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Impact of ICT on Unemployment: A Global Empirical Analysis

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Abstract

This study explores the relationship between ICT development and the unemployment rate in a cross-country setup. The relationship between the development of ICTs and human labour has always been debated among researchers. The debate revolves around whether ICT substitutes or complements human labour. This relationship still has not ended at a meeting point. This study utilizes the ICT index from International Telecommunication Unit to capture broader coverage of ICT development in the country. This index arguably improves the accuracy and comparability of variable measurement. Furthermore, this research conducts a heterogeneity analysis of ICT's impact by considering the unemployed education level and the country's development stage. The empirical method employs in panel data setup, namely Fixed Effect Model. The data consist of 57 countries in the period 2015-2017. Interestingly, this study finds that ICT development corresponds to a decrease in total unemployment by 1%, with the largest effect on unemployed with medium education. By heterogeneity analysis, this beneficial effect is only applied in developed countries. The study results indicate that the developing country should be more cautious and adaptive in mitigating the rapid ICT waves.

Keywords: ict, unemployment, cross-country

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1. Introduction

Concerns about the replacement of human labour by ICT (Information, Communication, and Technology) have occurred since the industrial revolution began until now. Historically, the anti-technology movement (Luddite Movement) emerged in England in the 19th century as a reaction to the industrial revolution (Vivarelli, 2014). 47% of jobs in the U.S. have a high risk of being replaced by computers in the next one or two decades (Frey & Osborne, 2017). The same phenomenon also occurs in OECD countries (Chinoracký & Čorejová, 2019). But on the other hand, ICT has also proven to increase productivity in almost all aspects of human life and

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encourage new jobs. The OECD (2019) documents that four out of ten new jobs are driven by ICT developments. The number of workers with new jobs or skills in the OECD countries increased by thirty million.

Furthermore, this issue progressively emerges in post-pandemic COVID-19. Working from anywhere and digital-based working has been rapidly changing the job system. Technology development and human labour seem to compete. ICT, because of civilization, is inevitable. Therefore, elaborating on the relationship between ICT development and employment might be prominent. The questions "Does ICT substitute or complement human labour?" and "Does the country's development stages matter in this relationship?" might need to be resolved.

Previous studies mostly used the single-country context and micro perspective or firm-level analysis. Therefore, using a cross-country setup, I examine ICT's impact on unemployment to see the macro view of ICT implications. I divide the unemployment rate by education (high, medium (secondary), and low (primary)). Moreover, I also compare the result in developed and developing countries.

Interestingly, the empirical test results find that ICT development negatively affects the total unemployment rate by 1%, with the most significant effect on the unemployed with medium education (1.6%). This result confirms the compensation theory by Karl Max. Technology and innovation might replace human labour, but on the other hand, production improvement also opens the possibility of new jobs or job shifting. However, heterogeneity analysis shows that this beneficial effect only applies in developed countries. Developed countries are arguably more prepared to deal with ICT developments than developing countries. Therefore, developing countries should seriously mitigate the rapid development of ICT, for example, by systematically improving technology savvy for the workforce.

This study contributes to the literature in two ways. Firstly, this study utilizes the ICT index from International Telecommunication Unit to capture broader coverage of ICT development in the country. This index arguably improves the accuracy and comparability of variable measurement. Secondly, this research conducts a heterogeneity analysis of ICT's impact by considering the unemployed education level and the country's development stage.

This study is organized as follows: (1) introduction, which discusses the issue of ICT infiltration in the workforce, (2) literature review, which explains how the effects of ICT development both empirically and theoretically, (3) methods research, which exhibits the variables, empirical models, and identification strategy, (4) the analysis and discussion, which will describe the results of the empirical tests along with explanations, and (6) conclusion, limitation, and recommendation, which summarize all the substance of the section, the limitations of the research, as well as policy recommendations.

The empirical debate regarding the relationship between ICT developments and workforce dynamics can be seen in various existing studies. The positive impact between the development of ICT and the employment rate can be explored in several studies, such as Reenen (1997) for the case in the U.K.; Crandall et al. (2007) in the U.S.; Evangelista et al. (2014) in Europe; and Falk & Biagi (2017) in Europe. However, this positive result was not found by Shideler et al. (2007) dan Bessen (2019) in the U.S. context. Bessen (2019) pointed out the negative impact of ICT on the employment rate in the manufacturing industry. Meanwhile, De Stefano et al. (2014) highlighted different results, where the development of ICT has no effect on the employment rate in the U.K.

Atalay et al. (2018) dan Balsmeier & Woerter (2019) conducted a more profound analysis at the firm level by evaluating the impact of ICT developments on the number of workers divided into three clusters: high, medium, and low-skilled workers. Using the U.S. context, Atalay et al. (2018) concluded that the development of ICT benefits high-skilled workers, while middle-low-skill workers tend to be degraded as their tasks are risky to replace by technology. Balsmeier & Woerter (2019) also found the same results by taking the research location in Switzerland. In terms of the unemployment rate perspective, Jayakar & Park (2013), using county-level in the U.S. context, found a negative nexus between ICT development and the unemployment rate, implying that ICT development stimulates a decrease in the unemployment rate. In the developing country context, women with higher skill and education correlates with the internet usage intensity (Suwadji, 2020).

Theoretically, the contradictory results of prior studies can be explained in two dimensions: process and product innovation. ICTs that encourage process innovation tend to reduce human labour roles in the operational process. However, ICTs that produce product innovations are more likely to increase labour demand due to increased demand for these products (e.g., sales officers). This theory is derived from the compensation theory proposed by Karl Max in 1986 (Vivarelli, 2014). This theory states that worker reduction due to technology will be compensated by increasing workers in other aspects. For example, when a machine or computer replaces a production process, human resources for production will be reduced (job destruction effect). Still, on the other hand, this innovation will increase the labour demand for the manufacture or maintenance of the machine or computer (a job creation effect). Nevertheless, whether this compensation effect produces a zero net result remains an open question.

Ing and Grossman (2023) recently published a book exhibiting a comprehensive literature review assessment related to the impact of robots and AI on several economic variables, such as productivity, trade, employment, and wages. They pointed out that the impact of robots and AI is diverse. Existing empirical studies show that automation drives a decreased labour share in the national income. Nevertheless, the complementary effect of ICT is also likely to occur for high-skilled workers. From the macro-perspective, Schlogl and Summer (2020) argue that the effect of ICT on the labour market depends on the development stage. The impact might be more adverse in the context of developing countries rather than high-income countries. The composition of clerical, administrative, and routine work is more likely to be dominant in developing countries. This kind of work is susceptible to being replaced with automation and artificial intelligence. However, they also discuss that the impact seems to be heavy on structural transformation, such as stagnant wages and deindustrialization, rather than unemployment. This opinion might raise empirical questions that would be answered in this study.

Existing literature shows that the relationship between ICT and the employment or unemployment rate is hotly disputed. In addition, the research locus is still concentrated in developed countries such as the U.S. and Europe. Vivarelli (2014) stated that the quality of ICT in developing countries is primarily derived from the effects of trade and investment inflows. Hence, instead of representing the ICT quality, the variables used in the literature tend to reflect the trade and investment inflows. The gap in the macro perspective of ICT development motivates this study to conduct cross-country analysis and use a more comprehensive measurement of ICT.

2. Research Method

Many researchers, such as Crandall et al. (2007), ITU (2012), Jayakar & Park (2013), and Atasoy (2013), use the intensity of internet usage or broadband as a proxy for ICT development because the internet might be the dominant factor of various business processes transformation and innovation. In another study, ICT variables were represented by internet usage intensity, ICT infrastructure readiness, and ICT empowerment (Evangelista et al., 2014). In addition, several researchers utilize a micro approach by assessing the quality of using ICT systems at the company level (Atalay et al., 2018; Balsmeier & Woerter, 2019; Bessen, 2019; Falk & Biagi, 2017).

The ICT variables used by previous studies are more likely to differ from country to country, so they cannot be used for empirical analysis in a cross-country setup due to comparability issues. Therefore, this study employs global data measurement to increase the comparability of variable measurement. Taking the ICT Development Index (IDI) published by the International Telecommunication Union (ITU), this research is expected to complement the prior works. In addition, IDI also represents broader aspects of ICT development and measurement, such as the level of facility readiness, the usage intensity, and the ICT user's capacity. Regarding the dependent variables, I divide the unemployment rate by high, medium, and low education levels. The empirical model is as follows.

$$UR_{it} = \delta_0 + \delta_1 IDI_{it} + \delta_2 GDP_{it} + \delta_3 GII_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

UR_{it}t is the vector of dependent variables representing: the high-education unemployment rate, medium-education unemployment rate, and low-education unemployment rate of country i in year t. IDI_{it} is the ICT Development Index of country i in year t. GDP_{it} is the Gross Domestic Product of country i in year t. GII_{it} is the Global Innovation Index of country i in year t. α_i and γ_t is country and year fixed effect, respectively.

The parameters of interest are δ_1 , representing the effect of ICT on the unemployment rate. This study employs the natural logarithm of GDP as a control variable to represent the level of labour supply-demand and the factor that affects IDI (Evangelista et al., 2014). Besides that, I also use innovation level (Global Innovation Index) as a control variable because this factor might simultaneously affect ICT development and the unemployment rate. Another potential confounder or control variable, such as human development or education, has been a component of IDI measurement. Including this variable in the model might be problematic. The remaining bias from unobserved time-constant heterogeneity and time trend is captured by country and year fixed effect in the Fixed Effect Model estimation (Wooldridge, 2010).

The sample covers 57 countries consisting of 27 developed and 30 developing countries in 2015-2017. The complete list of countries is in the Table 1. The unemployment data are retrieved from Word Development Indicator, World Bank. The IDI data from ITU is limited to 2015-2017 due to the measurement change in 2018. The The IDI data for 2019-2022 is not available yet. The GDP dan GII is from Word Development Indicator, World Bank.

Table 1. List of Countries

Developing Countries		Developed Countries	
No	Country	No	Country
1	Armenia	1	Austria
2	Brazil	2	Belgium
3	Bulgaria	3	Cyprus
4	Chile	4	Czech Republic
5	Costa Rica	5	Denmark
6	Croatia	6	Estonia
7	Dominican Republic	7	Finland
8	Ecuador	8	France
9	Egypt	9	Germany
10	El Salvador	10	Greece
11	Georgia	11	Iceland
12	Guatemala	12	Ireland
13	Honduras	13	Italy
14	Hungary	14	Malta
15	Indonesia	15	Mongolia
16	Latvia	16	Netherlands
17	Lithuania	17	Norway
18	Mauritius	18	Poland
19	Mexico	19	Portugal
20	Montenegro	20	Russian Federation
21	Panama	21	Slovakia
22	Paraguay	22	Slovenia
23	Peru	23	Spain
24	Romania	24	Sweden
25	Serbia	25	Switzerland
26	South Africa	26	United Kingdom
27	Turkey	27	United States
28	Ukraine		
29	Uruguay		
30	Viet Nam		

Source: World Bank

Table 2 presents the descriptive statistic of all variables. On average, the unemployment rate in all samples, developed group, or developing countries shows an identical pattern. The low-education unemployed dominate the unemployment rate (12.03%). It is followed by medium-education (9.23%) and high-education unemployed (6.19%). The high-education unemployed might still benefit from the ICT infiltration in the job system due to their adaptability. From this descriptive data, developing countries seem riskier than developed countries. The IDI level also shows that developed countries are undoubtedly higher than developing countries. The IDI means reaches 6.51 in all countries, 7.71 in developed countries, and 5.43 in developing countries.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
All Countries (57 Countries)					
UR_Total	171	8.297556	5.113717	1.851	27.327
UR_HighEdu	171	6.199282	4.455945	1.2518	21.6393
UR_MedEdu	171	9.232871	5.383362	2.4234	27.8656
UR_LowEdu	171	12.02928	7.593015	1.08	37.6736
IDI	171	6.510409	1.540029	3.14	8.98
GII	171	43.15491	10.68463	25.96	68.3
Ln GDP	171	25.81349	1.810128	22.2338	30.48454
Developed Countries (27 Countries)					
UR_Total	81	7.954803	4.667518	2.742	24.897
UR_HighEdu	81	5.245768	3.563499	1.4421	19.8544
UR_MedEdu	81	8.145869	5.150375	2.4234	27.6158
UR_LowEdu	81	13.87474	6.806931	3.0923	37.6736
IDI	81	7.714568	.851553	4.91	8.98
GII	81	51.92556	8.123473	35.74	68.3
Ln GDP	81	26.57791	1.799196	23.1586	30.4845
Developing Countries (30 Countries)					
UR_Total	90	8.606033	5.49216	1.851	27.327
UR_HighEdu	90	7.057444	4.993951	1.2518	21.6393
UR_MedEdu	90	10.21117	5.428542	2.6407	27.8656
UR_LowEdu	90	10.36837	7.911217	1.08	33.3357
IDI	90	5.426667	1.170907	3.14	7.26
GII	90	35.26133	5.071979	25.96	45.51
Ln GDP	90	25.12552	1.529183	22.2338	28.4800

Source: ITU and WDI (reprocessed)

3. Result and Discussion

3.1. Impact of ICT on Unemployment Rate

Table 3 exhibits the empirical result of the model (1) in all samples. The results delineate that ICT development negatively affects the total unemployment rate by 1.07%. Every one-unit increase in the ICT index corresponds to a decrease in the unemployment rate by 1.07%. This magnitude is sizeable compared to the unemployment rate mean (or 12.89%). Moreover, the heterogeneity analysis shows that the most significant effect is on the unemployed with medium education. Every one-unit increase in the IDI index corresponds to a decrease in the medium-education unemployment rate by 1.65%.

Table 3. Empirical Result of Models 1 in All Countries

	Unemployment Rate			
	Total	**High-Educ**	**Medium-Educ**	**Low-Edu**
IDI	-1.073**	-0.609*	-1.649**	-1.381*
	(-2.74)	(-2.07)	(-3.09)	(-2.39)
GII	-0.108	-0.151*	-0.0702	-0.187
	(-1.63)	(-2.38)	(-0.65)	(-1.46)
Log of GDP	-12.49	-7.360	-11.41	-11.34
	(-1.77)	(-1.31)	(-1.49)	(-1.53)
Obs	171	171	171	171
Country F.E.	V	V	V	V
Year F.E.	V	V	V	V
Outcome Mean		6.19	9.23	12.02

Robus standard errors in parentheses with ***, **, and * indicating 1, 5, and 10% significance levels, respectively. The empirical estimation employs Fixed Effect Model.

The empirical results in Table 3 align with Jayakar & Park (2013) and Evangelista et al. (2014). They argued that ICT development or access is necessary to build a digitalized community and open new opportunities in employment. From a different perspective, this study's finding also complies with Atalay et al. (2018) and Balsmeier & Woerter (2019). They pointed out that the relationship between ICT developments and skilled workers seems to be a complementary effect. Instead of substituting, the ICT presence will become a tool for solving high-order problems or complex assignments. By assessing the U.S. employment trends from 1960–2000, Atalay et al. (2018) documented an increasing demand for a skilled workforce accompanied by the ability to utilize ICT.

This finding also indicates that the unemployed with high-medium-low education (mainly medium education) might experience an adaptation process during the transition of process business innovation. Ultimately, the unemployed can adapt and take the opportunity during the job transition due to ICT developments. From a theoretical point of view, the compensation theory from Karl Max seems to be quantitatively proven. The total effect of ICT development might still be advantageous, implying the job creation effects might be larger than the job destruction effect.

To provide a contextual understanding, I estimate the effect of ICT on the unemployment rate by dividing the sample into developed and developing countries. Table 3 exhibits that the beneficial effect of ICT only applies to developed countries. There is a negative impact of ICT on the unemployment rate in developing countries, but the magnitude is not significant. This contrasting evidence may refer to the difference in responsiveness, readiness, and adaptation level.

3.2. Heterogeneity Analysis

Table 4 and 5 shows the heterogeneity analysis of ICT impact on employment considering the development stage of countries. The ICT development has a significant positive effect on high-skill employment rate in both developed and developing countries. These results are in line with research conducted by (Atalay et al., 2018) in the U.S. and (Balsmeier & Woerter, 2019) in Switzerland. This finding shows that highly skilled workers benefit from the development of ICT in both developed and developing countries. Meanwhile, the ICT impact on medium-low skill employment rate shows the negative sign in both subsamples with the greater effect for medium-skill worker in developed countries and low-skill worker in developing countries.

Table 4. Empirical Result of Models 1 in Developed Countries

	Unemployment Rate			
	Total	**High-Educ**	**Medium-Educ**	**Low-Educ**
ICT	-1.567***	-1.022***	-1.891**	-1.768
	(-3.88)	(-3.80)	(-3.30)	(-2.02)
GII	-0.0255	0.00333	-0.0304	-0.201
	(-0.33)	(0.05)	(-0.32)	(-1.47)
Log of GDP	-7.708	1.358	-2.511	-29.43*
	(-0.93)	(0.17)	(-0.23)	(-2.09)
Obs	81	81	81	81
Country F.E.	V	V	V	V
Year F.E.	V	V	V	V

Table 5. Empirical Result of Models 1 in Developing Countries

	Unemployment Rate			
	Total	**High-Educ**	**Medium-Educ**	**Low-Educ**
ICT	-0.699	-0.357	-1.284*	-0.969
	(-1.53)	(-0.66)	(-2.18)	(-0.79)
GII	-0.00705	-0.170	0.0862	-0.0906
	(-0.08)	(-1.67)	(0.42)	(-0.33)
Log of GDP	-17.56	-12.17	-18.89	-7.149
	(-1.77)	(-1.44)	(-1.66)	(-0.73)
Obs	90	90	90	90
Country F.E.	V	V	V	V
Year F.E.	V	V	V	V

Robust standard errors in parentheses with ***, **, and * indicating 1, 5, and 10% significance levels, respectively. The empirical estimation employs Fixed Effect Model.

The policymaker and unemployed in developed countries are more likely to be responsive and adaptive. According to Table 2, the Global Innovation Index in developed countries reaches

51.92, while in developing countries is only 35.26. The gap is so high. This index represents some indicators stimulating innovation, such as ease of doing business, ease of resolving bankruptcy, ease of getting a loan, microfinance, labor productivity, etc. These indicators indirectly represent the quality of institutional governance in the country.

4. Conclusion

ICT development corresponds to a decreased unemployment rate at all education levels. However, empirical tests show contrasting evidence in developed and developing countries. These results confirm that the compensation theory of the ICT presence is proven, implying the job-creating effect outweighs the job-destruction effect. This finding also indicates the adaptation process in the labour market due to the ICT transition occurs at all education levels. Some researchers argue that a low-skilled or low-educated workforce might experience a disruption effect, but this study shows the opposite proof.

Nevertheless, heterogeneity analysis by development stage shows a different result. In developed countries, ICT negatively affects the unemployment rate at all levels of education, but this effect does not apply in developing countries. This result signifies that the contextual aspect matters. In terms of institutional governance and human capital quality, developed countries are arguably more well-prepared to deal with ICT developments than developing countries. Therefore, developing countries might need to establish an anticipatory strategy related to institutional readiness, policy response, and technology-savvy issues.

This study has limitations in the sampling period due to the data availability and measurement change. The three-year trend might not fully describe and explain the co-movement of ICT development and the unemployment rate. Besides that, the empirical model still lacks confounder identification implying the remaining bias from time-variant factors. The model is also vulnerable to reverse causality due to the possibility of unemployment affecting ICT development. Future studies should consider a more sophisticated method to eliminate the potential bias from these problems.

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