Journal of Convergence for Information Technology
Vol. 12. No. 4, pp. 286-302, 2022
e-ISSN 2586-4440
DOI : https://doi.org/10.22156/CS4SMB.2022.12.04.286

A Role of Automation in the Triggering of Employment, Productivity, and Profitability among Korean Companies from 2005 to 2015

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자동화가 고용, 생산성, 수익성에 미치는 영향 : 2005년부터 2015년 사이의 한국기업을 중심으로

손정민
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Abstract This study examined the dynamic role that automation has had upon employment, productivity, and profitability. For the analysis, 342 companies of the Workplace Panel Survey of the Korea Labor Institute conducted from 2005 to 2015 was used. For analytical models, the fixed effect model, which is capable of controlling the endogeneity problems of variables, was used. According to the analysis results, the increased ratio of automation in Korean companies (1) resulted in the increase of turnover in the short and long terms, a temporary decrease in employment, and (2) a decrease of productivity in the short and medium terms, and thereby (3) failing to change profitability in a positive manner.

Key Words : Automation, Employment Growth, Labor Productivity, Corporate Profitability, Workplace Panel Data, Fixed Effect Models

요 약 자동화 기술은 노동력을 대체하여 인건비를 감소시키고, 생산성 및 수익성을 증가시킬 수 있을 것이라는 일련의 연구가 있다. 반면 자동화가 새로운 노동 수요를 창출할 가능성이 있으며, 장기적으로는 일자리가 감소하지 않았다는 연구도 있다. 이 연구는 자동화가 한국의 기업에서 단기 및 장기적으로 고용, 생상선, 수익성에 어떠한 효과가 있는지에 대해 설명하고자 한다. 이를 위해, 한국의 342개 기업에 대한 노동연구원의 2005년부터 2015년 사이의 사업체패널데이터를 분석하였다. 분석에는 패널데이터를 분석하기 위한 고정효과 모형을 이용하였다. 분석결과, 기업당 자동화 수준의 증가는 (1) 단기 및 장기적으로 고용을 감소시켰으며, (2) 단기 및 중기에 걸쳐 생산성을 감소시켰고, 결과적으로 (3) 생산성 향상의 효과는 누리지 못하였다고 할 수 있다.

주제어 : 자동화, 고용 증가, 노동 생산성, 기업 수익성, 사업체패널데이터, 고정효과모형

*This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2018S1A5A8027813).
*A part of this study was presented at the seminar for Workplace Panel Survey by Korea Labor Institute at October 2018.
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Received March 7, 2022 Revised April 2, 2022
Accepted April 20, 2022 Published April 28, 2022

1. Introduction

This study would explain the positive or negative long-term impact of automation on the intrinsic marginal effect of economy. This research question is meaningful in that automation has a very great influence on the entire industrial world. Recently, the continued advancement of IT technology such as automation, the acceleration in adopting new technologies, the robotization of production processes, and artificial intelligence is expected to eliminate a number of existing jobs and create new types of work. The ratio of employment growth for knowledge-based jobs such as ICT, engineering, and big data analysis is expected to show relatively high rates of increase. The automation of product manufacturing and service providing processes is an integral technological factor in gaining a competitive edge by increasing productivity [1,2]. Automation may become an opportunity to relocate a labor force that has been assigned to production more efficiently. Introducing automation enables the company to use its existing workforce for other operations and assign more labor and time to various additional tasks, such as customer management, that the company needs to perform apart from production[2].

On the other hand, if automation only replaces the existing labor force, it does not improve productivity and may also result in adverse effects to society, such as fewer job numbers. It is also estimated that approximately half of all existing full-time workers may be replaced or lose their jobs through automation worldwide[3]. According to a report, approximately 50% of the total working hours in Korea may be replaced by automation as of 2030, with the number of low-skilled jobs to decrease due to the use of automation technology.

Automation may lead to a tendency to overly rely on technology in the workplace as a means of technological innovation. There are many companies that may wish to automate their processes in order to improve productivity. Automation appears to be an urgent issue for many companies. However, it is possible that a company might rule out existing labor due to an over reliance on technology in the course of automation, potentially resulting in reducing the efficiency achieved by worker skill and even productivity, due to reduced efficiency. It was reported that Korean companies had a tendency to increase exclusive labor and outsider labor, overlooking the potential voluntary innovation activities in the existing workforce, as well as efforts to enhance functions in the course of adopting automation in the past[16,17]. The improvement of production quality requires workers to have a great sense of responsibility in their work process and get involved in new areas of knowledge or problems[18]. This raises the question about whether automation actually leads to productivity enhancements.

There is profound doubt about whether automation maximizes corporate performance while minimizing employment issues in the Korean market. In fact, the Korean manufacturing industry has been rapidly introducing and spreading automation facilities over the past 40 years and the number of employees has not increased greatly because of it[19]. While the economic growth rate has risen, the rate of employment growth has not as risen much in the same period. It is necessary to make a division to understand whether technological advancement increases employment at the national level (i.e., extensive margin) or changes the employment level at individual business units (i.e., intensive margin).

Productivity and profitability are the performance factors of another dimension that must be addressed in order to understand the negative effects of employment in the long term and in multidimensional aspects. In many companies, the aim to increase efficiency in product manufacturing and service providing processes through automation means that it is possible that they may reduce employment by replacing existing workers with automation facilities or systems. Labor productivity may improve if the total yield of the company stays or increases when employment decreases. Furthermore, the ultimate profitability of the company may increase if more efficient production and service processes are introduced. However, previous studies have revealed mixed results regarding the effect of automation on employment, from positive to negative and mixed (i.e., [1,2]). Moreover, it might have been difficult to expect productivity and profitability to increase, considering Korea's tendency to introduce overly labor-exclusive automation technologies. While previous empirical studies have dealt with the employment effects of automation in the Korean market[20], not many have empirically verified the productivity and profitability resulting from automation. In other words, it will be necessary to study the negative effects of automation – the reduction of employment – as well as the continued process – the change in labor productivity and profitability – using empirical data.

This study attempts to explain the long-term relationships of automation and employment with productivity and profitability. Previous studies showed its mixed effect on the employment while concerning productivity and profitability, only the short-term effects according to the process of the introduction of automation have been revealed. In addition, previous studies are mostly the analyses of data from foreign countries. Thus, this study would analyze the effects of automation and employment (i.e., intensive margin), not the effects at the national level (i.e., extensive margin). To explain employment, the impact on society because of automation and productivity and profitability, the impacts on companies from the long-term perspective as in this study, it would be urgently necessary to analyze the data that measured the automation level and change in performance of society and companies over the long term. Especially, this study would analyze the automation level and change in performance of Korean companies, which has little been attempted in previous studies.

This study aims to answer the research question how employment, productivity, and profitability change when the level of automation is increased in a company's product and service processes by empirical analysis using long-term data. Previous studies have described the mixed effects of automation on employment, productivity and profitability. This study takes a step further from these previous studies, performing additional analysis of Korean companies. Through this, it can be expected to contribute to the development of a research area related to the effects of automation on employment, productivity and profitability. The dependent variables for automation to examine these forces in this study are as follows: First, the sub-variables of employment are turnover, hiring, and the ratio of employment growth. There could be voluntary turnover due to workers voluntarily departing to perform similar duties in another company or being dismissed by the company in the process that replaces existing labor with automation facilities. Hiring, another

sub-variable of employment, can be analyzed as full-time employment and part-time employment. This is expected to show the qualitative aspects of the labor force replaced due to automation. The ratio of employment growth is expected to explain the increase and decrease in the ultimate level of employment in a company, which has been changed by turnover and hiring. Second, the sub-variables of productivity include sales per employee and added-value per employee. This study intended to analyze the changes in the productivity of a company due to the increase or decrease of its labor force size. Finally, profitability was analyzed with operating profit per employee. It is expected that these performance variables would explain the effect of introducing automation to the Korean labor market and corporate performance. Finally, this study intended to analyze how automation may influence employment, productivity, and profitability. The research model to be finally verified in this study is shown in Fig. 1.

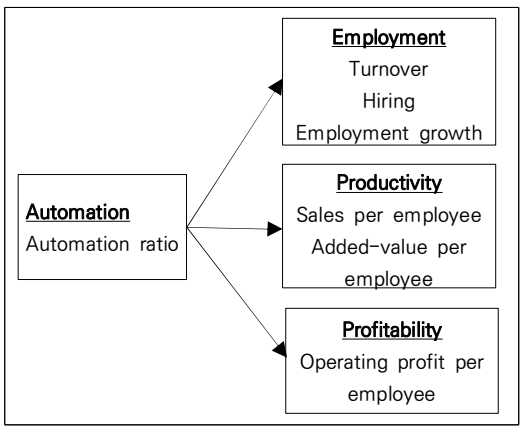

Fig. 1. Research framework

This study would be significant in that it could systematically explain the impacts of automation on (1) employment, the factor required for social stability and development and (2) productivity and profitability required for the continuous growth of the company, which have not been explained in previous studies. Since few previous studies comprehensively explained the impacts on society and companies, this study is expected to have a greater impact on the academic world and society compared to previous studies. Especially, this study has a merit that it presents the result of an analysis of companies in Korea, a country that has a very high automation ratio, recently. This study is expected to provide points to supplement concerning the explanation of the impacts of automation and mechanization, which have been explained previously in depth.

2. Theoretical Background

2.1 Automation and Employment

Existing studies have indicated that automation can bring about various results, such as reducing employment[4-9], increasing employment[2,10,11], and cause mixed effects[1,12,13].

The reason why there are various effects of the relationship between automation and employment can be explained with the sub-factors included in each study and factors according to the data window and the level of analysis unit. It was noted that various types of technological advances including automation caused job obsolescence, increasing unemployment in the long term and lowering the equilibrium level of employment. However, it turned out that employment increased by increasing job creation required for introducing new technology[26]. In addition, it turned out that technological advancement like patent decreased employment in the short-term[8], and the study assumed that technological

advancement increased skilled workers' productivity while it was not related to unskilled workers' productivity. This was consistent with the result of an important previous study[27] that the manpower required for introducing new technology was employed additionally before and after the introduction of automation technology.

In recent studies, there also have been attempts to explain how automation could change employment and the quality of labor. According to a very significant study by David and Dorn[28], the increased in routine occupations led to the increase in the employment of workers with non-college education from 1980 to 2005 in the U.S. Since the average wage has increased during the period, this indicates that it leads to wage polarization. Such a trend has particularly strengthened after 2000 more than before 2000. The interesting feature in the study is also found in the characteristics of the data, which suggest that the routine-intensive occupations have declined sharply between 1980 and 2005. This is presumed to be because the corresponding work was absorbed by automation.

Bartel et al.[29] argue that routine-intensive occupations have been transformed into occupations performing abstract-intensive tasks due to the adoption of automation.

Acemoglu and Restrepo[30] suggested that automation could reduce employment, but if accompanied by the development of new occupations, it had the opposite effect. Other studies also explain that automation such as production robots reduces employment for low-skilled workers and increases the number of workers in new technologies[31]. Therefore, it is necessary to take a comprehensive look at various effects of such automation. This study has an advantage of becoming an opportunity to verify the reasoning of previous studies empirically.

2.2 Automation and Firm Performance

As discussed before, automation may cause changes in employment in the short-term and long term, and this may be because automation causes changes like job productivity, profitability, and hire cost[27]. The spread of labor-saving production methods through the advancement of technology may lead to positive effects, such as the decrease of costs and increase of productivity and profitability in a corporate environment[11,14,15]. There are clearly limits and difficulties in reducing employment and improving results for companies through automation simultaneously. Thus, to understand the mechanism under the effect of automation on employment, it is necessary to understand productivity and profitability because of automation, which is a corporate performance.

Dorm et al.[27] included computer systems like CAM/CAD, computer-controlled automated laser machines, work robots, automation sensors in workshops, and automated transporting vehicles as the sub-factors of automation. This automation through computer draws the increase in employment because of the pre-and post-adoption of technology and the long-term effect on productivity and cost reduction after the introduction of technology. This change in technology did not have any significant impacts on employment and wage, and the authors assumed that it was because a time-series analysis of within-plant data was conducted. Thus, they point out that further analyses would be needed on changes in the exchange, employment, and wage of workers in the entire industrial world.

The service industry is expected to have

characteristics different from the introduction of automation in the production and manufacturing industries. In the service industry, the speed of productivity growth is slow while there are lots of differences in the level of service productivity by country[33]. The service industry can be expected dramatic improvement of productivity by introducing automation. It has a characteristic that there is a huge difference in face-to-face service costs between countries. For example, there is a tendency of using English in the customer service center field while the U.S. and U.K. that have high face-to-face service costs tend to outsource employees to India, where the cost is about a half level. Thus, the service sector can have an effect on the maintenance of employment, enhancing productivity and profitability by introducing automation through outsourcing employees overseas[15]. It is necessary to analyze cross-country data in the research on the automation of service sector because of this characteristic.

In a recent study[32], on industrial robots in 17 countries, it was found that robots did replace or reduce low skilled workers although their use was related to the increase in labor productivity and added values between 1993 and 2007. The study verified corporate performance of promoting profitability through productivity improvement and cost reduction while maintaining the company's employment. The study estimates that in the U.S. and Europe, automation by robot contributed to about 37% of the annual productivity improvement on average. The authors explain these relationships among employment, productivity, and profitability through the problem of the optimization of profits between consumers and the company, assuming the equilibrium of profits between them. They explained that since consumers consume to maximize utility within their wage, prices of corporate products and companies' profits cannot appear in the direction toward the inducement of a decrease in wage and employment in the long term.

3. Research Method

3.1 Model

This study intended to determine whether the ratio of automation in Korean companies has had a positive impact on the employment, productivity, and profitability of each company. Also, based on the determination, this study intended to provide clues as to whether the introduction of automation in Korean companies contributes to labor exclusion, labor-saving automation, efficiency and performance within the company, and socio-economic stability. The following model was suggested to perform this empirical analysis:

$$Y_{i,t}^{m} = \beta_1^m \cdot \Delta Auto_{i,t} + \beta_2^m \cdot \Delta Auto_{i,t-1} + \beta_3^m \cdot \Delta Auto_{i,t-2} + \alpha^m + \eta_t^m + \boldsymbol{\gamma}^{\mathbf{m}} \cdot \mathbf{Controls}_{\mathbf{i,t}} + \varepsilon_{i,t}^m$$

Here, if $Y_{i,t}^{m}$=dependent variable(i.e., m=1 then voluntary turnover, m=2 then involuntary turnover, m=3 then total turnover, m=4 then hiring in full-time equivalent units, m=5 then hiring in part-time equivalent units, m=6 then total hiring, m=7 then the increase in employment, m=8 then the ratio of employment growth, m=9 then sales per employee, m=10 then added-value per employee, m=11 then operating profit per employee). For all dependent variables in this study, the performances during the last year were measured. Meanwhile, for automation, the change in the automation level because of additional investment for the last year after the investment at a point in the past was measured.

Thus, both dependent variables and independent variables in this model can analyze changes over the past year.

$\Delta Auto_{i,t}$= Incremental ratio of automation (i.e., $\Delta Auto_{i,t}=Auto_{i,t}-Auto_{i,t-1}$) of company i at time t.

α^m = Intercept of model m.

η_i^m = Fixed effect at company i's level in model m.

$\mathbf{Controls}_{i,t}$ = The vector of control variables of company i at time t.

$\varepsilon_{i,t}^m$ = Error term of company i in model m at time t.

The incremental ratio of automation ($\Delta Auto_{i,t}$) is determined by subtracting the ratio of automation in the previous year from the ratio of automation in the current year at company i at time t year level. The incremental ratio of automation represents the degree of annual change in the ratio of automation variable, which is investigated every year. If the increase in the ratio of automation compared in the immediately previous year has a positive impact on the dependent variable, a positive value will be estimated for β_1^m and a negative impact, a negative value. This incremental ratio of automation variables was measured in three time points: t, t-1, and t-2. The coefficients corresponding to these are β_1^m, β_2^m, and β_3^m, respectively. The effect of the vector of the control variables ($\mathbf{Controls}_{i,t}$) is γ^m.

Employment, productivity, and profitability can be influenced by other performance factors, such as the scale of the company, sales, and number of customers. To control company-level effects, this study controlled the unobservable company-level effect with the fixed effect. This study intended to analyze the model with company-level and year-level panel data to control for company-level unobserved external effects. These panel data has the advantage of permitting the long term measurement of the variation in corporate activities and results compared with the company-level cross-sectional data.

3.2 Data

The empirical analysis of the models suggested above required panel data, which included the changes in various variables such as employment, productivity, and profitability in a number of companies in Korea recorded over a long period of time. Relevant data were obtained from the Korea Labor Institute in an effort to collect data that corresponds with the characteristics of this study. The Korea Labor Institute has performed the Workplace Panel Survey from 2005 to 2015. This survey has been conducted every two years, and the data were collected at six time points, 2005, 2007, 2009, 2011, 2013, and 2015. These data were sampled from companies that employ 30 or more full-time workers in Korea, excluding companies in the fields of agriculture, forestry, fishery, and mining. The samples were designed in the stratified sampling method by considering the industrial classification system, corporate scale, and region. The current status data on finance and labor operations included in these data were collected by post, and other items in the survey were collected by interviewing respondents in the form of computer assisted personal interviews at the workplace. This type of questionnaire survey is expected to raise the reliability of the questionnaire survey results. Among all questionnaire data, this study analyzed the data collected from the company's financial statements and interviews with personnel managers.

3.3 Measurement

3.3.1 Dependent Variables

The effects of automation that this study intended to clarify were the three performance factors: employment, productivity, and profitability. Each performance factor comprises a subset of measurement variables. Employment includes turnover, hiring, and the increase in employment, productivity includes sales per employee and added-value per employee, and profitability includes operating profit per employee.

Employment. As the level of employment in individual companies consists of turnover and hiring, this study analyzed the (1) turnover, (2) hiring, and (3) employment growth.

All three sub-variables of (1) turnover, (1-1) voluntary turnover, (1-2) involuntary turnover, and (1-3) total turnover, were measured and reviewed. Voluntary turnover included cases of turnover due to personal reasons, such as working for another company, studying, starting up a business, and others. Involuntary turnover included retirements, layoffs, requested resignations, and contract terminations. These variables were analyzed systematically to explain the characteristics of turnover by automation.

The sub-variables of (2) hiring comprised three variables: (2-1) hiring in full-time equivalent units, (2-2) hiring in part-time equivalent units, and (2-3) total hiring. For hiring in full-time equivalent units, the number of full-time workers hired in the same year and for hiring in part-time equivalent units, the number of hiring in full-time equivalent units was subtracted from total hiring, which includes workers on unlimited contracts, workers hired for a short term period, and part-time workers.

The sub-variables of (3) employment growth include two variables: (3-1) the level of employment growth and (3-2) the ratio of employment growth. The level of employment growth was determined by subtracting the number of workers in the previous year from the current number of workers at the company. The ratio of employment growth represents the importance of increases in employment compared with the previous year, and the method used in previous studies[35] was used. For example, the employment increase rate in 2015 was calculated by the equation, (Number of Workers in 2015 - Number of Workers in 2014)/((Number of Workers in 2015 + Number of Workers in 2014)/2)(%). This method has the advantage that the ratio of employment growth calculated is close to normal distribution as the moving average, which is calculated with current and previous values used for the denominator when calculating the increase rate.

Productivity. There are two variables used to measure productivity in this study: sales per employee[21] and added-value per employee[14, 22]. The productivity of a company (i.e., labor productivity) represents the production efficiency of an organization, which can be explained by output compared to input. The typical indicators representing the production capacity of a company are sales and added value. Sales is the company's total production volume and added value is the total wealth that the company created, measured before it was distributed among the company's interested parties. Productivity can be represented by labor input or the amount of the added value created by each worker, and it was measured as added-value per employee in this study. The added value calculated in this study is the gross value added, which is the sum of income before tax, personnel expenses, net financial expenses, rent, taxes and public charges, and depreciation costs.

Profitability. The operating profit per

employee, which is a profitability measurement variable in this study, is calculated by dividing the company's gross sales profit by the number of workers in operation. The operating profit per employee has been used as a typical variable to measure earnings results in existing studies[23].

3.3.2 Independent Variables

The major independent variable of this study is the incremental ratio of automation. The incremental ratio of automation is the change in the ratio of automation at present compared with a previous point in time. The ratio of the automation variable included in the data was used to measure the incremental ratio of automation. The questions for the ratio of automation were as follows: "How much of the product manufacturing processes/service providing processes for major products or services manufactured/provided by your company has been automated as of the end of last year? Please indicate the percentage of product manufacturing processes/service providing processes that have been automated when the entire process is considered as 100%." The respondent chose one of the following answers; (1) Less than 0-20%, (2) Less than 20-40%, (3) Less than 40-60%, (4) Less than 60-80%, or (5) 80% or over. As this study intended to explain the change in the ratio of automation in the previous point of time on current employment, productivity, and profitability, the incremental ratio of automation was determined by subtracting the ratio of automation at the previous point of time from that at present. Here, the response value converted to percentage was used for calculation. The measurements are categorical variable due to the limitation of the survey process, which cannot be added or subtracted directly. However, for convenience of calculation, they were calculated with the median value of each item. For example, if '(1) Less than 0-20%' was chosen, the value by year was calculated by assuming that it was 10%.

In other words, it was expected to prove the hypothesis of the study that the change from the existing ratio of automation to the current changed ratio of automation may have an impact on present employment, productivity, and profitability.

3.3.3 Controls

The control variables for this model included total labor, competition, price, and demand. Total labor was included as the indicator that can represent the level, scale, and result of employment in each company. Other indicators included were the market competition level, as answered on the basis of a year's worth of data to control the environmental elements of the market that each company feels, the average level of the price for products or service of each company, and average market demand.

Market competition was measured with the question, "How was the competition of your business's flagship product or service in the domestic market for the last year?," and the responses were made out of the following, "(1) Competition was very strong, (2) It was rather strong, (3) It was neither strong nor weak (4) It was rather weak, and (5) It was very weak."

Price level was measured with the question, "How was the price level of your business's flagship product or service compared to a rival company for the last year?," and the responses were made out of the following, "(1) It was much more inexpensive than that of the rival company, (2) It was rather inexpensive than that of the rival company, (3) It was similar to that of the rival company, (4) It was rather

expensive than that of the rival company, and (5) It was much more expensive than that of the rival company."

Market demand was measured with the question, "How was the market demand situation of your business's flagship product or service for the last year? Please respond including both domestic and overseas markets," and the responses were made out of the following, "(1) Market demand increased fast, (2) It tended to increase, (3) It neither increased nor decreased, (4) It tended to decrease, and (5) It decreased fast."

The environmental variable of each market was measured based on a five-point scale. Finally, the time effect was controlled, including the dummy variable for the year's level. The time variable has an advantage in that it can eliminate exogenous effects that are not observed from data divided by measured year[24,25].

3.4 Summary statistics

The basic statistics of the major variables included in this model are shown in Table 1. A total of 473 observed values were used in the analysis. For this, only those that retained an incremental ratio of automation variables at times t, t-1, and t-2 in the course of deriving the incremental ratio of automation variables were selected. The annual average sums of total turnover and total hiring are 110.16 and 100.72, respectively, and there tends to be more hires than turnover. Both the employment growth number and the ratio of employment growth show negative averages. The standard deviation is higher than average for both productivity and profitability variables. This can be attributed to the fact that there is a high number of small-sized companies and a small number of large companies. The level of change in the ratio of automation decreased by a maximum -3 points a year or increased by a maximum 5 points, indicating that there were companies that showed more or less extreme changes in the ratio of automation.

Table 1. Summary Statistics (N=473)

Variables	Mean	Std.	Max	Min	Skn.	Krts.
Dependent variables: Employment						
Total turnover	110.16	410.84	5889	0	11.88	158.05
Voluntary turnover	87.95	397.69	5889	0	12.99	182.07
Involuntary turnover	22.20	100.47	2006	0	16.69	323.97
Total hiring	100.72	393.36	6022	0	12.96	182.13
Hiring in full-time units	52.86	80.28	797	0	4.56	29.11
Hiring in part-time units	47.86	383.21	5967	0	13.84	199.98
Employment growth	-9.43	112.09	221	-2006	-12.68	216.17
The ratio of employment growth	-.01	.13	0.66	-1.48	-3.69	36.17
Dependent variables: Productivity						
Sales per employee (in thousand)	2.77	8.67	105.50	.01	.01	.05
Added-value per employee	104.98	303.43	4989.17	-446.63	1.15	124.23
Dependent variables: Profitability						
Operating profit per employee	168.97	33.33	13024.4	-632.21	6.79	76.08
Independent variables: Automation						
Incremental ratio of automation(t)	.07	1.16	4	-3	0.11	0.48
Incremental ratio of automation(t-1)	-.06	.95	2	-3	-0.11	0.43
Incremental ratio of automation(t-2)	-.05	1.01	3	-3	0.06	0.36
Controls						
Total laborers (in thousand)	.58	1.08	12.33	.05	.01	.07
Competition in the market	1.94	.74	5	1	0.6	0.49
Price advantage	3.00	.51	5	1	-0.57	3.74
Customer demand	2.88	.92	5	1	0.05	-0.63

4. Results

4.1 Employment effect

Table 2. shows the estimated result of the turnover model, which indicates that the incremental ratio of automation increases total turnover. The coefficient of the incremental ratio of automation at time t ($\beta_1^{m=1}$) was 11.96, the coefficient at time t-1 ($\beta_2^{m=1}$) was 15.89, and

the coefficient at time t-2 ($\beta_3^{m=1}$) was 20.70. This matches the findings of past research; automation has an impact on labor decreases and turnover[5]. According to the basic statistics of the analyzed data, the annual turnover at an average company is approximately 110.16, which makes the coefficient at time t-2, 20.70, approximately 18.8% of the average number of employees. This implies that a 20% increase in the ratio of automation may induce an additional 18.8% turnover.

Table 2. Estimation results for the turnover models

Variables	Models		
	Total turnover	Voluntary turnover	Involuntary turnover
Automation			
Automation (t)	11.96* (6.05)	14.93*** (5.45)	-.82 (1.93)
Automation (t-1)	15.89* (9.39)	13.64* (7.41)	-2.16 (2.98)
Automation (t-2)	20.70*** (7.68)	17.19** (6.87)	.48 (2.49)
Controls			
Intercept	120.57 (73.41)	100.93 (65.94)	10.56 (23.32)
Total laborers	-.13** (.07)	-.13** (.06)	.022 (.022)
Competition	.35 (.81)	.739 (.73	-.212 (.25)
Price	-.23 (.61)	-.32 (.55)	.074 (.19)
Demand	-.21 (1.03)	-.78 (.94)	.264 (.33)
Time dummy: 2013	-.45 (9.04)	-7.26 (8.13)	2.67 (2.89)

Note. *** p(.01, ** p(.05, * p(.10, ( ) standard error, N=473.

An interesting aspect of this study which differentiates it from other studies is the tendency for the ratio of automation in the past to have a greater impact on current turnover. Time t-2 indicates the time which is four years after the change in the ratio of automation took place, showing that the ratio of automation not only has a short term impact on turnover, but also a greater long-term impact. A similar tendency can be found in voluntary turnover. As for the voluntary turnover model, the coefficients of the increase/decrease in the ratio of automation at each time were 14.93, 13.64, and 17.19, respectively. The coefficients of t and t-1 are similar, while the coefficient for t-2, which is the latest time, has the greatest impact. This shows an interesting result, suggesting automation has a short term effect on turnover and also the effect appears with a delay of at least four years.

Such significant short-term and long-term effects could not be derived in the involuntary turnover model. While automation can be a factor that determines voluntary turnover, such as working for another company or starting up a business, it could not explain involuntary turnover events such as dismissal and retirement. It can be assumed that automation encourages workers to leave the company voluntarily. However, since there is a general tendency for unreported involuntary turnover, affected by the will of others or the company in part, is reported as voluntary turnover rather than involuntary turnover. Therefore, additional investigation is required for these estimated results.

Table 3 is the estimation results for the hiring models. According to the table, the incremental ratio of automation has a significant effect on the total hiring only at time t-2. The hiring in full-time equivalent units and hiring in part-time equivalent units models confirmed the tendency of the incremental ratio of automation in increasing hires in the long term. However, the finding did not show statistically significant results. Whether automation increases the number of new hires required for the operation and management of automation facilities while increasing the turnover of existing workers is a very important factor for the increase of employment. According to the estimation results, automation four years ago had a significant impact on current new hiring. However, that impact was

not as significant as turnover. This can be inferred as a result of changing existing workers' jobs rather than hiring new people for the operation of automation.

Table 3. Estimation results for the hiring models

Variables	Models		
	Total hiring	Hiring in full-time equivalent units	Hiring in part-time equivalent units
Automation			
Automation (t)	-1.48 (6.19)	.45 (3.84)	-1.60 (4.59)
Automation (t-1)	12.56 (9.66)	5.83 (6.13)	6.19 (7.12)
Automation (t-2)	15.17* (7.87)	7.43 (4.92)	8.56 (5.90)
Controls			
Intercept	64.86 (75.15)	49.08 (46.66)	66.50 (55.42)
Total laborers	.023 (.07)	.03 (.04)	-.04 (.05)
Competition	.18 (.83)	.19 (.51)	-.05 (.61)
Price	.00 (.62)	-.04 (.39)	.06 (.46)
Demand	-.25 (1.07)	-.03 (.66)	-.18 (.79)
Time dummy: 2013	15.40* (9.27)	11.21* (5.76)	4.76 (6.88)

Table 4 is the estimation made based on employment growth and the ratio of employment growth models. The analysis shows that the incremental ratio of automation has a negative impact on employment growth (i.e., change in the number of total labor employed) in the short term. The coefficient at time t was -12.59, which can be attributed to the fact that job turnover is greater than hiring in the short term. Since employment growth for an average company is -9.43, it can be inferred that employment growth by one unit of automation, which is about -12.59, is quite significant. The long term effects of employment growth and the short-term and long-term effects of the ratio of employment growth were both estimated as insignificant values, however, showing negative trends. This indicates that automation has little effect on the ultimate increase in employment. This can be inferred from the theoretical and macroscopic analysis results of existing studies[1]. Existing studies estimated that automation does not create additional employment or that existing manpower has been replaced.

According to the review of employment models above, it is possible to observe that automation decreases employment in the short term and recovers the decrease through additional small-scale employment in the long term to eventually return to the previous level of employment or to a level slightly below the previous level.

Table 4. Estimation results for the employment-growth models

Variables	Models	
	Employment growth	The ratio of employment growth
Automation		
Automation (t)	-12.59*** (4.34)	-.01 (.01)
Automation (t-1)	-6.47 (6.78)	-.01 (.01)
Automation (t-2)	-6.00 (5.50)	-.01 (.01)
Controls		
Intercept	-55.69 (52.70)	-.09 (.12)
Total laborers	.20*** (.05)	.01* (.00)
Competition	-.45 (.58)	.01 (.01)
Price	.28 (.44)	.01 (.01)
Demand	.23 (.75)	-.01 (.01)
Time dummy: 2013	11.41* (6.54)	.02 (.01)

4.2 Productivity effect

The productivity effect can be comprehended based on the estimation results in Table 5. The analysis of the productivity model shows that automation does not have a significant impact on sales per employee. Rather, it is shown that automation has negative effects (i.e., each coefficient value -36.45, -38.92) on the added-

value per employee at times t and t-1. Both academic and industrial circles have generally predicted that automation can lead to labor-saving production activities. However, the analysis results of this study showed that automation rather reduces corporate productivity in the short and medium terms. This is a very interesting result that supports the arguments of previous studies that the type of automation that Korean companies have promoted could be labor-exclusive, which is estimated to be attributed to the negative influences on laborers' voluntary efforts to enhance productivity. It was also found that it would take a long time, at least four years, to restore this effect on decreasing productivity to pre-automation levels.

Table 5. Estimation results for the productivity models

Variables	Models	
	Sales per employee	Added-value per employee
Automation		
Automation (t)	-172.68 (198.203)	-36.45*** (7.69)
Automation (t-1)	-212.14 (307.72)	-38.92*** (11.95)
Automation (t-2)	45.22 (250.90)	-13.79 (9.71)
Controls		
Intercept	3264.36 (2411.73)	138.05 (93.52)
Total laborers	-1.09 (2.28)	-0.04 (.08)
Competition	2.11 (26.64)	6.81*** (1.03)
Price	-1.88 (20.13)	3.81*** (.78)
Demand	-5.46 (34.45)	-8.91*** (1.33)
Time dummy: 2013	-241.63 (296.70)	-23.44** (11.67)

4.3. Profitability effect

No statistical basis was found to say that automation affected the improvement of profitability. Table 6. is the result of the estimation of the profitability model. As in the estimation result, all coefficients of automation count at each time were insignificant. And yet, the effect of automation was -22.15 at time t, -0.05 at time t-1, and 33.67 at time t-2, so there might be a tendency according to time, but it was not a statistically significant result. This could have been attributed to the simultaneous decline in productivity even under the condition that labor costs have declined due to the decrease in employment, in part. It appears that it is difficult to find the difference in ultimate profitability between companies that introduced automation and companies that did not, based on these results. These estimations suggest that questions about goals and processes in the introduction of automation by Korean companies and the efforts to coordinate labor and automation shall be reconsidered.

Table 6. Estimation results for the productivity model

Variables	Model
	Operating profit per employee
Automation	
Automation (t)	-22.15 (29.42)
Automation (t-1)	-0.05 (45.48)
Automation (t-2)	33.67 (37.27)
Controls	
Intercept	124.96 (356.51)
Total laborers	-0.14 (.33)
Competition	-1.46 (3.95)
Price	0.43 (2.98)
Demand	0.72 (5.10)
Time dummy: 2013	-21.94 (44.18)

The results of the analysis above are summarized in Fig. 2. Panel A in the following figure shows that the impact of automation on turnover was time-lagged over two to six years (i.e., times t, t-1, and t-2), that on hire appeared after six years, and that on the ultimate

increase in employment decreased in the second year and did not show a statistically significant effect in the fourth to sixth years. Panel B shows that automation has a time-lagged effect only on added-value per employee in the second to fourth years. However, it is difficult to state that there is a statistically significant effect on other performance variables, such as sales per employee and operating profit per employee. Nevertheless, since it is marginally observed that the trend of productivity and profitability increased in the long term, it may be necessary to confirm the possibilities related with this in future studies.

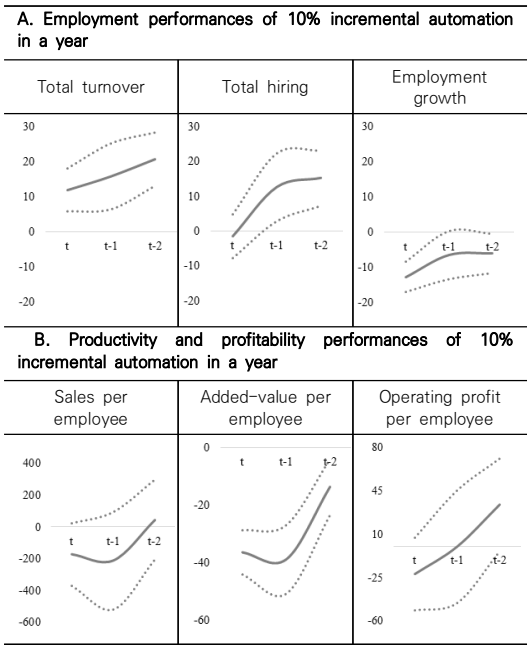

Fig. 2. Contribution of automation to employment, productivity, and profitability

5. Conclusion

Based on the results of this, automation in Korean companies had a positive effect on employment to some extent, but that rather decreased productivity and did not have any impact on profitability. In particular, employment decreased in the short term; however, it had a pattern of restoring the original status in the long term. Although automation is supposed to lead to an increase in productivity and profitability in the long term as it leads an increase in efficiency, no positive effect was observed in the data of this study. A clue to the interpretation of this result can be found in the result of a recent study of the pattern of the growth of the productivity of the companies that introduced new technology[34]. In the study, since new technology provides a foundation or foundational engine for the increase of productivity, it is not easy to capture the performance earlier. It is also assumed in this study that it is necessary to analyze longer-term data in this study.

This study has the following theoretical implications. This study analyzed employment on a multidimensional scale like turnover, employment, and employment growth rate, which is an important foundation for economic development. Like the result of the analysis, turnover and employment increased while employment growth rate did not change. In other words, it is assumed that changes in the composition of workers and exchange between companies can be expected while the total number of jobs does not change. This result shows a result similar to that of the related studies conducted in the 1990s[27] and the 2000s[32]. On the other hand, in terms of profitability and productivity, no positive long-term effect because of automation was found. This is a result conflicting the results of the previous studies[11,14,15,33] that automation had advantages of increasing productivity and profitability. It would be necessary to conduct an additional study of the reason why productivity and profitability did not increase.

This study provides policy makers and firm managers with important practical implications. At the national level, to manage economic stability at the individual and company levels, it is necessary to manage both employment and corporate performance, and this study can be utilized as a guide to deriving policy strategies. In addition, companies and workers can establish long-term strategies by expecting how the employment details change when new automation technology is introduced and how workers' stable jobs are affected. For example, it was expected that earlier after the introduction of automation technology, the levels of turnover and increase in employment would decrease while later, the number of employment would increase the most, and companies and individual workers can prepare response strategies according to changes in employment at each point in time. This strategic response is expected to contribute to lowering volatility and instability in the employment market.

There are limitations that could not be considered regardless of the academic and practical achievements of this study. First, the causal relationship between automation, productivity and profitability needs to be taken into consideration more accurately. In actual corporate activities, automation is adopted with the aim of increasing productivity and profitability. However, higher productivity and profitability could serve as an opportunity to adopt more automation. Other studies suggested models that allowed considering the issues of endogeneity of automation and its reverse causality with other variables[28, 30]. Sophisticated assumptions and fine analyses of the relationship among variables will be required in future studies.

Second, our research implies the possibility of endogenous profitability and confounding effects between automation and profitability. In the estimated results, the effects of automation are insignificant. Acemoglu and Restrepo[28] examined that rapid automation increases new labor-incentive tasks for less profitable. They also pointed out that automation could make more profitability by the highly productive process. The confounding effects should be examined in the future study.

Third, the index for measuring the level of automation failed to measure the various aspects of automation. There are various aspects in the subtypes of automation, such as standardization, analysis and innovation of the production process, the expansion of machines and facilities, and the development of human resources. Furthermore, the empirical materials of this study overlooked the qualitative aspects of automation and innovation, such as how the labor force was relocated or retrained during the course of automation.

Fourth, it is necessary to increase the generalizability of the study by diversifying the companies investigated. This study targeted companies with 30 or more employees in Korea as the samples. It would be possible to compare the details of automation and the outcomes thereof by expanding the subject of investigation to companies in various other countries. This study also failed to analyze the difference between company types, due to an insufficient amount of observed data required for model estimation, although it included samples of various types of companies such as manufacturers, service providers, and public institutions. Industries other than the manufacturing industry may have different purposes for automation.

Finally, an additional analysis should be performed on the reason productivity was

reduced by automation. For example, the decrease in productivity could have been influenced by the qualitative deterioration of the labor force due to labor replacement or the decrease in the desire to participate voluntarily. It would be possible to more clearly clarify the causal relationship between automation and decline in productivity derived from this study by performing additional analyses on various possibilities in the future.

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