Korea and the World Economy, Vol. 15, No. 2 (August 2014) 289-307

The Effects of Technological Change on Employment: The Role of ICT*

Jaeuk Ju**

This paper empirically analyzes the effects of technological change, particularly the Information & Communication Technology (ICT) utilization, on employment structure. A relative labor compensation model and an employment model are estimated to find out the characteristics of change in technology and complementarity between capital and labor, which are the critical variables determining the relationship between technological change and employment. In the relative labor compensation model by technological level, empirical results show a significant capital-augmenting effect of technological change and a consequent substitutability between capital and labor at the mid-low level of skill group in the manufacturing industry, which is the only critical evidence of a decrease in employment due to technological advancement. Through the rest of the models, the effects of technological progress on employment can be represented in both positive and negative directions. Therefore, it is not true that technology is always the cause of jobless growth.

JEL Classification: J23, L16, L60, O33
Keywords: ICT, employment, technological change, panel data, fixed effect model, OECD

---

* Received May 7, 2014. Revised June 13, 2014. Accepted July 16, 2014. This research has been made as a part of KISDI's annual research, "The Employment Effect of New ICT Technology and Service," Ju, Jaeuk and Jung, Hyun Joon (2012).
** Korea Information Society Development Institute (KISDI), E-mail: jujaeuk@kisdi.re.kr

1. INTRODUCTION

Declining labor share can be currently found in almost all OECD countries. And it is interpreted as an evidence of jobless growth. Since the decreasing labor share negatively affects employment, it is considered as an important policy issue. So, various studies have been conducted to find out reasons behind the trend. Technological development has been considered as the most influential factor of the falling labor share. Still, there is an ongoing debate on the effects of technological change, such as ICT utilization, on employment, and various arguments coexist.[1] And a fundamental question arises: Does technological change increase employment? The question leads directly to an examination to see whether it is labor-augmenting or capital-augmenting. If technological change is found to be labor-augmenting, it directly raises employment. However, if it turns out to be capital-augmenting, it has no contribution to an increase in employment. In this case, it is necessary to check complementarity between labor and capital. If labor and capital are substitutes when technology is capital-augmenting, technological change in technology decreases employment. Therefore, examining labor and capital complementarity and characteristics of technological change are the main subjects for identifying the effects of technological change on employment.

In addition, technological progress may have different employment effects for each industry and each skill level of workers. Therefore, structural characteristics across industries or skill levels should be considered in this examination. This paper provides empirical evidence of the effects of technological change, represented by ICT utilization, on employment. The OECD (2012) and O'Mahony *et al*. (2008) present theories dealing with the employment effects of the technological change. This paper applies their theories to the case of ICT industry, using panel data of almost all OECD countries. The existing studies are limited only to several cases in a few of highly industrialized countries, such as the US, UK, and France. Their

[1] See Literature Review for details.

findings may not be appropriate to be applied to other developed countries, which have experienced a rapid development of technology. Thus, it is needed to provide an unbiased and more general finding, using a larger group of samples. To overcome this problem, this research employs a panel analysis approach based on samples of 28 developed countries. In addition, this paper deals with the issues on industry and skill level structures, analyzing the effects for each industry and each skill level. However, in this research, the effect for each skill level is analyzed only for the manufacturing industry due to the limitations of available data.

Empirical results show that technological change is capital-augmenting in the retail industry, while there is a complementarity relation between capital and labor. In the manufacturing industry, technological change is labor-augmenting among high level and low level of workers. Capital-augmenting technological change is found in mid-low level of workers, when capital and labor are found to be substitutable. In conclusion, there is no consistent evidence that technological growth depresses employment with the only exception of mid-low level of workers in the manufacturing industry.

The rest of this paper is organized as follows: Literature is reviewed in section 2. Empirical models are described in section 3, and results in section 4. This paper concludes in section 5.

2. LITERATURE REVIEW

ICT, as a general-purpose technology, like the telegraph, telephone, steam engine, or electric motor, raises productivity dramatically at the level of whole industries. A variety of studies have attempted to examine the impact of ICT on the economy, especially on employment. The impact of human capital on the economic growth has also been studied in various ways (Kim, 2013). The ICT industry changes the distribution of employment depending on proficiency, that is, the structure of employment. Moreover, according to the level of industrialization or economic development, ICT could result in either a rise or a fall in employment. Previous studies categorized these employment effects as two categories: process innovation and product innovation (Utterback, 1975). Process innovation contributes to a decline in employment, and product innovation encourages a rise in employment. Therefore, comparing these two effects is equivalent to finding out whether ICT actually increases employment or not. And then, the employment effect of ICT has been more elaborately analyzed at the levels of firm, industry and macro economy. Studies at the firm level include Northcott (1984), Kaplinsky (1985), Brouwer *et al*. (1993), Doms *et al*. (1995), Brynjolfsson and Hitt (2000), Bresnahan, Brynjolfsson and Hitt (2002), Jaumandreu (2003), Peters (2004), and Harrison *et al*. (2008); studies at the industry level include Rosenbrock (1982) and TEMPO (Technological Trends and Employment, 1985); and studies at the macroeconomic level include Bentolila and Saint-Paul (1999), O'Mahony *et al*. (2008), Arpaia *et al*. (2009), Driver and Muñoz-Bugarin (2010), Raurich and Sorolla (2012) and Hutchinson and Persyn (2012).

Northcott (1984) shows that the introduction of ICT led directly to a less than 0.5% of decrease in total employment in the manufacturing industry, which implies the effect of product innovation is relatively large. Evidence is found in a research released in 2000 that ICT has an effect on changes in employment structure. Brynjolfsson and Hitt (2000) analyze the effect of ICT investment in improving firms' productivity and organizational structure. The results provides empirical evidence that ICT enables complementary investment in organizational structure, and contributes to productivity enhancement through cost saving, product quality improvement, production of new goods, and an increase in diversity. Bresnahan, Brynjolfsson and Hitt (2002) try to search for empirical evidence on the assumption that ICT plays an essential role in increasing demand for skilled labor. They consider ICT as a driver of change in economic structure, and insist that employers with high frequency of ICT usage bring complementary innovation to their organization and services they provide. That is, skill-augmenting technological change is brought by a collection of complementary changes with ICT. In the analysis of skill bias of labor from industry-level data by ICT usage level, a significant evidence of complementarity is observed. Jaumandreu (2003) estimates the direct effect of product innovation. In a study at the industry level, the Rosenbrock (1982) concludes that there is no close relationship between technological change and a fall in employment.

The employment effect of ICT at the macroeconomic level is still debated. Current studies on a decrease in labor share are also dealing with the role of capital accumulation and capital-augmenting technological change. Bentolila and Saint-Paul (1999) confirm their hypothesis through an empirical analysis, estimating the equation derived from the standard production function, including total factor productivity, as a proxy variable for technological change. In the research, it is found that both capital intensity and total factor productivity have negative effects on labor share. O'Mahony *et al*. (2008) try to measure the effect of ICT on skilled labor with a cross-country comparison. And their study shows that the effect of ICT on the demand for skilled labor is declining at least in the US. However, it has limitations as their panel data analysis is done for each country and each skill group by industry and time, following analyzing data separately for each country and its technological level. The three countries, the US, UK and France, have significantly different characteristics in technology and employment structure. Though O'Mahony *et al*. (2008)'s results identify individual characteristics of these countries, which are useful to see how different they are, the study still does not tell what is common features regarding the effect of technological change on employment shared by all developed countries, including the rest of OECD countries. In order to establish a more generalized mechanism to figure out a relationship between technological change and employment, it is necessary to analyze the effects on all developed countries. This paper tries to find out the common characteristics among almost all developed countries by replicating O'Mahony *et al*. (2008)'s approach and doing a panel data analysis by country and time, using the extended data set.

3. EMPIRICAL MODELS

A model to capture the effect of technological development on employment can be constructed by deriving wage and employment from cost and production functions. The model is a modification of the cost function, proposed by Brown and Christensen (1980), Chun (2003) and O'Mahony *et al*. (2008). The first model is about the relative labor cost, and is made by applying Shephard's lemma from translog cost function. In this model, the ratio of wage of industry i to the total wage of labor for each country is used as a dependent variable. The log of the ratio of capital to output is an explanatory variable to represent the degree of complementarity between capital and labor. Another explanatory variable is the ratio of fixed capital injected into the ICT of a country to its fixed capital, which is used as a technological indicator. In the second model, the ratio of wage by skill level j to the total wage is a dependent variable to capture the effect of technological change on the movement of employment among skill levels in the manufacturing industry. The third and fourth models are proposed to evaluate the direct effect of technological change in relative employment ratio. These models are used to test a hypothesis that ICT adoption causes an increase in demand for ICT skilled labor, as well as changes in wage structure.

The methodology of this research is basically inspired from O'Mahony *et al*. (2008), but is different from their research for the following reason. First, this paper employs a more generalized approach, utilizing the panel data of OECD countries. Second, the effects of technological change on employment are estimated from two different perspectives: i) employment among four major industries, including the agriculture-fishing, manufacturing, retail and finance-service industries, and ii) employment among four skill groups, including high, mid-high, mid-low and low groups.[2)]

[2)] Due to the limitation of the data, the effects on skill groups are estimated only in manufacturing industry.

To summarize, this research examines the impact of capital intensification and technology adoption on employment in both various industries and various skill levels in OECD countries. In order to do this, employment, value-added, fixed capital, and ICT fixed capital data are used.

$$\Delta \frac{W_{ki}}{W_k} = \beta_0 + \beta_K \Delta \ln \frac{K_k}{Y_k} + \beta_I \Delta \ln \frac{IK_k}{K_k} + \beta_A \Delta \ln \frac{E_{ki}}{E_k} + \varepsilon_k . \quad (1)$$

The first model is for relative labor compensation by industry, the ratio of the labor compensation of an industry $i(W_{ki})$ to the total labor compensation of country $k(W_k)$. This model includes capital intensity, that is, the capital-skill complementarity represented by the ratio of capital (K_k) to value added (Y_k), the technological indicator represented by the ratio of ICT fixed capital (IT_k) to fixed capital (K_k), and the relative employment by industry, the ratio of employment of an industry $i(E_{ki})$ to total employment (E_k) as explanatory variables. The time subscript and dummy variables have been dropped for simplicity.

$$\Delta \frac{W_{kj}}{W_k} = \beta_0 + \beta_K \Delta \ln \frac{K_k}{Y_k} + \beta_I \Delta \ln \frac{IK_k}{K_k} + \beta_A \Delta \ln \frac{E_{kj}}{E_k} + \varepsilon_k . \quad (2)$$

The second model is about relative labor compensation by skill level in the manufacturing industry. A dependent variable is the ratio of labor compensation of a skill level *j* in the manufacturing industry (W_{kj}) to total labor compensation of a country $k(W_k)$. The same explanatory variables, as in model (1), are used except for the third variable. Instead of employment of an industry, the employment of a skill level *j* in the manufacturing industry (E_{kj}) is used.

$$\Delta \frac{E_{ki}}{E_k} = \beta_0 + \beta_K \Delta \ln \frac{K_k}{Y_k} = \beta_I \Delta \ln \frac{IK_k}{K_k} + \varepsilon_k , \quad (3)$$

$$\Delta\frac{E_{kj}}{E_k} = \beta_0 + \beta_K \Delta\ln\frac{K_k}{Y_k} = \beta_I \Delta\ln\frac{IK_k}{K_k} + \varepsilon_k . \quad (4)$$

The third and the fourth models are built to estimate the direct effect of capital intensity and technological indicator on employment structure by both industry and skill level.

4. EMPIRICAL RESULTS

4.1. Data

For this research, employment shares in total economy, labor compensation per employee in total economy, investment intensity based on value added, investment shares relative to total economy and employment share of ICT industry in total economy were extracted from the STAN (structural analysis) database provided by OECD. The sub-categories of the data are indicated in appendix.

Because data were partially missing for 6 countries, including Chile, Israel, Japan, Mexico, Switzerland, and Turkey Twenty, 28 of the 34 OECD countries are included. And their annual data until 2009 were used. Capital intensity is gross fixed capital formation, current price divided by value added, which means capital skill complementarity. The technology indicator is the fixed capital formation of ICT divided by the gross fixed capital formation, which means the degree of ICT technology adoption. The share of ICT employment is the ratio of employment in the ICT industry in a country to total employment in that country. Relative labor compensation for an industry is the average wage in an industry in a country divided by the average wage in the country. The share of employment in an industry is employment for the industry divided by total employment. The basic statistics of these variables are shown in table 1 and table 2. Considering the characteristics of the model, capital intensity, technological

Table 1 Basic Statistics of Explanatory Variables

(unit: %)

Country	Period	Investment Intensity		Technological Indicator		ICT Employment Portion	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Australia	1981-2007	25.8	2.1	3.6	0.9	7.6	1.9
Austria	1981-2009	25.7	1.4	13.4	2.2	9.8	0.2
Belgium	1981-2009	22.3	1.7	6.6	5.2	8.9	2.2
Canada	1981-2006	21.9	1.7	8.9	1.7	8.3	0.4
Czech Republic	1995-2009	29.9	2.9	11.9	2.8	10.9	0.6
Denmark	1981-2009	22.6	2.0	6.4	5.6	11.0	0.7
Estonia	1995-2007	33.3	4.1	10.3	2.6	6.0	0.5
Finland	1981-2009	25.0	4.1	8.2	1.4	9.7	1.2
France	1981-2008	22.3	1.5	7.0	3.1	9.1	0.7
Germany	1981-2008	23.0	1.8	11.6	6.9	10.5	0.8
Greece	1995-2009	22.6	2.3	8.0	1.9	8.0	1.0
Hungary	1995-2009	25.8	1.0	14.0	2.6	8.4	1.4
Iceland	1991-2008	25.6	6.1	3.8	1.7	0.0	0.0
Ireland	1986-2008	23.0	4.1	9.7	3.1	7.2	4.2
Italy	1981-2009	23.0	1.5	2.9	1.8	7.1	2.8
Korea	1990-2006	36.0	3.9	6.2	2.8	3.9	0.2
Luxembourg	1995-2009	23.4	1.8	14.6	2.9	8.5	0.9
Netherlands	1981-2007	23.6	1.3	11.8	2.3	8.8	2.7
New Zealand	1989-2006	21.6	2.0	4.9	1.6	1.4	0.7
Norway	1981-2009	25.2	4.0	6.7	2.4	9.0	1.9
Poland	1994-2007	23.0	2.8	12.2	3.6	1.2	0.1
Portugal	1995-2006	28.0	2.3	2.9	3.4	7.1	1.7
Slovak Republic	1995-2009	30.4	4.4	12.1	2.5	12.4	1.5
Slovenia	1995-2008	28.8	2.1	10.1	1.3	9.9	0.2
Spain	1981-2009	26.3	3.9	1.0	0.3	4.8	2.2
Sweden	1981-2009	21.7	2.8	6.5	2.8	5.2	0.9
U.K.	1981-2008	18.8	1.7	9.4	4.4	1.7	0.4
U.S.A.	1981-2009	18.0	1.2	9.7	1.9	4.2	0.5

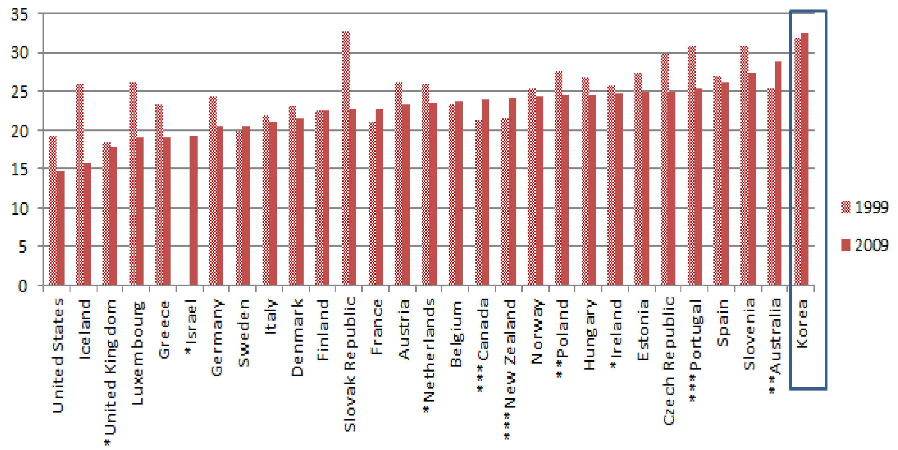
indicator, and the ICT employment share by country are shown in table 1, and relative labor compensation and employment share by industry are shown in table 2.

Table 2 Relative Labor Compensation and Labor Portion by Industry

Category		Relative Labor Compensation		Labor Portion	
		Mean	S.D.	Mean	S.D.
Total	Agriculture & Fishery	43.1	14.1	6.3	1.0
	Manufacturing	118.0	2.1	18.6	1.8
	Retail	75.9	0.9	19.6	0.4
	Finance & Service	124.6	3.0	12.1	1.9
Manufacturing	High technology	148.8	13.2	1.7	0.1
	Mid-High technology	139.5	2.3	4.6	0.8
	Mid-Low Technology	122.4	3.3	4.5	0.5
	Low technology	100.1	3.0	8.2	1.0

Figure 1 Investment Intensity by Country[3)]

(unit: %)



Source: STAN Database for Structural Analysis, OECD.

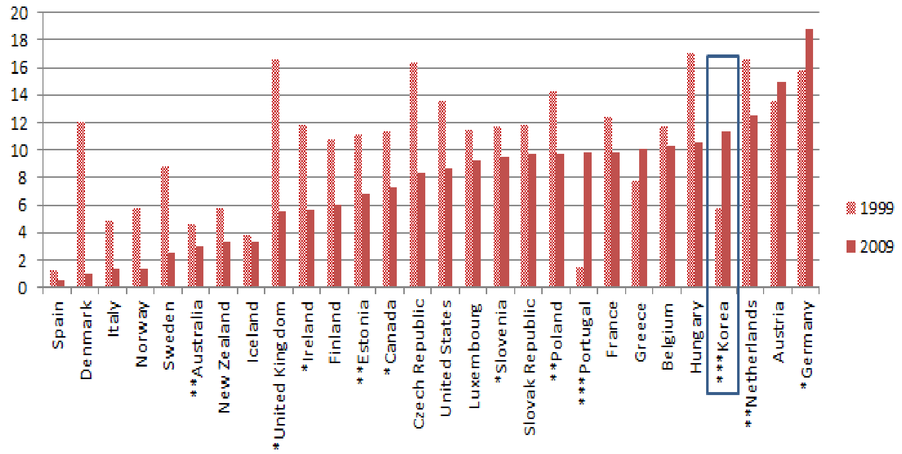
Figure 1 is the comparison of investment intensity by country between 1999 and 2009. As of 2009, Korea is the highest in investment intensity, while the US is ranked the lowest.

---

3) 2008 (*), 2007 (**), and 2006 (***) data were used because the data were not reported.

Figure 2 Technological Indicators[4)]

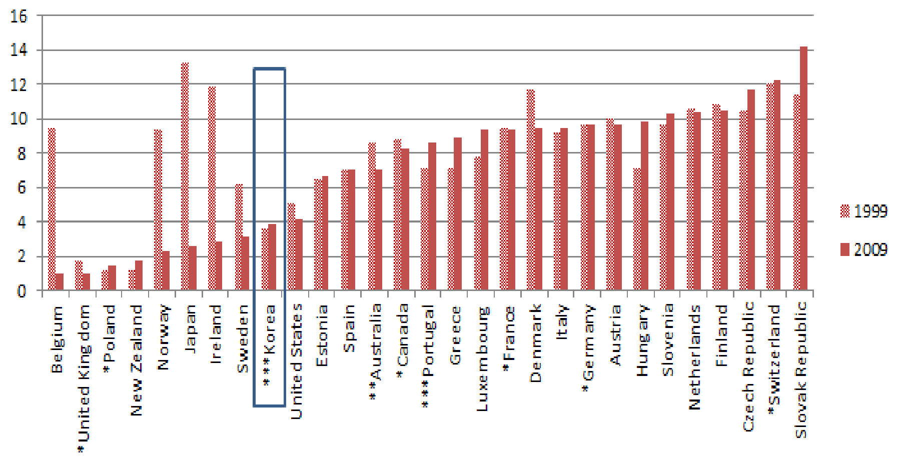
(unit: %)



Source: STAN Database for Structural Analysis, OECD.

Figure 3 ICT employment portion[5)]

(unit: %)



Source: STAN Database for Structural Analysis, OECD.

4) 2008 (*), 2007 (**), and 2006 (***) data were used because the data were not reported.
5) 2008 (*), 2007 (**), 2006 (***) data were used because data were not reported.

Figure 2 is the comparison of technological indicators by country between 1999 and 2009. While the UK, Czech, Hungary, and the Netherlands were the countries with high technological indicators in 1999, Germany's technological indicator is the highest in 2009. Korea's technological indicator in 2009 ranks the nation as the 4th highest among OECD countries.

Figure 3 is the comparison of the ICT employment share by country between 1999 and 2009. While Japan's ICT employment portion was the highest in 1999, Slovakia is the highest in the share in 2009. Korea's ICT employment portion is lower than the mean of the OECD countries.

4.2. Results

As all models in this research are estimated using the fixed effect models, country and time effects are controlled. The results of the regression model for relative labor compensation are shown in table 3. In case of the model the retail industry. These results could be evidence of capital-labor complementarity only in the retail industry, but they are not statistically

Table 3 Model for Relative Labor Compensation

	Agriculture & Fishing	Manufacturing	Retail	Finance & Service
Capital Intensity	–6.049 (12.94)	–1.492 (1.63)	1.128 (1.52)	–1.473 (3.59)
Technological Indicator	1.986 (2.56)	–0.453 (0.32)	0.166 (0.30)	0.816 (0.71)
Employment Share	1.914 (3.96)	0.266 (0.50)	–0.219 (0.46)	0.432 (1.10)
Constant	0.965 (6.19)	–0.57 (0.78)	0.97 (0.73)	–2.164 (1.75)
Observations	573	573	567	572
R-squared	0.074	0.229	0.102	0.148

Note: values in ( ) are standard errors, *** p<0.01, ** p<0.05, * p<0.1.

Table 4 Regression Results by Technological Level: Relative Labor Compensation

	High	Mid-High	Mid-Low	Low
Capital Intensity	–13.181** (5.91)	–0.529 (4.92)	–10.693*** (3.23)	–0.487 (1.56)
Technological Indicator	0.178 (1.17)	0.489 (0.85)	–1.010* (0.57)	–0.389 (0.33)
Employment Share	–7.574*** (2.45)	2.208 (1.76)	0.343 (1.19)	0.158 (0.49)
Constant	1.594 (5.25)	0.291 (2.74)	–4.249** (1.92)	–0.362 (0.77)
Observations	361	332	347	560
R-squared	0.197	0.182	0.271	0.164

Note: values in ( ) are standard errors, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

meaningful, because there are large standard errors.[6)]

Table 4 is the estimated result of the model for relative labor compensation by technological level in the manufacturing industry. The coefficient of technological indicator is significantly negative among mid-low level of skill group in the manufacturing industry, which implies that employment in that skill group is affected by capital-augmenting technological change. The coefficients of investment intensity are negative at all levels, especially at the high and mid-low levels. This can be interpreted as the substitutability between capital and labor among high level and mid-low level of skill groups in the manufacturing industry. In other words, when closely analyzing only the manufacturing industry, it is found that technological development depresses employment in mid-low level of skill group. On the other hand, such a significant result was not derived at the mid-high and low levels, which means that the substitution of capital for labor due to capital-augmenting

6) The model is using unbalanced panel data. In case of model by industry, panel data is used for country and year. 28 countries are included and the number of years is different for each country. For example, Austria has 27 years (1981-2007), while Czech Republic has 15 years (1995-2009). In case of model by technological level, only 18 countries are included. For those reason, the number of observation can be different.

Table 5 Regression Results: Employment Share by Industry

	Agriculture & Fishing	Manufacturing	Retail	Finance & Service
Capital Intensity	–0.531** (0.21)	1.009*** (0.28)	0.564** (0.25)	0.077 (0.23)
Technological Indicator	–0.007 (0.04)	0.074 (0.06)	–0.108** (0.05)	–0.005 (0.05)
Constant	–0.273** (0.11)	–0.930*** (0.15)	0.332** (0.13)	0.113 (0.12)
Observations	601	601	597	600
R-squared	0.324	0.26	0.192	0.22

Note: values in ( ) are standard errors, *** p<0.01, ** p<0.05, * p<0.1.

technological change does not occur consistently at the technological level. In order to clarify this inconsistency, further analysis will be required.

Table 5 is the estimated result of the model determining employment share by industry. Technological indicator represents a significant negative coefficient in the retail industry. That is, the employment in the retail industry is affected by capital-augmenting technological change. However, since the coefficient of capital intensity in the retail industry is found to be significantly positive, there is complementarity between capital and labor. Thus, it is appropriate to explain that there is no critical evidence of a decline in employment caused by technological change.

Table 6 is the estimated result for employment share by technological level in the manufacturing industry. It shows that employment among high and low levels of skill groups in the manufacturing industry is affected by labor-augmenting technological change, and capital-labor complementarity is found in mid-high and mid-low levels of skill groups. All of these results imply the possibility that technological progress may positively affect employment in various levels of skill groups in the manufacturing industry, and at least there is no critical evidence of a fall in employment resulted from technological change.

Table 6 Regression Results by Technological Level: Employment Share

	High	Mid-High	Mid-Low	Low
Capital Intensity	0.112 (0.11)	0.409** (0.19)	0.593*** (0.14)	0.203 (0.16)
Technological Indicator	0.054** (0.02)	0.001 (0.03)	0.03 (0.02)	0.052* (0.03)
Constant	0.012 (0.07)	–0.033 (0.15)	–0.213*** (0.08)	–0.402*** (0.07)
Observations	355	327	340	563
R-squared	0.274	0.271	0.383	0.257

Note: values in ( ) are standard errors, *** p<0.01, ** p<0.05, * p<0.1.

To sum up, there is capital-augmenting technological change in the retail industry. It would be valuable to compare the result of this research with O'Mahony *et al*. (2008) since this paper is a replication of their research's approach. O'Mahony *et al*. (2008) tried to find out if there is capital-skill complementarity in diverse skill levels of workers in the US, UK and France. It turned out that there is capital-skill complementarity among the most educated workers in all the three countries, while, for the unskilled workers, there is capital-skill complementarity in US and UK, and substitutability in France. Among intermediate workers, there is capital-skill substitution in all the three countries, with the exception of French workers with a Baccs2.[7] In all the three countries, the ratio of ICT capital to total capital has negative impacts on wage shares of unqualified workers. The focus of O'Mahony *et al*. (2008) is whether the demand for skilled labor affected by technology is temporary or permanent. They insist that it is temporary by showing that the demand for skilled labor is slowing down only in the US. This paper is focusing on the effect of technological change on the inter-industry movement of employment and on the inter-skill level movement of

[7] A baccallaureate plus 2 years of college.

employment in the manufacturing industry. Therefore, I tried to find whether ICT development is a culprit for jobless growth.

5. CONCLUSION

In this research, the impact of technological change in production, particularly the utilization of ICT, on employment structure is empirically analyzed based on the data of 28 countries. As explanatory variables, investment intensity, which is the ratio of investment to value-added technological indicator, the ratio of ICT fixed capital to total fixed capital, and the share of ICT employment to whole industry are used. The effects of country and year are eliminated, using dummy variables. As a result, there is no significant relationship between technological indicator and capital intensity in the relative labor compensation model by industry. Meanwhile, in the relative labor compensation model by technological level, there is a significant capital-augmenting technological change and capital and labor substitutability in mid-low level of skill group, which is the only evidence of a decline in employment caused by technological change in this empirical analysis. In the employment share model, capital-augmenting technological change is found in the retail industry, but there is complementarity between capital and labor. In the employment model in the manufacturing industry by skill level, there is labor-augmenting technological change in high and low levels of skill groups. Complementarities between capital and labor are found among mid-high and mid-low level in the manufacturing industry. Although all these models do not show a completely consistent relationship between technological change and employment and there is no critical evidence of falling labor share caused by technological change, this result suggests that among mid-low level of skill group in the manufacturing industry, technological change significantly discourages employment.

Comprehensively, it is observed that technological change, particularly the adoption of ICT technology, has impacts on changes in employment structure. But it is not true that technology is always responsible for jobless growth. As this result shows, technological change can affect employment in both directions of capital-augmenting and labor augmenting. And the effect can also be different depending on complementarity between capital and labor. Since these effects are inconsistently observed, a more advanced study is necessary to find differences in employment effects according to industrial or technological levels.

REFERENCES

Arpaia, Alfonso, Esther Perez, and Karl Pichelmann, "Understanding Labour Income Share Dynamics in Europe," *Economic Papers*, 379, 2009.

Bentolila, Samuel and Gilles Saint-Paul, "Explaining Movements in the Labor Share," Centro de Estudios Monetarios y Financieros, 1999.

Bresnahan, T., E. Brynjolfsson, and L. M. Hitt, "Information Technology, Workplace Organization, and the Demand Skilled Labor: Firm-level Evidence," *Quarterly Journal of Economics*, 117, 2002, pp. 339-376.

Brouwer, Erik, Alfredd Kleinknecht, and Jeroen O. N. Reijnen, "Employment Growth and Innovation at the Firm Level," *Journal of Evolutionary Economics*, 3, 1993, pp. 153-159.

Brown, R. S. and L. R. Christensen, "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to US Agriculture, 1947 to 1974," Workshop Series, Social Systems Research Institute, University of Wisconsin, No. 8007, 1980.

Brynjolfsson, E. and L. M. Hitt, "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *The Journal of Economic Perspectives*, 14(4), 2000, pp. 23-48.

Chun, H., "Information Technology and the Demand for Educated Workers: Disentangling the Impacts of Adoption versus Use," *Review of Economics and Statistics*, 85, 2003, pp. 1-8.

Doms, Mark, Timothy Dunne, and Mark J. Roberts, “The Role of Technology Use in the Survival and Growth of Manufacturing Plants,” *International Journal of Industrial*, 13(4), 1995, pp. 523-542.

Driver, Ciaran and Jair Muñoz-Bugarin, “Capital Investment and Unemployment in Europe: Neutrality or Not?,” *Journal of Macroeconomics*, 32(1), 2010, pp. 492-496.

Harrison, Rupert, Jordi Jaumandreu, Jacques Mairesse, and Bettina Peters, “Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparable Micro-Data from Four European Countries,” NBER Working Paper, No. 14216, 2008.

Hutchinson, John and Persyn, Damiaan, “Globalisation, Concentration and Footloose Firms: in Search of the Main Cause of the Declining Labour Share,” *Review of World Economics*, 148(1), 2012, pp. 17-43.

Jaumandreu, Jordi, “Does Innovation Spur Employment? A Firm-level Analysis Using Spanish CIS Data,” *Innovation and Employment in European Firms: Microeconometric Evidence*, Universidad Carlos III de Madrid, 2003.

Kaplinsky, Raphael, “Electronics-based Automation Technologies and the Onset of Systemofacture: Implications for Third World Industrialization,” *World Development*, 13(3), 1985, pp. 423-439.

Kim, Young-Joon, “Effective Human Capital and Long-run Economic Growth,” *Korea and the World Economy*, 14(3), 2013, pp. 475-515.

Northcott, J. and P. Rogers, *Microelectronics in British Industry: The Pattern of Change*, London: Policy Studies Institute, 1984.

O’Mahony, Mary, Catherine Robinson, and Michael Vecchi, “The Impact of ICT on the Demand for Skilled Labour: A Cross-country Comparison,” *Labour Economics*, 15(6), 2008, pp. 1435-1450.

OECD, *Employment Outlook*, 2012.

Peters, Bettina, “Employment Effects of Different Innovation Activities: Microeconometric Evidence,” ZEW-Center for European Economic Research Discussion Paper, No. 04-073, 2004.

Raurich, Xavier and Sorolla, Valeri, “Growth Models with Exogenous

Saving Rates, Unemployment and Wage Inertia," Working Paper, E12/287, 2012.

Rosenbrock, H. H., "Microelectronics, Robotics and Jobs," *OECD Report*, ICCP No 7 OECI, Paris, 1982.

Utterback, James M., "A Dynamic Model of Process and Product Innovation," *Omega*, 3(6), 1975, pp. 639-656.