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A Research on the effect of ICT Capability on the Society's Welfare: Multidimensional Deprivation Analysis including Technology as Attributes

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Abstract

Nowadays, the concept of multidimensional poverty, inequality, deprivation, and well-being is not uncommon. While theoretical progress such as capability theory has provided rigorous framework for multidimensional analysis, empirical methods and tools such as UNDP's MPI (multidimensional poverty index) are rapidly growing. Apart from income, various attributes—e.g. health, educational attainment, crime rate of neighborhood, and so forth—are being included for measurement of society's deprivation level. This article attempt to use technology, especially ICT as one of main factors with South Korea's data. Specifically, by comparing deprivation between 5 years in Korea, it analyzes how ICT affects the overall welfare of society.

Keywords: Multidimensional deprivation, ICT, Welfare economics, Poverty and Inequality

1. Introduction

This paper aims to analyze the socio-economic inequality—that is, dispersion of distributions of socio-economic attributes such as income—of society in a multidimensional framework in which technology plays an important role. Until now,

many researches have conducted an inequality analysis in a unidimensional framework that considers only a single attribute—that is, income. However, Sen (1985, 1992) states that inequality, poverty, and social welfare should be assessed by a multidimensional view. It means that well-being needs to be measured not by income alone and should be assessed in terms of ‘capabilities’.

Capability approach suggests that well-being should be measured by ‘functionings’ and ‘capabilities’ people enjoy. While functionings are defined by “beings and doings that people value and have reason to value”, capability indicates “various combinations of functionings that the person can achieve” (Sen, 1992). Although Sen has been reluctant to specify a list of capabilities, many researchers have tried to make lists that specify dimensions of human development (Nussbaum, 2000; Narayan et al., 2000; Schwartz, 1994). By these efforts, recent inequality analysis generally include non-monetary attributes such as health, education, crime rate, access to water, and so forth. Therefore, “[T]he lack of health attributes in any study on poverty now appears as a major drawback. Education appears as another important dimension which is even more complex to apprehend owing to its impact in dynamics on income streams” (Trannoy, 2005, p. 284)

However, technology, especially ICT, has been overlooked in these studies despite its importance and influence. In these days, ICT can affect society’s inequality and welfare in many different ways, especially for developed countries. People with high ICT capability can easily participate in the labor market, and they are highly paid due to their capabilities, while they can readily communicate with other people by using ICT capability. In consideration of the importance of ICT capability, it deserves to be contained in a list of capabilities.

This article conducts an empirical analysis including ICT capability as one of attributes and uses South Korea’s data. According to ITU (2017), South Korea topped the ICT development index in 2016 and hold the second rank in 2017. It shows that ICT is firmly established within everyday life in Korea, For example, computer programming education in middle/high school became compulsory in 2018 and it will be applied to elementary school in 2019. Therefore, ICT can be considered as a factor that affects individual well-being in Korea in view of its importance.

In this paper, research question is that multidimensional deprivation measurement including ICT capability as attributes can make different consequences for poverty, inequality, and social welfare comparison in Korea. For this purpose, deprivation index and stochastic dominance analysis are undertaken both in univariate and multidimensional framework. Index approach has the advantages of simply comparing various society's overall deprivation, whereas it compresses society's diverse phenomenon in a single parameter. On the other hand, stochastic dominance approach carefully examines how attributes are distributed in a society, but it is too restrictive in that conditions for stochastic dominance are difficult to hold. In addition, changes in deprivation with time will be analyzed. Specifically, deprivation changes between 2017 and 2012 in Korea are of interest.

The rest of the paper is as follows. Section 2 describes data and variables that will be used for empirical analysis. The empirical methods and results are presented in Section 3. Finally, Section 4 provides the implications and conclusion.

2. Data and Variables

1. Data

In the empirical analysis, "The Reports on the Digital Divide" (hereafter, '*Report*') raw data of 2017 and 2012 are employed. It is collected and issued every year by Korea's the Ministry of Science and ICT and National Information Society Agency (NIA). *Report* measures not just the ICT development level of individuals, but also their socio-economics characteristics such as monthly income, education, occupation, gender and so on.

Survey targets are divided into the general group (*Group 1*) and vulnerable social group (*Group 2-4*) and vulnerable group consists of (1) the people who engage in farming and fishing (*Group 2*), (2) the disabled (*Group 3*), (3) low-income group (*Group 4*). Excluding samples who have missing values, 2017 and 2012 data covers 13,575

individuals (6,978 in *Group 1*, 2,200 in *Group 2*, 2,197 in *Group 3*, 2,200 in *Group 4*) and 16,251 individuals (7,260 in *Group 1*, 3,000 in *Group 2*, 2,993 in *Group 3*, 2,998 in *Group 4*), respectively. For precision of estimation, all samples are drawn with proportionate stratified sampling method that considers gender, age, region as stratum.

2. Variables

Deprivation is measured the following 3 ordinal variables:

ICT capability

In this research, ICT capability takes integer value from 1 to 5. Specifically, the basic score starts with 1 and the values of 4 dimensions (*Access, Ability, Utilization, Sharing*) where each dimension is measured as binary 0-1 values are added. (For more detailed measurement criteria, see Appendix.)

Survey question to measure value of the same dimension are not totally identical in 2017 and 2012 due to the progress of ICT. In the *Access* dimension, for instance, survey in 2012 investigated the accessibility to the mobile phone and tablet PC for checking accessibility to the mobile device, whereas smart devices such as smart watch and smart health band are additionally included in the questionnaire. This is because in 2017, smart devices such as smart watch are distributed more widely than 2012. Since the ICT capability in specific period should correspond to the ICT development level of that period, survey questions of 2 periods (2017 and 2012) may be different from each other.

Income

As with ICT capability, monthly income is measured in an ordinal scale. It takes 1 if an individual's monthly income is lower than KRW 10m (million), 2 if income belongs to [10m, 20m), 3 if income belongs to [20m, 30m), 4 if income belongs to [30m, 40m),

and 5 if income is greater than KRW 40m.

Education

This variable takes 4 values: 1 if the person is uneducated or has graduated from elementary school alone, 2 if the person has graduated from middle school, 3 if the person has graduated from high school, and 4 if the person has graduated from university.

[Table 1] Descriptive statistics of ICT

ICT	Mean(2017)	S.E.(2017)	Mean(2012)	S.E.(2012)
Full sample	2.805746	.8949028	2.166759	1.024142
<i>Group 1</i>	3.029665	.9346467	2.39022	1.075565
<i>Group 2</i>	2.480455	.7482463	1.804333	.8268066
<i>Group 3</i>	2.508421	.7981919	2.019713	.9428589
<i>Group 4</i>	2.717727	.7840232	2.13509	1.019052

[Table 2] Descriptive statistics of Income

Income	Mean(2017)	S.E.(2017)	Mean(2012)	S.E.(2012)
Full sample	3.06674	1.41222	2.492524	1.310686
<i>Group 1</i>	3.828747	1.202236	3.125344	1.280581
<i>Group 2</i>	2.847727	1.173062	2.376	1.092561
<i>Group 3</i>	2.253528	1.199914	2.217173	1.244888
<i>Group 4</i>	1.680909	.8836221	1.351568	.4892735

[Table 3] Descriptive statistics of Education

Education	Mean(2017)	S.E.(2017)	Mean(2012)	S.E.(2012)
Full sample	2.553738	1.006482	2.316965	.996928
<i>Group 1</i>	2.821725	.9957791	2.563636	.9941002
<i>Group 2</i>	2.230455	.9832984	2	.983356

<i>Group 3</i>	2.422394	.9242774	2.381223	.944309
<i>Group 4</i>	2.158182	.8836221	1.972648	.8756059

3. Methodology and Result

As mentioned above, the empirical analysis of deprivation of Korea consists of the (ICT) univariate and multidimensional analysis. The objective of ICT univariate analysis is to figure out changes in ICT capability and its contribution to social well-being. In multivariate analysis, in addition, the results of analysis including ICT and not including ICT as one of the attributes are compared.

Also, empirical research will be conducted by indices approach and stochastic approach. Index approach can easily measure the ‘overall’ degree of deprivation of society and compare them, while it has been criticized for not making use of full information of distribution because it translates various attributes and aspects into a single parameter. On the other hand, stochastic dominance approach can take advantage of much information about distribution than index approach. However, it is relatively restrictive method since conditions for stochastic dominance approach does not hold easily. Therefore, the paper mainly conducts the empirical analysis through index approach and will be complemented by stochastic dominance analysis.

1. Univariate Analysis, ICT only

(1) Univariate Index Analysis

Poverty Indices: Headcount ratio and Poverty gap index

This subsection measures Korea’s ICT poverty changes by using Headcount ratio (HCR) and Poverty gap index (PGI). They are the most commonly used poverty measure and belongs to a class of Foster-Greer-Thorbecke (FGT) indices. Definition of HCR is as

follow:

Headcount ratio:

$$HCR = \frac{H}{N}$$

where N is the number of a population and H is the number of people living below poverty line

In other words, HCR means the proportion of population living below poverty line. Therefore, null and alternative hypotheses for test are as follows:

$$H_0: \Delta_{HCR} \geq 0$$

$$H_1: \Delta_{HCR} < 0$$

where HCT_{2017} and HCR_{2012} is HCR of 2017 and 2012,

$$\Delta_{HCR} = HCT_{2017} - HCR_{2012}$$

HCR has a weakness that it cannot identify the ‘depth’ of deprivation because HCR does not change even when the poor become poorer. Poverty gap index imposes more weight on ‘poorer’ individuals, then reflects poverty ‘gap’.

Poverty gap index:

$$PGI = \frac{1}{N} \sum_{i=1}^N \left(\frac{(z - y_i)I(y_i < z)}{z} \right)$$

where z is poverty line and $I(\cdot)$ is an indicator function

$$H_0: \Delta_{PGI} \geq 0$$

$$H_1: \Delta_{PGI} < 0$$

where PGI_{2017} and PGI_{2012} is PGI of 2017 and 2012,

$$\Delta_{PGI} = PGI_{2017} - PGI_{2012}$$

Each index was calculated twice in the case of $z=2$ and $z=3$ for robustness and results are as follows:

[Table 4] Poverty indices

Poverty line	Estimate of Δ_{HCR}		Estimate of Δ_{PGI}	
	$z = 2$	$z = 3$	$z = 2$	$z = 3$
Full sample	-.2533427***	-.3086794***	-.1266713***	-.1873407***
Group1	-.179983***	-.3523376***	-.0899915***	-.1774402***
Group2	-.3771515***	-.2451818***	-.1885758***	-.2074444***
Group3	-.2793523***	-.1874162***	-.1396762***	-.1555895***
Group4	-.2806119***	-.2944602***	-.140306***	-.1916907***

*Significance level of 5%.

**Significance level of 1%.

***Significance level of 0.1%

As seen in [Table 4], ICT poverty in Korea has been significantly declined. There has been a greater reduction in vulnerable group (especially, in *Group 2*) than the general group.

Inequality Indices: Gini index and Atkinson Index

Strong point of poverty index is that it can identify the poor and non-poor with ease. However, dispersion degree of attributes of the distribution is also important aspect in deprivation analysis. Then, through additional 2 indices—Gini index and Atkinson

index—ICT inequality between 2017 and 2012 can be compared.

Gini index (or “Gini coefficient) is the most widely used measurement of inequality. It would be zero when all individuals have equal attributes. Conversely, if one person has all attributes of society, it would be one. Therefore, our hypothesis is Gini coefficient of 2017 is lower than that of 2012, that is, $\Delta_{GINI} = GINI_{2017} - GINI_{2012} < 0$.

Atkinson index is also famous measure of inequality. (Atkinson, 1970) Different from Gini index, it has a parameter ε , “inequality aversion parameter”. The more ε is, the more averse to inequality a society becomes. In this article, ε is set to 0.5, 1, 1.5 for robustness of analysis. Definition and hypotheses about Atkinson index is as follows:

$$A_{\varepsilon} = \begin{cases} 1 - \frac{1}{\mu} \left(\frac{1}{N} \sum_{i=1}^N y_i^{1-\varepsilon} \right)^{1/1-\varepsilon} & \text{for } \varepsilon \neq 1 \text{ and } \varepsilon \geq 0 \\ 1 - \frac{1}{\mu} \left(\prod_{i=1}^N y_i \right)^{\frac{1}{N}} & \text{for } \varepsilon = 1 \end{cases}$$

$$H_0: \Delta_A \geq 0$$

$$H_1: \Delta_A < 0$$

The analysis results about difference of 2 indices are presented in the next tables.

[Table 5] Gini coefficients

	Estimate of Δ_{GINI}	Standard Error	t	P value
Full sample	-.0797969***	.0016865	-7.3151	0.0000
Group1	-.0744226***	.0022518	-33.0503	0.0000
Group2	-.0840111***	.0045928	-18.2919	0.0000
Group3	-.0822367***	.0048057	-17.1123	0.0000

Group4	-.1051147***	.003967	-26.4973	0.0000
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[Table 6] Atkinson index

$\epsilon = 0.5$	Estimate of Δ_A	Standard Error	t	P value
Full sample	-.0288007***	.0005151	-55.9128	0.0000
Group1	-.0264342***	.0006958	-37.9911	0.0000
Group2	-.0270862***	.0013035	-20.7796	0.0000
Group3	-.0273127***	.0013515	-20.2092	0.0000
Group4	-.0345258***	.0011993	-28.7883	0.0000
$\epsilon = 1$				
Full sample	-.0570928***	.000978	-58.3771	0.0000
Group1	-.053058***	.0013681	-38.7823	0.0000
Group2	-.053166***	.0023538	-22.5873	0.0000
Group3	-.0542357***	.0025102	-21.6061	0.0000
Group4	-.0683404***	.0022475	-30.4073	0.0000
$\epsilon = 1.5$				
Full sample	-.0841201***	.0013659	-61.5858	0.0000
Group1	-.0791973***	.0019768	-40.0634	0.0000
Group2	-.0776807***	.0031652	-24.5421	0.0000
Group3	-.0802629***	.0034518	-23.2525	0.0000
Group4	-.100356***	.0030971	-32.4032	0.0000

*Significance level of 5%.

**Significance level of 1%.

***Significance level of 0.1%

Through above results, it is shown that in all indices and groups, reduction of inequality in Korea between 2017 and 2012 is statistically significant. As with poverty

indices, difference levels are greater in vulnerable group (especially, in *Group 4*) than general group. Then, ICT deprivation in Korea seems to be declined in 5 years.

(2) Stochastic Dominance Analysis

Definition of Stochastic dominance

Deprivation measurement analysis belongs to ‘group aggregation problem’. In the past, the normative approach that makes a single index such as Gini index has been used for this problem. This approach has advantages that one can make a complete order for all distributions. However, since Atkinson (1970), Kolm (1977) and Atkinson and Bourguignon (1982)’s seminal contributions, the alternative approach that uses dominance criteria has provided an adequate basis to compare the inequality of well-being within and between populations. While the normative approach needs to impose strong restrictions on an individual utility function, the stochastic dominance approach has an advantage that it imposes relatively less restrictions on utility function.

In stochastic dominance approach, utility function have only to increase and concave in attributes. Also, while the normative approach is “confined to welfare judgements of a limited nature rather than presenting a total judgement about overall social welfare” (Sen, 1997, p. 54), a stochastic approach can use much information of the overall distributions.

This approach starts with the simple notion that compares the distributions of attributes and can make social welfare comparisons because social welfare functions are designed to be sensitive to inequality. Since then, Anderson (1996) and Davidson and Duclos (1997, 2000) presented a specific estimation and testing method for statistical inference.

Let the cumulative distribution function (CDF) of two society A and B be F_A and F_B , and define $D_A^1(x) = F_A(x)$ and

$$D_A^s(x) = \int_0^x D_A^{(s-1)}(y)dy$$

Then,

$$D^s(x) = \frac{1}{(s-1)!} \int_0^x (x-y)^{s-1} dF(y)$$

Distribution B dominates distribution A stochastically at order s if dominance curve $D_A^s(x) \geq D_B^s(x)$ for all x. In the perspective of poverty analysis, B stochastically dominates A at order s “up to poverty line” if $D_A^s(x) \geq D_B^s(x)$ for all “ $x \leq z$ ”, In the 1st order case, it means that $F_A^s(x) \geq F_B^s(x)$ for $x \leq z$. and therefore HCR is always lower in B than in A for all poverty line $x \leq z$. In the 2nd order circumstances, the average PGI, instead of HCR, is always lower in B than in A for any $x \leq z$.

On the other hand, stochastic dominance curve can be interpreted in the perspective of social welfare. Assume that social welfare function (SWF) is additively separable and symmetric for individual utility function $u(y)$ with one ordinal attribute y as argument.

$$SW(p) = \sum_{y_i=1}^s u(y_i)p(y_i)$$

$$\text{where } p(a) = \Pr[y_i = a] \text{ and } \sum_{y_i=1}^s p(y_i) = 1$$

Let $\Delta W = W^A - W^B$, then

$$\Delta W \geq 0 \text{ if and only if } \Delta F(i-1) \leq 0 \forall i \in [1, \dots, S] \text{ and } u \in U^1,$$

$$\text{where } U^1 = \{u | u(i) - u(i-1) \geq 0 \forall i \in [1, \dots, S]\}$$

. This is extended version of Atkinson and Bourguignon (1982)’s 1st order stochastic dominance argument for discrete ordinal attribute. (Yalonetzky, 2013) Therefore, we can check the changes of social welfare that uses “increasing (in y)” individual utility function by analyzing differences of CDFs (1st order stochastic

dominance).

In the 2nd order case, a class of individual utility function changes into a set of increasing and ‘concave’ utility functions; that is,

$$\Delta W \geq 0 \text{ if and only if } \sum_{j=0}^{i-2} \Delta F(j) \leq 0 \forall i \in [1, \dots, S+1] \text{ and } u \in U^2,$$

$$\text{where } U^2 = \{u | u \in U^1 \text{ and } ([u(i) - u(i-1)] - [u(i-1) - u(i-2)]) \leq 0 \forall i \in [1, \dots, S]\}$$

Inference, and Statistical test for Stochastic dominance

The results for 1st and 2nd order stochastic dominance by these criterion are as follows:

[Table 7] Stochastic dominance for full sample

Full Sample	1 st order		2 nd order	
Stochastic Dominance	>		>	
	ΔF_1	-0.0397***	ΔF_1	-0.0397***
	ΔF_2	-0.4533***	$\Delta F_1 + \Delta F_2$	-0.493***
	ΔF_3	-0.0334***	$\Delta F_1 + \Delta F_2 + \Delta F_3$	-0.5264***
	ΔF_4	-0.0435***	$\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4$	-0.5699***

[Table 8] Stochastic dominance for Group 1

Group 1	1 st order		2 nd order	
Stochastic Dominance	>		>	
	ΔF_1	-0.0299***	ΔF_1	-0.0299***

	ΔF_2	-0.4325***	$\Delta F_1 + \Delta F_2$	-0.4624***
	ΔF_3	-0.0414***	$\Delta F_1 + \Delta F_2 + \Delta F_3$	-0.5038***
	ΔF_4	-0.0652***	$\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4$	-0.5690***

[Table 9] Stochastic dominance for *Group 2*

<i>Group 2</i>	1 st order		2 nd order	
Stochastic Dominance	>		>	
	ΔF_1	-0.0610***	ΔF_1	-0.0610***
	ΔF_2	-0.5167***	$\Delta F_1 + \Delta F_2$	-0.5777***
	ΔF_3	-0.0344***	$\Delta F_1 + \Delta F_2 + \Delta F_3$	-0.6121***
	ΔF_4	-0.0198***	$\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4$	-0.6319***

[Table 10] Stochastic dominance for *Group 3*

<i>Group 3</i>	1 st order		2 nd order	
Stochastic Dominance			>	
	ΔF_1	-0.0406***	ΔF_1	-0.0406***
	ΔF_2	-0.4105***	$\Delta F_1 + \Delta F_2$	-0.4511***
	ΔF_3	-0.0067	$\Delta F_1 + \Delta F_2 + \Delta F_3$	-0.4578***
	ΔF_4	-0.0162**	$\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4$	-0.4740***

[Table 11] Stochastic dominance for *Group 4*

<i>Group 4</i>	1 st order		2 nd order	
Stochastic Dominance			>	
	ΔF_1	-0.0401***	ΔF_1	-0.0401***

	ΔF_2	-0.438***	$\Delta F_1 + \Delta F_2$	-0.4790***
	ΔF_3	0.0140	$\Delta F_1 + \Delta F_2 + \Delta F_3$	-0.4676***
	ΔF_4	-0.0180***	$\Delta F_1 + \Delta F_2 + \Delta F_3 + \Delta F_4$	-0.4856***

*Significance level of 5%.

**Significance level of 1%.

***Significance level of 0.1%.

'>' means that distribution of 2017 stochastically dominates distribution of 2012

For the 1st order case, stochastic dominance does not exist in *Group 3-4*, while 2nd order stochastic dominance conditions hold for all groups. Therefore, social welfare from ICT capability has increased from 2012 to 2017 in all groups if individual utility functions are increasing and concave in ICT capability. However, if concavity conditions does not hold, then social welfare increase does not exist in *Group 3* (the disabled) and *4* (low-income group).

2. Multidimensional Analysis

(1) Multidimensional Index Analysis

Now we will measure the multidimensional deprivation index, AF index (Alkire & Foster, 2011). It is the extended version of FGT index for multidimensional framework and depends on parameter α . If $\alpha = 0$, then AF index is multidimensional-adjusted version of HCR (M_0). If $\alpha = 1$, AF index is multidimensional-adjusted version of GPI (M_1). For robustness, both union approach (if a person is deprived in one or more dimensions, then this person is regarded as 'poor') and intersection approach (if a person is deprived in all dimensions, then this person is regarded as 'poor') will be used. Poverty line is set to 2 in all dimensions.

[Table 12] Multidimensional index analysis: Union approach

Group	Year	3-dim	2-dim	3-dim	2-dim
		ΔM_0 (S.E.)	ΔM_0 (S.E.)	ΔM_1 (S.E.)	ΔM_1 (S.E.)
Full Sample	2012	0.272 (0.003)	0.281 (0.003)	0.136 (0.001)	0.141 (0.001)
	2017	0.126 (0.002)	0.188 (0.003)	0.063 (0.001)	0.094 (0.001)
	Diff.	-0.146***	-0.093***	-0.073***	-0.047***
Group 1	2012	0.169 (0.003)	0.162 (0.004)	0.084 (0.001)	0.081 (0.002)
	2017	0.067 (0.002)	0.100 (0.003)	0.034 (0.001)	0.050 (0.001)
	Diff.	-0.102***	-0.062***	-0.050***	-0.031***
Group 2	2012	0.169 (0.003)	0.322 (0.007)	0.084 (0.001)	0.161 (0.003)
	2017	0.067 (0.002)	0.215 (0.007)	0.034 (0.001)	0.108 (0.004)
	Diff.	-0.102***	-0.107***	-0.050***	-0.053***
Group 3	2012	0.290 (0.006)	0.294 (0.007)	0.145 (0.003)	0.147 (0.003)
	2017	0.183 (0.005)	0.273 (0.007)	0.092 (0.002)	0.136 (0.004)
	Diff.	-0.107***	-0.021*	-0.053***	-0.011*
Group 4	2012	0.437 (0.006)	0.515 (0.006)	0.219 (0.003)	0.257 (0.003)
	2017	0.235 (0.005)	0.352 (0.007)	0.118 (0.002)	0.176 (0.004)
	Diff.	-0.202***	-0.163***	-0.101***	-0.081***

[Table 13] Multidimensional index analysis: Intersection approach

Group	Year	3-dim	2-dim	3-dim	2-dim
		ΔM_0 (S.E.)	ΔM_0 (S.E.)	ΔM_1 (S.E.)	ΔM_1 (S.E.)
Full Sample	2012	0.094 (0.002)	0.147 (0.003)	0.047 (0.002)	0.074 (0.001)
	2017	0.000 (0.000)	0.034 (0.002)	0.000 (0.000)	0.017 (0.001)
	Diff.	-0.094***	-0.113***	-0.047***	-0.057***
Group 1	2012	0.056 (0.003)	0.082 (0.003)	0.028 (0.001)	0.041 (0.002)
	2017	0.000 (0.000)	0.034 (0.002)	0.000 (0.000)	0.017 (0.001)
	Diff.	-0.056***	-0.048***	-0.028***	0.024***
Group 2	2012	0.138 (0.006)	0.174 (0.007)	0.069 (0.003)	0.087 (0.003)
	2017	0.000 (0.000)	0.095 (0.006)	0.000 (0.000)	0.047 (0.003)
	Diff.	-0.138***	-0.079***	-0.069	-0.040***
Group 3	2012	0.091 (0.005)	0.162 (0.007)	0.045 (0.003)	0.081 (0.003)
	2017	0.000 (0.000)	0.115 (0.007)	0.000 (0.000)	0.058 (0.003)
	Diff.	-0.091***	-0.047***	-0.045***	-0.023***
Group 4	2012	0.145 (0.006)	0.266 (0.008)	0.072 (0.003)	0.133 (0.004)
	2017	0.000 (0.000)	0.142 (0.007)	0.000 (0.000)	0.071 (0.004)
	Diff.	-0.145***	-0.124***	-0.072***	-0.062***

*Significance level of 5%.

**Significance level of 1%.

***Significance level of 0.1%

In most cases, 3-dim index including ICT is lower than 2-dim index not including ICT and this phenomenon is remarkable especially for vulnerable group. It suggests that ICT moderates other deprivation from income and education. Also, both in 2-dim and 3-dim index, deprivation of 2017 is generally lower than that of 2012. Moreover, 3-dim index has more decreased than 2-dim index between 5 years.

4. Implications and Concluding Remarks

Until now, this paper tried to investigate the deprivation changes in Korea between 2017 and 2012 by including ICT capability as main attribute. Through several univariate analysis, we found that deprivation in ICT capability has decreased in Korea and stochastic dominance occur in most groups. It provides a basis for considering ICT as ‘deprivation-moderating’ factor. Moreover, the paper figured out this deprivation-moderating effect in a multidimensional framework by using index comparison analysis including and not including ICT capability.

Therefore, this research can give new point of view to look at ICT capability and social welfare. In univariate perspective, income-raising policy has been the unique one that reduces deprivation and promotes social welfare. Also, digital divide phenomenon has been considered separate issue from traditional social welfare policy. However, by including ICT capability in inequality analysis, policy makers can measure the overall inequality and social welfare changes more exactly. In addition, they can relax the overall inequality of society by increasing ICT capability, so ICT can play an important role for welfare policy. It represents an insight that inequality and social welfare could be improved in diverse ways. In other words, policy makers can increase social welfare by reducing ICT inequality, not by raising income of the poor.

However, it has several limitations. First of all, the reason why ICT capability is included in welfare and well-being research should be more obvious. Korea is extraordinary case and ICT does not hold an important position yet in daily life or workplace in many countries. Then, above results should be carefully applied in the light

of the context. Also, this research does not explicitly take account of interactions between different attributes even if it conducts multidimensional index analysis with union and intersection approach. For instance, income and education can be closely related to ICT capability, so their interaction effects should be explicitly specified and analyzed in further research.

Appendix: ICT capability score

Report is available at <https://www.nia.or.kr/>.

ICT capability score is organized as follows:

Access

If a person does not have PC (desktop, laptop) *and* does not have mobile device (mobile phone, tablet PC, and other smart mobile devices) *and* does not access Internet, then *Access* score is 0, otherwise 1. For more detail, see Q1, Q2, Q3 of *Report*.

Ability

Report investigates subjects' ICT ability level with diverse question (mainly about PC, mobile, Internet ability). It is measured as integer from 1(the least) to 4(the best). Then, the average of these scores was calculated and normalized. If this normalized score is greater than 0.5, then *Ability* score is 1, otherwise 0. For more detail, see Q4, Q5 of *Report*.

Utilization

As with *Ability*, *Report* investigates subjects' ICT utilization level with diverse question (for example, search, e-mail, media contents, social media, e-commerce, and so on). It is measured as integer from 1(the least) to 4(the best). Then, the average of these scores was calculated and normalized. If this normalized score is greater than 0.5, then *Utilization* score is 1, otherwise 0. For more detail, see Q7, Q8, Q9, Q10, Q13 of *Report*.

Sharing

As with *Ability* and *Utilization*, *Report* investigates subjects' ICT sharing level with diverse question (for example, information creation/sharing, networking, social participation). It is measured as integer from 1(the least) to 4(the best). Then, the average of these scores was calculated and normalized. If this normalized score is greater than 0.5, then *Sharing* score is 1, otherwise 0. For more detail, see Q10, Q11, Q12 of *Report*.

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