) and (ii) how much data is collected, shared and utilized for business decision-making (data sharing and utilization or DSU).

Based on this definition, a survey was conducted to measure the actual level of smartization. Manufacturing factories in Korea are classified according to their size (no. of employees), industrial classification and whether or not they are recipients of government support to foster smart factories. About 1,000 factories were randomly selected from each group, and the heads/chief managers, who have an understanding of the overall factory system, were directly contacted for the survey. The questionnaire is designed to measure the level of the factory's smartization on a scale from 0-1,<sup>5)</sup> along with questions about the factory's recent adoption of IT and OT, management practices, level of automation, CEO's understanding of and interest in smart factories, presence of an ICT department, type of production process, the demand for each occupation, and various key performance indicators (KPIs) of the factory.

Recent technological progress is drawing much attention to smart factories, but adopting the technology is a way of helping factories become smarter, and not directly transforming them into a smart factory.

The level of smartization in a factory can be measured based on their levels of system interconnection and data sharing and utilization.

3) The case on Nobilia is based on PC Control (2014) and Lee and Kim (2014).

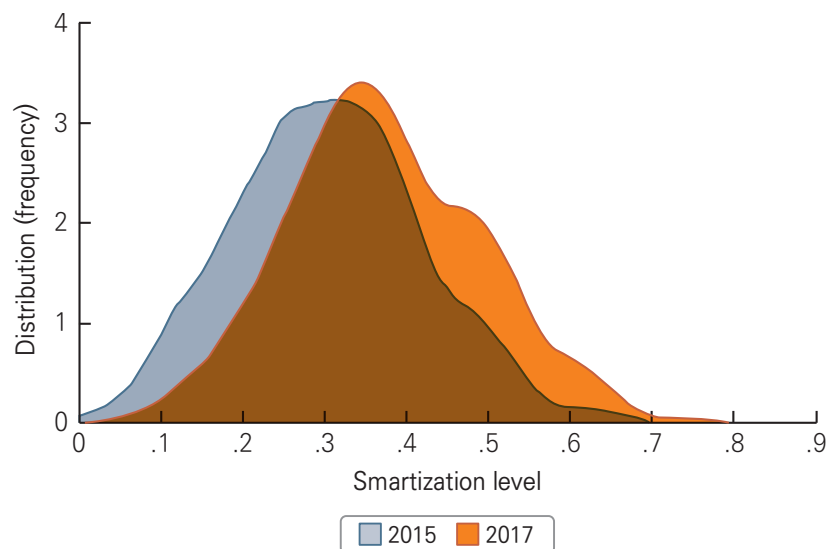
4) Toyota's lean method has been widely accepted around the world from the 1990s, becoming the standard of modern production methods in manufacturing. Professor Zühlke's concept of a smart factory is an extension of the philosophy of lean production to the entire factory (Zühlke, 2010).

5) Specifically, the smartization level of a factory is measured by the averaged values of system integration level (0-1) and data sharing and utilization level (0-1) of the factory. A factory with its smartization level at 0 means that it has no technology for system integration and no data sharing and utilization at all. A factory at level 1 means that all factory processes are connected to IT and OT through which digitized information is shared in real-time and used for optimization of factory operation. Also, in the event of any malfunction, the factory is capable of autonomous control and problem solving.

According to the analysis, the level of smartization in Korean firms is low overall with a huge gap between factories.

[Figure 1] shows the distribution of smartization levels in 2015 and 2017, measured from the survey. The results reveal that the level of smartization is low overall with a huge disparity between factories. The average level of smartization was 0.31 in 2015 and 0.37 in 2017,<sup>6)</sup> meaning that most factories were at the rudimentary stage in terms of system interconnection and data sharing and utilization. Although a meaningful improvement of 0.06 was observed over two years, only 60% of factories exhibited actual improvements and a few even showed a reduction, further widening the overall smartization gap. Ultimately, there was a 0.3 gap in 2017 between the bottom 10% (0.22) and the top 10% (to 0.52) of factories. This difference was also found to be significantly related to the difference in terms of factory size, and levels of automation, technology adoption, and management practices.

[Figure 1] Distribution of the Smartization Level of Sample Factories by Year



Source: Kim et al. (2019), [Figure 2-2], p.30.

### III. Effects of Smartization on Performance

Companies try to smartize their factories in order to increase operational efficiency, ultimately creating new value. However, there may be questions as to whether smartization—via a tighter connection of production processes and more data sharing and utilization as mentioned above—actually improves performance, and if so, exactly in what aspects.

This study analyzes the effects of factory smartization on three aspects of factory performance: productivity of main products; efficiency of resource use and; product variety. The productivity of main products is measured through the daily output and lead time (time between initial order and shipment) of a main product while the efficiency of resource use is gauged by the defect rate and the factory's capacity utilization rate, and product variety by the number of products manufactured and clients.

Consideration was also given to the potential heterogeneous effects of smartization on each aspect of factory performance depending on the type of production process. As such,

6) The median value is 0.3 in 2015 and 0.36 in 2017, not very far from the average value.

Smartization is found to have varying effects on factories' performance depending on the type of production process, but in general, smartization helps to significantly improve productivity.

the process was divided into: (i) batch and job shop processes suitable for small quantity batch production; (ii) assembly line process suitable for manufacturing a product with many parts and; (iii) continuous process designed for the mass production of the same product. The effects of smartization on the respective processes are then compared. The results of the panel regression analysis are summarized in <Table 1>.

The US-China trade conflict could directly/indirectly reduce Korea's exports, which in turn, could lead to a fall in GDP.

<Table 1> Effects of Factory Smartization by Type of Production Process

Process type	Productivity		Efficiency		Diversity	
	Daily output	Lead time	Defect rate	Capacity utilization rate	No. of products manufactured	No. of clients
Batch (job shop)	+	n.s.	n.s.	n.s.	+	+
Assembly line	+	n.s.	-	n.s.	+	n.s.
Continuous	+	-	n.s.	n.s.	n.s.	+

Note: 'n.s.' means statistically insignificant and '+' is a statistically positive effect while '-' is a statistically negative effect.  
Source: Calculation by authors based on Kim *et al.* (2019).

According to <Table 1>, factory smartization varies by process, which is in line with expectations when the unique characteristics of a process is taken into account. For instance, the lead time, which is a productivity indicator, significantly decreased only in the continuous process which concentrates on mass production. On the other hand, the defect rate, an indicator of efficiency, dropped significantly in the assembly line process wherein the correct assembly of parts is most important. In terms of product variety, the largest positive effect (+) was found in the batch (job shop) process, which produces a large number of customized products.

In daily output, which can be interpreted as an indicator of the overall performance, significant positive effects were observed in all three process types with little difference in the size of the effect. Hence, productivity measured by daily output can be used to quantify the effect of factory smartization on the entire sample. Specifically, if the smartization level of the bottom 10% (as of 2017) was raised to the median level (50%) of 0.36, the daily output-based productivity would improve approximately 9.1%p.<sup>7)</sup>

#### IV. Effects of Factory Smartization on Employment

The various positive effects of smartization could come at the cost of employment. Prior studies reveal that technological changes, such as the adoption of robots, have scaled back employment and wages (Acemoglu and Restrepo, 2017).

Smartization is different from automation as its ultimate goal is not just to replace human labor with machinery, but to fundamentally transform the manufacturing system through data digitization. It is expected that there will be an increase in the demand for management and

The nature of smartization is a fundamental transformation of the manufacturing system, using data as a proxy, and not replacing human labor through automation.

7) It should be noted that these estimates do not consider other conditions at all. In reality, even the same level of improvement in smartization may have different effects depending on factors such as internal conditional changes in factory, competitors' responses, and economic fluctuations. In addition, this study used different samples and analysis methods from the commissioned research project conducted by Smart Manufacturing Innovation Promotion Team (<https://www.smart-factory.kr/>), making it difficult to directly compare the results between the two studies.

technical personnel during the pursuit of smartization, e.g., strengthening process connectivity, analyzing data and decision-making, and improving the flexibility based on a consumer-oriented management strategy. Germany's Industrie 4.0—often cited as the originator of smart factories—regards labor as a key element of manufacturing system innovation.

This study looks into how factory smartization differs from automation in terms of the employment effect. Using data from the time of the survey (2017), the relationship between the level of smartization that firms plan to achieve in the next two years and the ensuing changes expected in labor demand by occupation is investigated.<sup>8)</sup> Given that smartization is not limited to the manufacturing process but also aims to integrate all areas including inventory management and logistics, factory smartization was classified into improvement in the production stage (production-stage smartization) and strengthening connectivity between sectors (enterprise-wide smartization).

According to the analysis, firms with plans to improve their level of automation expect a decrease in the demand for all occupations, while those with plans to smartize anticipate that there would be a decrease in demand for production and office workers but not for process management technicians. This corresponds with the expectation that factory smartization will generate demand for the establishment and management of process systems, and education. Furthermore, those planning an enterprise-wide smartization expect that there would not be a negative impact on any occupation.<sup>9)</sup>

<Table 2> Changes in Labor Demand from Automation and Smartization

Plan	Employment demand by occupation		
	Production	Process management	Office work
Automation	-	-	-
Production-stage smartization	-	n.s.	-
Enterprise-wide smartization	n.s.	n.s.	n.s.

Note: 'n.s.' means statistically insignificant while '+' is a statistically positive effect and '-' is a statistically negative effect.  
Source: *Ibid.*

The results show that there is a huge difference in response measures among factories expecting a decline in employment. Those with higher levels of smartization are more likely to have in-house upskilling and training programs and relocation plans for existing occupations, particularly production, in which employment is most likely to be cut. On the other hand, those with low levels of smartization are more likely to have no relocation plans and rely on affiliated large enterprises or specialized agencies for staff training. That is, firms' ability to provide effective retraining and relocation plans in their pursuit of smartization will be the key to minimizing the negative repercussions on employment.

8) In research by Morikawa (2016), which analyze the employment effect of digital technology, employers' outlook for the future is an important analysis subject.

9) Labor demand appears to be sustained on the expectation of performance improvement such as more clients owing to strengthened connectivity between sectors.

Automation is likely to curtail labor demand while smartization is found to have different effects on different occupations. In particular, the demand for technicians specialized in process management is not expected to decrease.

Responsive measures should be developed to support occupations that will likely experience a contraction in employment amid factory smartization.

## V. Determinants of Smartization

Considering the overall effect on output performance and employment, smartization clearly enhances competitiveness. So what does it take to make a factory smarter? In other words, what determines the level of smartization? It is likely that the level of smartization will increase when the firm adopts relevant technologies, although we should not neglect the importance of organizational complementarities. A key factor of the organizational feature is the use of structured management practices. The Toyota factory can be considered smart because of its unique management practices, the so-called lean manufacturing. Indeed, it turns out that the level of smartization is highly dependent on how the adopted technologies are deployed in the organization.

Specifically, this study analyzes the potential determinants that affect the level of smartization: the number of smartization-related technologies adopted; the number of employees; the index of structured management practices for production and personnel; the presence of a department or personnel dedicated to technology-based process optimization; CEOs' interest in process innovation and; beneficiaries of government support.<sup>10)</sup>

The analysis finds interesting results, as summarized in <Table 3>. Firstly, the adoption of technologies, which was thought to be the most direct determinant of smartization, had a varying effect depending on the factory's management practices. Among such practices, the level of structured personnel management, an indicator of how well the incentives are managed, shows complementarity with the technology adopted. In fact, the adoption of new technologies had no impact in the bottom 20% of factories by the levels of personnel management. But, the effect of technology adoption on smartization increases disproportionately with the level of structured personnel management.<sup>11)</sup> Interpreting this result, the adoption of technologies for smartization is effective only when it is well aligned with workers' incentives.

In addition, both the presence of a dedicated department or personnel and the CEO's interest in process innovation are found to be important factors for smartization. The question of receiving a government subsidy is not as important, but considering that such support is provided mostly in the form of funding for technology adoption, it can be said that the government's policy aids the adoption of technologies, which has an indirect affect on the level of smartization.

The finding that technical and organizational factors have a complementary relationship means that it would be difficult to improve the level of smartization with just one of the two factors (Figure 2). The adoption of technologies can create a synergy when it is combined with the interests and capabilities of all factory workers, from top management to field workers. Hence, incentives must be given to employees in a way that their interests and capabilities are compatible with smartization. Incentives here may refer to financial compensation or promotion, and even penalties, but it can also include providing workers with an initiative to

The adoption of technologies for smartization can be helpful only when it is well aligned with workers' incentives.

Technological and organizational factors that determine the level of smartization are complementary, meaning that it would be difficult to smartize by focusing on just one factor.

10) Bloom and Van Reenen (2007) show that management practice is an important causal factor behind the productivity gap between firms or countries. Survey questions used in this study are borrowed from the US Management and Organizational Practices Survey (MOPS) (Buffington *et al.*, 2016).

11) According to Chung (2018), overall the level of personnel management in the domestic manufacturing industry is significantly lower than in the US'.



engage in the smartization process.

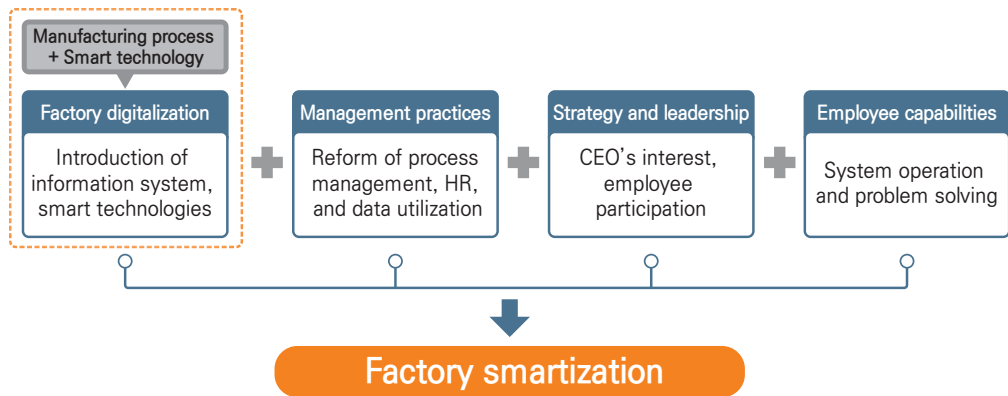
<Table 3> Analysis of the Determinants of Smartization

Determinants	Increase in smartization level	
	System interconnection	Data sharing and utilization
Technology adoption	n.s.	n.s.
Personnel management	n.s.	n.s.
Production management	n.s.	n.s.
Technology adoption x Personnel management	+	+
Technology adoption x Production management	n.s.	n.s.
CEO's interest in process innovation	+	+
Presence of dedicated department/personnel	+	n.s.
Number of employees	n.s.	n.s.

Note: 'n.s.' means statistically insignificant while '+' shows statistically positive effect.

Source: *Ibid.*

[Figure 2] Factors of Factory Smartization



Source: Based on Kim et al. (2019).

## VI. Conclusion and Policy Suggestions

The results of this study calls for policymakers' attention to the need for reforms in the current policy for smart factories. The adoption of smart factory technologies must be accompanied by structured management practices and organizational changes to integrate systems and utilize data. This section presents suggestions to effectively support the smartization of SMEs.

Firstly, policies should help firms to make investments in smartization based on an accurate diagnosis of its organizational practices and the recognition of its need and expected effects of smartization.<sup>12)</sup> Before installing new systems or technologies, companies should have

12) Smart factory has not been fully realized yet and is still a futuristic factory that keeps evolving. So, related policies need to

an accurate understanding of what the problems are and how they can be solved through smartization. As discussed above, for a successful smart-technology adoption, organizational transformations must be achieved together, such as reforming management practices in a way that improves employee engagement by enhancing their understanding of smart technology and aligning their incentives with the changes driven by technology adoption. It is also important to standardize the system in preparation for future upgrades. All these tasks are not something that can be solved in a hurry. There is ample evidence showing that a premature adoption of technology often leads to a loss of existing competitive edge.<sup>13)</sup>

The role of government begins with creating an environment for firms to learn in advance. Prior to adopting technologies for smartization, it is strongly recommended that factory chief managers are offered sufficient management training and consultation to help them develop a blueprint for smartization and prepare technological and organizational solutions to actualize the blueprint. Companies without such preparations should not be offered any support. No matter how well-prepared, adopting new technology naturally comes with trials and errors. Thus, at least for a certain period of time, education and support should be provided continuously until they are successfully adopted. At present, such efforts are being made through projects like 'Smartization Capability Improvement' and 'Smart Meister,' which provide consulting services and professional coordinators, but their role is temporary and fragmentary. It is recommended that the budgetary focus, which is placed on supporting technology adoption, should shift to consulting, training and human resource development while support programs are further systemized.

Second, smartization should be pursued not only at the company level but also at the level of the government's policy support system, which means utilizing information acquired in the process of providing support. Diagnoses, evaluation results and consulting information obtained in the process of supporting the smartization of a factory should be linked and reapplied to other fields such as technology development and training assistance so that policies can maximize their effectiveness.<sup>14)</sup> In addition, this study suggests that information on smart technology suppliers need to be specified further to include not only their expertise (as they do today) but also accomplishments along with their client's' characteristics and satisfaction level after the completion of smartization. Based on this data, potential clients can be given recommendations that fit their needs. In Germany, the 'Map of Industrie 4.0 Use Cases' provides information on companies that have adopted the smart factory under the categories of use case, product, development stage and company size.<sup>15)</sup> If such information is available in Korea—when the government provides data on cases with support—including goals, the means used for smartization, the benefits from smartization, and the failures and

To make the policy work more effectively, companies should be provided with management training and consulting support so that they can prepare for technological change. It is recommended support programs for consulting, training and human resource development are systemized.

The government's support system needs to be smartized to enhance the efficiency of support and to provide companies with more practical information.

be structured in a way that can continue to be upgraded from a long-term perspective. Even Germany, a leading country in the smartization trend, has a target year of 2030 and beyond in which to complete Industrie 4.0 policy and has consistently updated relevant plans. This is a good example of how long and comprehensive the approach to smartization should be.

13) Details are well summarized in Davenport (1998).

14) Such an idea is not necessarily confined to smartization-related projects. It would be possible to make support more efficient in more diverse ways through information integration between the support project for 'materials, parts and equipment firms' by Ministry of SMEs and Startups and 'Fourth Industrial Revolution-related' project by Ministry of Science and ICT and Ministry of Trade, Industry and Energy.

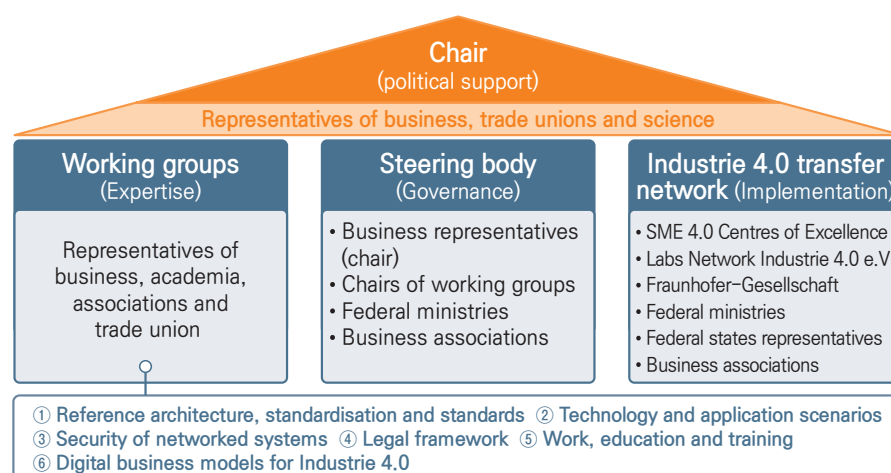
15) Website for Map of Industrie 4.0 Use Cases (<https://www.plattform-i40.de/PI40/Navigation/EN/InPractice/UseCases/use-cases.html>, last access: Oct. 14, 2019).

their causes, it could provide practical help in the smartization of factories.

Third, it is necessary to develop a system for job training programs that meets employers' needs. Retraining can help relocate workers to new positions from old ones that face a reduced demand due to factory smartization. However, there is a large gap between firms in terms of the ability to educate and retrain workers, and small firms may lack the resources to provide employees with training to develop their skills. Thus, it is important that the cooperation between large enterprises and SMEs and between smart technology suppliers and users is promoted. What is critical in this process is that a system for education and training programs is designed to help workers consistently develop suitable skill sets that meet the changing needs of employers. Consideration should also be given to more effective ways to use vocational training programs supported by Korea's employment insurance system.

Lastly, Korea needs an innovative shift towards a network-driven platform like Germany's 'Plattform Industrie 4.0', in which a public-private-academic network—not government-led governance—serves as the substantive and actual authority in charge of developing strategy. Currently, each ministry is in charge of its own projects, which are independently operated. However, this may not be effective in realizing industry-wide manufacturing innovation through digitalization when 'connectivity, convergence' serves as the core concept of the Fourth Industrial Revolution era. The government should serve as the coordinator of the manufacturing innovation policy via a platform which enables collaboration between various stakeholders. Germany established working groups for 'Plattform Industrie 4.0' to present core concepts for industry-wide digitalization in order to take the lead in the rapidly changing manufacturing environment (Figure 3). In reference to the German platform, this study recommends the following suggestions to operate a Korean public-private-academic network platform in order to develop concrete solutions to enhance the competitiveness of overall industries.

[Figure 3] Germany's Plattform Industrie 4.0



Source: Recited from BMWi, at 'Plattform I4.0' website, July 2018.

First, the platform should be comprised of bodies with real authority over the innovation strategy for the manufacturing industry. Second, the platform should have explicit goals for the

Effective educational and retraining programs should be provided, targeting occupations that will likely face a decrease in demand, through cooperation between large enterprises and SMEs and between suppliers and users.

A public-private-academic network platform holding real authority should take the driving role in developing manufacturing innovation strategies and responding to the coming changes.

manufacturing innovation strategy. Third, the platform should present a digital transformation and innovation roadmap and set priorities among the challenges in light of Korea's actual situation. And fourth, the platform should operate working groups for problem-solving which will continue to develop core concepts for each field and provide specific recommendations.

The public-private-academic network platform proposed in this study has a different governance system from the typical control tower or committee. It is hard to develop effective innovation strategies when they are occasionally formed by a few government officials. Therefore, the governance system should shift to a private sector-driven approach to effectively respond to the era of the Fourth Industrial Revolution.<sup>16)</sup>

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16) Kim et al. (2019) discuss specific goals and operations of the council.