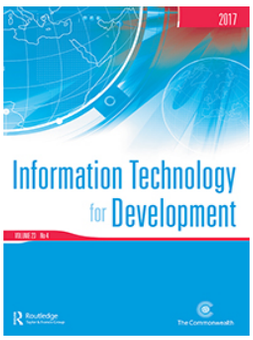

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ICT diffusion as a determinant of human progress*

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ABSTRACT

This research poses the question of whether the diffusion of information and communications technology (ICT) in countries can affect human progress. Human progress in this research is defined as progress that allows every member of a society to live in an environment with high economic, political, and civil liberties. To examine the posed question, the authors developed the following three hypotheses. First, ICT diffusion serves as a determinant in human progress. Second, the size of the impact of diffusion of ICT on human progress may differ depending on the income level of the economy. Lastly, the impact of ICT on human progress may differ depending on the type of technological medium. These hypotheses were tested with a sample of 102 countries panel for 14 years from 2000 to 2013 with data from the International Telecommunications Union to see the status of diffusion of ICT, the Heritage Foundation and the Freedom House in order to employ the measure of human progress by a year-lagged seemingly unrelated regression analysis with both pooled and grouped samples. The results suggest that the diffusion of ICT is a determinant of human progress at the global level and that the effects differ depending on the type of technology or the income level of the country.

KEYWORDS

ICT; human progress; country income; SUR; cross-sectional analysis

1. Introduction

Currently, information and communication technology (ICT) exists everywhere in varied forms. The diffusion of ICT is clearly a global phenomenon that has witnessed a steep increase in the number of people connected, rather than remaining a privilege held by a few wealthy nations. According to the International Telecommunications Union (ITU), Internet users increased from 400 million in 2000 to 3.2 billion in 2015. In addition, there are seven billion mobile cellular subscriptions, nearly equal to the total population of the world (ITU, 2015). Furthermore, the poor have gained greater accessibility to fixed-broadband subscriptions due to the 82% decrease in subscription price from 2008 to 2012 (ITU, 2015). As these numbers suggest, in less than two decades, humans have been enriched with greater connectivity than ever before.

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As ICT develops and spreads, however, worries about the digital divide between the wealthy and poor arise at both the individual and national level. Depending on the relative wealth of a nation, the diffusion rate of ICT greatly differs among nations due to infrastructure costs and the national commitments of each country (Mariscal, 2005). At the same time, international organizations such as the United Nations Development Programme (UNDP, 2013), the World Bank, and several multinational corporations (Packard, 2006) are recognizing the importance of using and facilitating ICT in the developing world as a key method to mitigate the digital divide and, ultimately, poverty (UNCTAD, 2002). Additionally, as overcoming the digital divide is a key agenda in developmental efforts worldwide, academics and professionals have started to ask questions about the role of ICT in the context of further growth around the world.

ICT can be referred to as a type of general-purpose technology (GPT), a notion proposed by Helpman (1998), given the peculiarities of the variability and adaptability of ICT with regard to other technologies or industries (Basu & Fernald, 2007). The potency of ICT diffusion for social change has been recognized by various sectors. At the 2000 G8 Summit in Okinawa, all of the leaders of the developed nations agreed on the power of ICT, as enshrined in the Okinawa Charter on Global Information Society. "The Charter" states that ICT is one of the most potent forces shaping the twenty-first century (Virchow & von Braun, 2001). Unlike other technologies with certain purposes, ICT allows other technologies to be enhanced in terms of productivity through optimization and technological convergence. Based on the variability and adaptability of ICT as a GPT, the diffusion of this technology can affect diverse sectors in the world.

While ICT diffusion has omnidirectional impacts around the world, previous research has mainly focused on the relationship between ICT and economic development. A number of studies have focused on enhancing productivity through the use of ICT in certain markets or industries, assuming that ICT as an input will affect output, i.e. that which is produced. However, as a vehicle of technology, ICT is also viewed as a catalyst for national development (Soeftestad & Sein, 2002).

This research raises the argument that the diffusion of ICT matters in everyday lives when considering ICT as a GPT. Given that ICT is a GPT, we assume that ICT diffusion will not only affect productivity enhancements, but will also improve human society as a whole. Therefore, this study examines whether changes in the diffusion rate of ICT impact human progress factors such as economic freedom, political rights, and civil liberties. The following sections present a review of the literature on the impact of ICTs. First, the issue of economic growth demonstrates how ICT diffusion has affected growth accounting efforts. Next, we explore earlier work on the relationship between ICT diffusion and human progress. Building on these studies, the present study proposes a framework for model analysis. Finally, the paper concludes with its main findings from the analysis.

2. ICT diffusion and economic growth

Quah's (1999) definition of the "new economy," which he coined along with the "weightless economy," includes ICT and the Internet, as well as knowledge products and intellectual properties. Among these factors, Quah (2001) argues that, because ICT output typically has few physical manifestations or rivals and is infinitely expansible, it differs from other high-tech industries, which are characterized by increasing returns, as it offers technological innovations

driving economic growth (Solow, 1956). Therefore, with its exceptional peculiarities, many studies have examined the relationship between ICT and economic development.

Since the time of fixed-line telephony as the main form of communication, the impact of ICT on economic growth has been discussed. For example, telephony allows organizations or societies (i) to remove the physical constraints between organizational communication, (ii) to achieve higher effectiveness from telecommunications and (iii) to enhance the efficiency of household operations (Wellenius, 1977). Based on data from the United States, Hardy (1980) argued that the diffusion of fixed-line telephones at the organizational level contributed to economic growth, as it is a communicational medium that leads to better resource allocation, achievement of economies of scale, and advancements in productive knowledge. Nearly a decade later, Cronin, Parker, Colleran, and Gold (1991) conducted a time series analysis of 31 years of United States data, indicating that investments in telecommunications infrastructure positively affected economic growth and stimulated demand for further investments in telecommunications infrastructure. Outside of the United States, another study showed that, over the previous two decades, ICT had contributed between 0.2 and 0.5 percentage points per year to economic growth depending on the country (Colecchia & Schreyer, 2002). A similar study in Taiwan also showed evidence of a positive relationship between ICT infrastructure and national competitiveness (Wang, 1999).

Given the technological development of ICT with cost reductions at present, the use of ICT has widened more than in any other prior period. The emergence of the Internet has sparked general interest in ICTs, including how these technologies can help the developing world achieve further growth (Heeks, 2008). In addition, recent research in Korea has proven that ICT convergence enhances productivity (Jung, Na, & Yoon, 2013). On this backdrop, numerous studies have discussed the economic impacts of ICT. Cette, Mairesse, and Kocoglu (2005) showed that ICT diffusion contributes to potential output growth in the long-term and to productivity enhancements in the short-term.

However, not every study fully supports the role of ICT in economic growth in every case. Lee, Gholami, and Tong (2005) conducted cross-country time series analyses and concluded that ICT investments have contributed to improvements in national productivity levels within developed and newly industrialized economies, but not in developing countries. Moreover, there is skepticism about the direct economic impact of ICTs. While Avgerou (1998) was uncertain about the direct economic impact of ICT, she discussed the productivity paradox in which ICT diffusion at the organizational level is likely to bring redesigns of business processes, reorganizations of work procedures, restructuring of management, or changes in the range of products and services, all of which can lead to potential productivity enhancements.

Therefore, it is clear that there have been many efforts to assess the relationship between ICT and economic growth. Even if the debate over the interrelations between ICT and economic growth is ongoing, there is general agreement and much evidence that ICT affects economic growth.

3. ICT diffusion and greater prosperity: economic freedom, political rights, civil liberties, and human progress

According to the Universal Declaration of Human Rights (UDHR) by the United Nations, human rights are defined as "the right to free communication, religious and political

participation, and the right to engage in economic activity. Freedom is one of the key issues by which a human being can be affected by the expansion of ICT. Increased access to information leads to greater resources and opportunities (Flor, 2001), and freedom of access to information is needed for ICT diffusion. Therefore, this study divides freedom into three parts in agreement with the UDHR and provides their definitions: economic freedom, political rights, and civil liberties.

We define human progress as advancements in the basic privileges of economic freedom, political rights, and civil liberties, which increase opportunities to social participants. Adopting the three human progress indicators of economic freedom, political rights, and civil liberties, we analyze whether the diffusion rate of ICT has had an impact on human progress indicators. An explanation of each indicator is in the next section.

Earlier studies analyzed the relationships between freedom indicators and ICT diffusion. Baliamoune-Lutz (2003) conducted an empirical study of 47 developing countries with three freedom indicators (economic, civil, and political freedom indexes) and four ICT indicators to find the key determinant of ICT diffusion, showing a result of income. In addition, Shirazi, Gholami, and Higón (2009) conducted an empirical analysis of economic freedom and the roles of ICT in Islamic Middle Eastern countries. Shirazi, Ngwenyama, and Morawczynski (2010) verified the link to political freedom, with both studies showing that ICT and freedom indicators were positively correlated.

Previous empirical studies contain two issues that will be addressed by the present study. First, prior analyses of ICT diffusion have attempted to determine the relationship between productivity, broad economic growth, and dissemination of ICT since 1980 (Hardy, 1980). According to Table 1, researchers have started to extend their examination to socioeconomic impacts driven by ICT diffusion. Considering ICT as a GPT, researchers have started to examine the actual relationships between the ICT diffusion rate and effects on society. In this study, we attempt to extend the discourse of socioeconomic impacts of ICT diffusion at the global level, specifically focusing on the human progress perspective.

Second, in analyses of the relationship between human progress and the diffusion rate of ICT, limited samples were used depending on income group or region within a relatively short period. For example, Baliamoune-Lutz (2003) analyzed three years of data from 47 developing countries. Shirazi et al. (2009) analyzed data from 1995 to 2005, focusing on the Middle East. However, the period they analyzed cannot easily be used to show the impact of the Internet or mobile phones because, while both technologies were introduced to the region, they were not widely utilized by most of the public at that time.

Based on these limitations of previous studies, there is a need for research that examines the relationship between the diffusion rate of ICT and human progress. The detailed focus of this study is presented in the next section.

4. Research framework

Prior studies on the relationship between ICT and economic growth commonly insist that there is an underlying consensus regarding the diffusion of ICT at the nation, industry, and organization levels, i.e. that ICT diffusion enhances the productivity of growth accounting, which leads to quantitative economic growth. However, the relationship between human

Table 1. Trends of ICT diffusion studies.

Author/categories	Target states	Analysis	Methodologies	Period	Findings
Kiiski and Pohjola (2002)	23 OECD countries	The factors that determine Internet diffusion	Gompertz model of Technology Diffusion, Panel Analysis	1995–2000	GDP per capita and Internet access cost best explain the observed growth in computer hosts per capita. Competition in the telecommunications market does not appear to exert any independent influence on Internet penetration. Education investment is not a statistically significant predictor of Internet diffusion.
Ngwenyama et al. (2006)	Senegal, Niger, Benin, Cameroon, Benin	The relationships among investments in ICT, healthcare, education, and socioeconomic development	OLS Stepwise Regression	1993–2003	The three independent variables are significant in predicting HDI score. ICT and education have a positive impact on development, while health has a negative impact.
Andoh-Baidoo, Osatuyi, and Kunene (2014)	53 African states	The influence of ICT capacity on economic development, human development endowment, political and population conditions	OLS Stepwise Regression	1990–2008	In African nations, a combination of political, economic, human development endowment, and population factors influence ICT capacity. Private entities in the ICT sector appear to have a more complex relation to corruption perceptions.
Qureshi and Najjar (2015)	32 very small island states	The relationships between economic indicators and ICT usage	Linear Regression	2010–2012	Presence of a cyclical effect from the increased usage of ICT that leads to future growth in per capital incomes is found. The multiplier effect is present between growth in ICT usage and GDP per capita.
Sağlam (2016)	34 OECD countries	The links among ICT diffusion, research and development (R&D) intensity, and economic growth	Time stationary VAR, Panel Granger Causality	1990–2012	Bidirectional causality between ICTs and economic growth is found. Internet users and mobile phone users have positive causal impacts on the share of labor devoted to R&D. Investment in ICTs and widespread use of Internet and mobile phones have contributed to human capital formation in OECD countries.

well-being and ICT diffusion has rarely been assessed. Nonetheless, several studies have analyzed the use of ICT and its impact on everyday lives. These studies argue that there is a relationship between human progress and ICT diffusion at the societal level. In this context, this study asks whether the diffusion of ICT can increase societal well-being.

Based on the issues mentioned in the previous section, this paper summarizes the following issues with the status quo. First, the trend in ICT diffusion research is moving from its impact on economic to socioeconomic development. Second, previous studies had limitations in sample sizes in their cross-country analyses due to data limitations and low rates of ICT diffusion at the global level. Third, prior empirical analyses intending to fully explain the implications of ICT diffusion were too brief. Since 2000, the world has experienced dynamic diffusion of ICT, somewhat invalidating earlier findings. These prior analyses might not appropriately convey the role and impact of ICT diffusion as a determinant of human progress.

Therefore, this research attempts to understand the impact of ICT diffusion on human progress considering the hypotheses mentioned below. First, we believe that the diffusion of ICT serves as a determinant of human progress. Human progress measures are assumed to be linked to economic growth. As economic growth is achieved by productivity enhancements, there is a higher likelihood of participants in the corresponding economy enjoying a better quality of life with higher incomes. Previous studies have attempted to examine the relationships between ICT and human factors. Ngwenyama, Andoh-Baidoo, Bollou, and Morawczynski (2006) showed that investments in ICT and education were statistically significant for predicting the Human Development Index (HDI) scores in African Nations from 1993 to 2008. Furthermore, Baliamoune-Lutz (2003) showed that ICT diffusion promotes economic development and enhances civil liberties and political rights in 32 middle-income countries. To extend the analysis sample with alternative iterations, we analyzed the relationships among the dependent variables of economic freedom, civil liberties, and political rights with the diffusion rate of ICT to determine the tangibility of intangible notions of human progress.

H1: ICT diffusion can serve as a determinant of human progress.

In addition to the diffusion of ICT, which can impact human progress, we also examine whether the income level of a nation affects the impact of ICT. The aforementioned works analyzing the relationship between the diffusion of ICT and socioeconomic impact have addressed the significance in certain regions (Ngwenyama et al., 2006; Shirazi et al., 2009) or income groups (Colecchia & Schreyer, 2002; Mariscal, 2005). In this study, we focused on whether the income level of a state will affect the impact of diffusion of ICT. Mainly, rapid growth rates of ICT diffusion occur in upper- and lower-middle-income countries compared to high- or low-income countries. High-income countries can experience a smaller impact on human progress with a greater usage of ICT for the following reasons. First, regardless of ICT being used by more of the population than before, high-income countries have already achieved high levels of economic freedom, political rights, and civil liberties. Thus, the impacts of higher ICT usage on human progress are difficult to determine.

H2: The impact of ICT diffusion will differ significantly depending on the income level of a country.

Middle- and low-income countries are not only facing dynamic ICT infrastructural changes, but are also facing large social changes at a rapid rate. For example, Kenya, a low-income country with a per capita GNI less than 1045 USD, has experienced rapid growth in the diffusion of mobile cellular networks. Figure 1 shows that nearly 80% of the Kenyan population subscribed to a mobile cellular network over one decade (ITU, 2015). However, in the period analyzed in this study, wealthy nations already had a mature rate of ICT diffusion. It is therefore expected that a greater impact of a change in the ICT diffusion rate will be better explained by examining middle- or low-income nations.

H2.1: Upper- and lower-middle-income countries will experience a greater impact of diffusion of ICT than countries with lower income level.

Returning to the example above, Kenya had a key technology that has changed the economic activities of participating agents. M-PESA, with M standing for mobile and PESA representing an acronym in Swahili, a local language, is an SMS-based mobile payment system widely available in Kenya. This simple technology allows the unbanked, unconnected, semi-literate, and physically challenged in Kenya to enjoy banking services (Hughes & Lonie, 2007). With M-PESA facilitating banking needs, its users also increased sharply as mobile cellular subscriptions increased. With wider economic opportunities through banking services, increased economic activities might have changed the daily lives of the Kenyan population. However, this might not be the case for all low-income nations. Before banking services can be established, poorer countries' main concerns might be more closely related to survival. In contrast, upper and lower income countries can enjoy the dynamics of the rapid growth rate of ICT diffusion and human progress given their rapid economic growth and social changes.

H2.2: Low-income countries will experience the weakest impact of human progress.

To tackle the issue of technological diffusion of ICT, income levels as well as the types of technology used by users can affect the size of an impact. In this research, we measured ICT diffusion with three types of technologies: fixed-line telephones, fixed-line broadband subscribers, and mobile cellular subscriptions. Depending on the diffusion rate of each technology, its impact on human progress is measured.

H3: For each human progress indicator, different rates of technological diffusion in ICT will have different scales of impact.

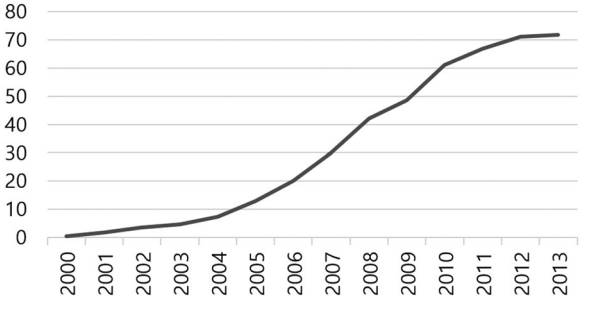

Figure 1. Mobile cellular subscription per 100 inhabitants in Kenya.

As modern politics have become more complex, political participation by individuals in a country in order to secure the interests of individuals has become a key issue related to political rights. However, for discourse on common interests, the underlying restrictions of the time and space needed to collect opinions and naturally formed barriers related to minor issues of a society must be overcome. However, the Internet, which allows multidirectional communication regardless of time or space, facilitates this discourse and overcomes the barriers. According to Flor (2001), increased information generates resources and allows greater access to resources and opportunities. Therefore, the diffusion of Internet technology, as represented by the diffusion rate of fixed-line broadband technology, will have the greatest impact on political rights enhancements.

H3.1: The diffusion of fixed-line broadband technology will have the strongest impact on political rights enhancements.

At the same time, increasing communication between individuals will increase economic freedom of constituents. According to Jack and Suri (2011), with reference to M-PESA in Kenya, for mobile phones, which have ubiquity regardless of whether they are located in urban and rural parts of the country, even at places which lack regular banking services, M-PESA serves as a substitute for bank accounts. Mobile phone mobility can allow more economic activities to be accomplished by users. Even if a mobile phone does not have mobile banking features such as M-PESA or an up-to-date mobile payment service, economic freedom can be derived through transfers of mobile traffic at any place and time. In addition, the technological literacy of mobile phones is more accessible than that of the fixed-line Internet due to its simpler features and lower implementation cost.

H3.2: The diffusion of mobile technology will have the greatest impact on economic freedom.

Civil liberties, defined as "the freedom of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state" (House, 2013), can be affected by the enhanced connectivity caused by the increased diffusion rate of ICT. More people are online for various purposes, such as for a hobby, political influence, religion, or other purposes. Social networks, formed by interconnections among participants of a society, are prevalent on the Internet. As mentioned above, considering the period of our study, which began in 2000, Internet access via mobile phones is a relatively recent trend. Mobile subscription data per 100 inhabitants as employed in this research contain 3G and 4G networked subscriptions. Therefore, we propose the final hypothesis of this research:

H3.3: The diffusion of fixed-line broadband technology will have the greatest impact on civil liberties.

The following section describes the data used and methodologies applied to test the hypotheses.

5. Data and variables

This study divides variables broadly into ICT diffusion variables as independent variables and human progress variables as dependent variables. As mentioned above, the scope of ICT is limited to the Internet (fixed-line broadband), fixed-line telephones, and mobile

telephones. The data are sourced from the World Telecommunication ICT Indicators by ITU. The period of the analysis is from 2000 to 2013. The list of variables and correlations are described in Tables 2 and 3.

Given that this study examines the impacts of ICT diffusion, a diffusion measure is employed starting with the actual subscription to each service. Recently, due to the wide acceptance of smart devices, there are separate subscription measures using 3G or 4G networks. However, because this study starts its analysis in 2000 when smart phones were not widely in use, we only analyze mobile cellular subscriptions of 2G-, 3G-, and 4G-connected phones. Human progress indicators are employed from multiple sources in order to cover key aspects of human progress as the dependent variables: economic freedom (EF), civil liberties (CL), and political rights (PR) indicators.

The Index of Economic Freedom is employed as the economic freedom variable in this study and is published by the Heritage Foundation. The index is a mean score of 10 indexes measured on 5-point Likert scales, with a score of 5 indicating the lowest level of economic freedom. The 10 indexes evaluate monetary policies, trade policies, capital flows and foreign investment, wage and price controls, banking and finance regulations, intellectual property and black markets, regulations, property rights, transparency and bureaucracy, government intervention, and government burden (i.e. taxes and government expenditure).

The political rights and civil liberty indicators were imported from Freedom House, which assesses democracy grades by rating them on a 7-point Likert scale, where a score of 1 represents the highest degree of democracy. The indicator classifies countries as free, partly free, and not free depending on the score. The Freedom House estimation is widely imported for the study of human progress. For analytical purposes, both the political rights and civil liberty indicators were graded on a scale of 0–100 in this research (Table 4).

The sample consists of cross-sectional time series data from 102 countries categorized by income group. The categorization of income groups employs the criteria from the World Bank Atlas. Based on the GNP per capita for 2014, the income group criteria are listed in Table 5.

Based on the given criteria, the 102 countries in the sample are categorized as shown in Table 6. Due to data availability, low-income countries are less represented than high-, upper-, and lower-middle-income countries.

Table 2. Descriptions of the independent variables.

Variables	Description
FBS100	Fixed-line broadband subscriptions per 100 inhabitants
FTS100	Fixed-line telephone subscriptions per 100 inhabitants
MCS100	Mobile cellular subscriptions per 100 inhabitants

Table 3. Correlations between the independent variables.

	FBS100	FTS100	MCS100
FBS100	1		
FTS100	0.679	1	
MCS100	0.6927	0.4969	1

Table 4. Summary statistics.

Variable	Observation	Mean	Std. Dev.	Min	Max
EF	1427	62.07856	10.79874	21.4	90
PR	1190	59.30252	34.93185	−2.5	100
CL	1191	60.88441	29.81051	0	100
FBS100	1360	7.315555	10.26739	0	42.51738
FTS100	1427	23.55242	19.55737	0.1640425	74.76247
MCS100	1428	69.28706	46.64689	0.0318169	237.3519

Table 5. Income group criteria.

Income group	Criteria (USD)
Low-income	~$1035
Lower-middle-income	$1036–$4085
Upper-middle-income	$4086–$12,615
High-income	$12,615–

Table 6. Country codes by income level.

Countries ($n = 102$)			
High-income ($n = 40$)	Upper-middle-income ($n = 24$)	Lower-middle-income ($n = 27$)	Low-income ($n = 11$)
ARE AUS AUT BEL BHR CAN CHE CHL CYP CZE DEU ESP EST FRA GBR GRC HKG HRV IRL ISL ISR ITA JPN KOR LTU LUX MLT NLD NOR NZL OMN POL PRT QAT SAU SGP SVK SVN SWE USA	ALB ARG AZE BGR BIH BLR BRA CHN COL CUB ECU FJI GAB HUN JOR MEX MUS MYS PAN PER ROM TUN TUR VEN	ARM CMR CPV DJI EGY GEO GHA HND IDN IND LAO LKA MAR MDA MNG MRT PAK PHL SEN SLV SWZ SYR UKR UZB VNM YEM ZMB	BEN BFA BGD KEN KGZ KHM MDG MWI RWA UGA ZWE

6. Model

Because the panel dataset for this study shows a degree of autocorrelation, we employed the seemingly unrelated regression (SUR) model to analyze the hypotheses above. According to Moon and Perron (2006), the SUR method allows a comparison between several individual relationships that are linked by a correlation between their respective distances by summing the constraints to restrict the parameters of different equations. In addition, because the cross-equation restriction is difficult to test with ordinary least squares (OLS), this study employed the SUR method for analysis (Wooldridge, 2002). The basic model[1] of this study is as follows:

$$\mathrm{EF}_t = \beta_0 + \beta_1 \mathrm{FBS100}_{t-1} + \beta_2 \mathrm{FTS100}_{t-1} + \beta_3 \mathrm{MCS100}_{t-1} + \mu_t$$

$$\mathrm{PR}_t - \beta_0 + \beta_1 \mathrm{FBS100}_{t-1} + \beta_2 \mathrm{FTS100}_{t-1} + \beta_3 \mathrm{MCS100}_{t-1} + \mu_t,$$

$$\mathrm{CL}_t = \beta_0 + \beta_1 \mathrm{FBS100}_{t-1} + \beta_2 \mathrm{FTS100}_{t-1} + \beta_3 \mathrm{MCS100}_{t-1} + \mu_t.$$

The diffusion of ICT will have an impact on people within a certain time period. As both short-term and long-term effects of ICTs need to be studied, we employed a year-lagged analysis with short-term effects of ICTs. If the technology is new, the rate of acceptance differs based on consumer behavior. The diffusion of innovation to a user can be divided into five categories: innovators, early adopters, early majority, late majority, and laggards (Rogers, 2010). The proportion in each category follows a nearly normal

distribution. Thus, we employed a year-lagged analysis in order to determine the impact of ICT diffusion at time $t-1$ on the human progress indicators in time t.

The pooled dataset has four groups: high-, upper-middle-, lower-middle-, and low-income countries. First, the study undertakes a pooled analysis of the data to examine the relationships between the freedom indicators and ICT diffusion. This tests H1, i.e. whether or not the diffusion of ICT has an impact on human progress.

Subsequently, the study conducts an analysis by income group, using identical steps in the pooled analysis for all four income groups. These results will determine whether the income level of a country determines the size of the impact of diffusion of ICT. At the same time, the relationships between each human progress indicator and the three technologies (i.e. fixed-line broadband, fixed-line telephones, and mobile cellular phones) will be compared to determine whether the technology type matters with regard to its impact on human progress.

Finally, an additional analysis will involve the rate of ICT diffusion and the composite human progress index. The composite index is composed of the three human progress indicators with equal weights. This composite index will show the general impact of ICT diffusion on human progress and will convey supplementary evidence to test H1.

7. Results

Table 7 shows the results of the SUR analysis of the pooled panel to examine whether changes in the diffusion rate of ICT impact human progress. All of the results corresponding to each indicator are significant at the 1% level. Overall, at the global level (pooled panel), the Internet had the greatest impact on every human progress indicator, with political rights demonstrating the greatest impact, followed by civil liberties. In contrast, all of the dependent variables had a comparatively minor impact of the diffusion of mobile cellular technology at the global level.

The diffusion of ICT might have a direct impact in the corresponding years in which the technology was introduced. However, considering the technological diffusion process, it is necessary to consider a grace period when measuring the impact of ICT diffusion. Thus, this study undertook a year-lagged analysis of the pooled panel as shown in Table 8.

The results were used to test H1 and H3 regarding the impact of ICT diffusion in general and the difference in the size of the impact depending on the form of technology used, respectively. By employing a year-lagged analysis, the results show slight changes from

Table 7. Pooled panel SUR analysis results.

	EF	PR	CL
FBS100	.2265014***	.891443***	.8692387***
	(.0399174)	(.1351144)	(.1091702)
FTS100	.1688442***	.5559943***	.4447508***
	(.02010015)	(.0710871)	(.00574372)
MCS100	.052065***	.0709875***	.0818243***
	(.0067543)	(.0228622)	(.0184723)
Observations	1159	1159	1159
R^2	.4223	.3675	.4261

*$p < .05$.
**$.01 < p < .05$.
***$p < .01$.

Table 8. Year-lagged pooled panel analysis results.

	EF	PR	CL
FBS100	.1863313***	.6103857***	.6236478***
	(.0396006)	(.1319441)	(.1046472)
FTS100	.1938716***	. 717045***	.5987829***
	(.0194314)	(.0647429)	(.00513487)
MCS100	.0516297***	. 052942**	.0567894***
	(.0070627)	(.0235321)	(.0186637)
Observations	1136	1136	1136
R^2	.4249	.3637	.4267

*$p < .05$.
**$.01 < p < .05$.
***$p < .01$.

the previous analysis. Overall, H1 is accepted as all variables are related, as demonstrated in Table 8. However, the level of statistical significance between MCS100 and political rights decreased slightly from the previous 1% level.

The Internet (FBS100) has an effect on every human progress indicator. Out of three dependent variables, the Internet has the greatest impact on political rights, followed by civil liberties and economic freedom. In the previous analysis without a one-year-lagged model, economic freedom experienced the second largest effect from the Internet.

The changes in fixed-line telephones also had an impact. However, during the period of this study, the number of subscriptions for fixed-line telephones decreased, as shown in Figure 2. Therefore, the positive coefficients in the results convey a negative correlation. Overall, fixed-line telephones have a marked negative relationship with the human progress indicators at the global level. This decreasing trend is derived from the increasing trend of mobile cellular phone usage. According to the ITU (2015), there are currently more cellular phones in use than the entire global population.

Lastly, mobile cellular phones showed a marked positive relationship with every human progress indicator. However, the impacts were smaller than those by the Internet. Furthermore, H3.2 was rejected because the coefficient was smaller than that for the Internet.

Even if, at the global level, the results show a general impact of ICT diffusion on human progress, it is difficult to generalize the result to every circumstance, especially in the case of different income levels of countries. Therefore, the following analyses account for the impact of ICT diffusion by examining differences in the income levels of countries in the sample. Given that this study considers that the diffusion of ICT will need a grace period to demonstrate its impact, the analyses employed a one-year-lagged method. Additionally, analyses by income level are performed with SUR to illustrate the individual relationships that are linked by the correlations of individual distances by summing the constraints so as to restrict the parameters of different equations.

Table 9 shows the results of the SUR analysis grouped by corresponding income level. H2 is accepted because the results illustrate a different impact or no impact on the human progress indicators due to the change in the diffusion rate of ICT. H2.1, regarding middle-income countries experiencing a stronger impact by the diffusion of ICT on the human progress indicators, is rejected for the following reasons. MCS100 was the only variable that showed a statistically significant result in the upper-middle-income group. Furthermore, in the lower-middle-group, the economic freedom indicator was the only variable that showed an impact of a change in ICT diffusion rate. Concerning H2.2, the only statistically significant result was conveyed in the relationship between FTS100 and PR. In a

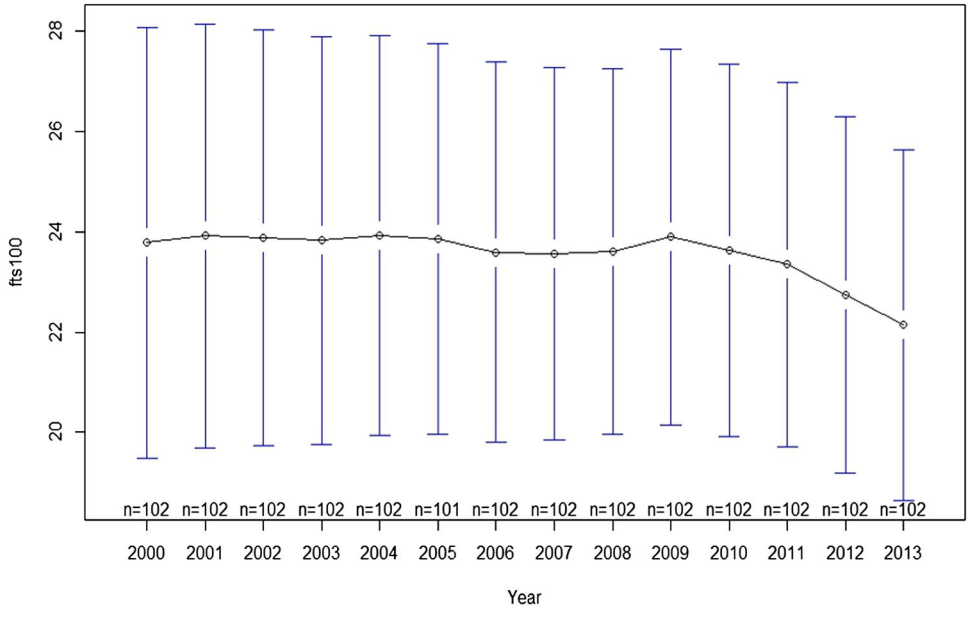

Figure 2. Global changes in fixed-line telephone subscriptions per 100 inhabitants.

comparison with other income groups, the significant outcome was observed at the lowest level. However, the results illustrate fairly well the lack of an impact by the diffusion of ICT on human progress. Therefore, H2.2 is also rejected.

Table 9. SUR analysis by income level.

	FBS100	FTS100	MCS100	Observation	R^2
EF-High	.1454607***	.0790981**	.0255874	439	.1117
	(.0432337)	(.0307635)	(.0134791)		
PR-High	.8118889***	.5827429***	−.238589***	439	.3545
	(.1287396)	(.0916064)	(.0401375)		
CL-High	.6777896***	.6499364***	−.124168***	439	.4161
	(.1054299)	(.0750201)	(.0328702)		
EF-UM	.0250373	−.049847	.0668455***	316	.0974
	(.1410933)	(.0657932)	(.0157503)		
PR-UM	.1562694	.3687343	.3764281***	316	.2746
	(.4574586)	(.2133177)	(.0510662)		
CL-UM	.0203414	.1564944	.3777278***	316	.3277
	(.3789544)	(.1767104)	(.0423027)		
EF-LM	.1913206	.1174083**	.0355146***	254	.1216
	(.2406125)	(.053246)	(.0125313)		
PR-LM	2.21618	.0174611	.058251	254	.0451
	(1.201578)	(.2659012)	(.062579)		
CL-LM	1.605278	.0198682	.0692754	254	.0637
	(.859165)	(.1901275)	(.0447459)		
EF-Low	−7.25301	.0582099	.0413728	118	.0293
	(3.969278)	(.3986507)	(.0327869)		
PR-Low	−5.418925	−1.758967**	.0714926	118	.0512
	(8.161676)	(.8197102)	(.0674167)		
CL-Low	−12.93582	−1.245035	.0784281	118	.0805
	(6.658096)	(.6686997)	(.0549969)		

*$p < .05$.
**$.01 < p < .05$.
***$p < .01$.

Only a few results were found to be statistically significant. In the low-income group, only fixed-line telephones (FTS100) were estimated to have a statistically significant effect on political rights at the one to five percent levels. However, considering the limited number of samples, and that most low-income countries had low human progress indicator scores, it is difficult to determine the impact of ICT diffusion on human progress in this group. On the other hand, the result illustrates that, rather than the diffusion of ICT for human progress, there is an urgent need for items such as food and clothing as well as means to earn a living. Without satisfying the basic needs of the corresponding countries, the diffusion of ICT will not have a large impact on human progress.

Second, two results were found to be statistically significant in the lower-middle-income group. The economic freedom of lower-middle-income countries was affected by fixed-line telephones and mobile cellular phones. Based on the diffusion trend for the two types of technologies, as illustrated in Figures 3 and 4, the diffusion rate of fixed-line telephones increased but started to decrease in 2011, while the diffusion rate of mobile phones increased globally. In other words, the increase in the diffusion rate of mobile cellular phones had a positive impact on enhancing the economic freedom of countries in the lower-middle-income group. In contrast, the increase in the diffusion rate of fixed-line telephones had a negative impact on enhancing economic freedom in countries in the lower-middle-income group.

In the upper-middle-income group, the diffusion rate of mobile cellular subscriptions had an impact on every human progress indicator at the 1% level of statistical significance. The greatest impacts were on civil liberties, political rights, and economic freedom, in that order. In the upper-middle-income group, the change in the diffusion rate of mobile cellular phones was the only determinant affecting human progress.

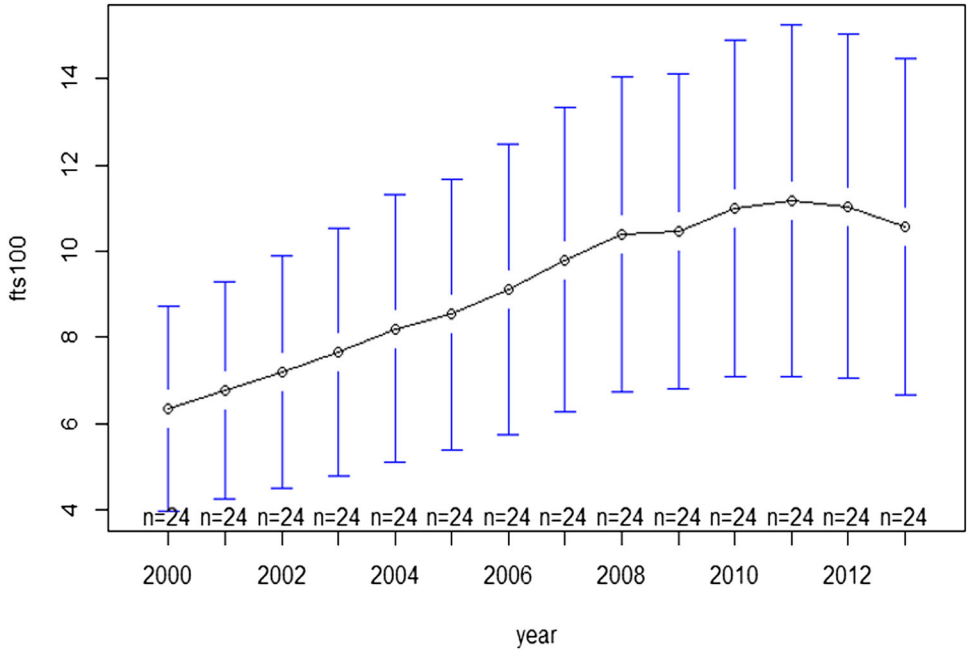

Figure 3. Fixed-line telephone subscriptions per 100 inhabitants in the lower-middle-income group.

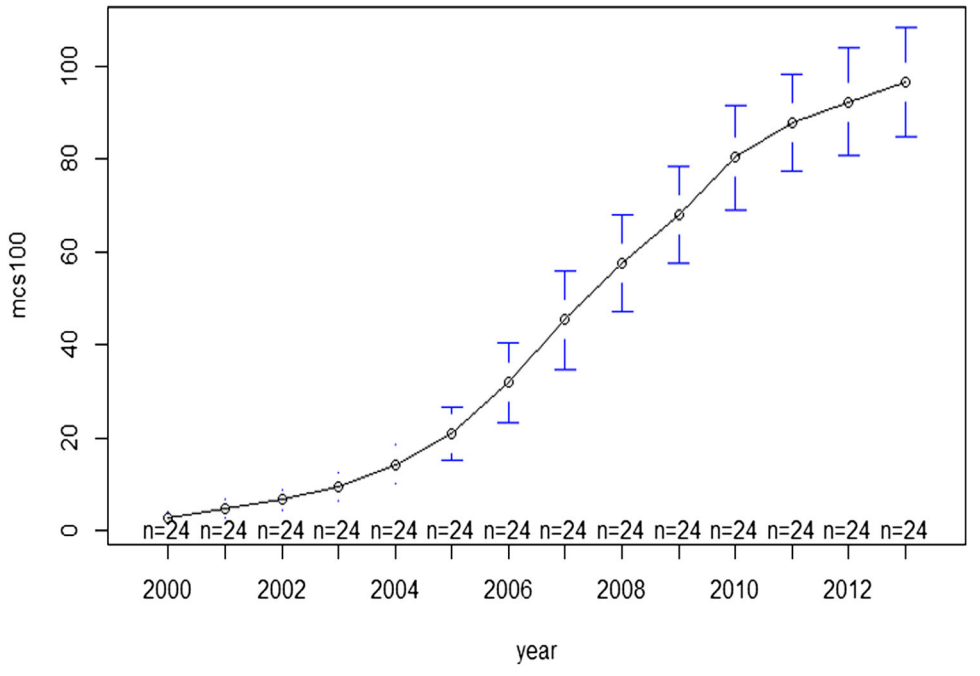

Figure 4. Mobile cellular subscriptions per 100 inhabitants in lower-middle-income group.

In the high-income group, all of the analyses except that of the relationship between MCS100 and economic freedom showed significant results at the 1% level. The change in the fixed-line broadband diffusion rate had the largest impact on political rights, followed by civil liberties and economic freedom. The change in the diffusion rate of fixed-line telephones had the greatest impact on civil liberties. Interestingly, there was no statistical significance shown by the change in the diffusion rate of mobile cellular phones on economic freedom, but the change in number of mobile cellular subscriptions had negative impacts on political rights and civil liberties.

8. Conclusion

This research attempted to examine the relationships between ICT diffusion and human progress indicators at the country level. In this study, economic freedom, political rights, and civil liberties were analyzed by a cross-sectional time series analysis with 102 sample countries broken down into different income groups from 2001 to 2013. We developed three main hypotheses with extensions based on the research question of whether the diffusion of ICT affects humans by allowing them to enjoy a better social environment. We chose to utilize the SUR method after considering the characteristics of the data. This study also included a one-year-lagged analysis to reflect the peculiarities of ICT, which requires a certain length of time for users to adopt. The results are conveyed at both the global pooled country level and at different income levels of the four country groups, i.e. high-, upper-middle-, lower-middle-, and low-income groups.

In the analysis at the global level, the diffusion rate of ICT served as a determinant of human progress. As expected, the Internet had the largest impact on political rights

among the three ICT variables. Fixed-line broadband technology showed the greatest impact on civil liberties compared to other types of technologies. Fixed-line telephones, for which the civil liberty diffusion rate is in decline, had an overall negative impact on human progress. At the same time, the impact of the change in the diffusion rate of mobile cellular phones had less of an impact than that of broadband technology. Through this analysis, H1, H3, H3.1, and H3.3 are accepted, but H3.2 is rejected because the impact of mobile cellular phones was weaker than predicted.

Further findings were conveyed by narrowing the research boundary to individual income groups by country. Each income group experienced different impacts on human progress due to changes in the diffusion rate of ICT. In the low-income group, an impact from the diffusion of ICT was rarely found. With greater incomes, greater impacts on human progress by the diffusion of ICT were found. In the lower-middle-income group, only two factors were found to have significant effects on economic freedom: fixed-line telephones and mobile cellular phones. In addition, only mobile cellular technology had an effect on all of the human progress indicators in the upper-middle-income group. Needless to say, high-income countries were impacted by ICT diffusion according to nearly every human progress indicator. However, this stands in contrast to the upper- and lower-middle-income groups, where mobile technology had negative impacts on the human progress indicators. Again, the results from the grouped analysis confirm a difference in the impact on human progress by the diffusion of ICT.

To summarize, it is clear that the change in the diffusion rate of ICT serves as a determinant of human progress at the global level. This research also found that the impact on human progress of ICT diffusion varies depending on the technology type and income level of a country. For instance, the upper-middle-income group demonstrated the greatest impact on human progress by mobile cellular phones, while this technology had a markedly negative impact in the high-income group. Still, the rich felt a stronger impact on human progress of diffusion of ICT than the poor. The grouped analysis approach based on income level suggests that both differences in technology and income level matter when attempting to measure the impact of the diffusion of ICT.

The findings of this research have several implications regarding the development of policies and the promotion of the diffusion of a GPT in a country. First, development policymakers should address the results of this study when considering whether to promote the diffusion of ICT at the national level in order to introduce improvements in human progress. At the organizational level, ICT diffusion can increase productivity, as mentioned above. However, because a country-level analysis is a collection of different types of constituencies compared to a profit-maximizer organization, the impact of ICT diffusion at the country level should also consider the issue of human progress based on the findings of this research.

Second, this study contributes to extending the debate on the spread of different GPT forms to impact human progress in countries. This is not only limited to ICT, but also to other technological regimes, such as electricity or transportation, which can also be categorized as forms of GPTs with great variability and adaptability. Because GPTs are used for multiple purposes, other types might play similar roles affecting human progress in a country.

Third, this work compares the impact of ICT diffusion on human progress indicators by both type of technology and income group. ICT was segmented into technology type, namely fixed-line telephony, broadband Internet, and mobile telephony, depending on the income level of the countries for a period of more than a decade. This study extended

the discourse from other previous ICT studies, which mainly focused on short-term, technology-specific, or region-specific analyses. This extension will provide empirical grounds in the decision-making process of policy-makers by dividing the technologies according to ICT and the income level of a country. The empirical analysis of 14 years of data will also strengthen the credibility of these results.

However, this study has several limitations. First, the 14 years analyzed do not contain the recent technological change in the ICT environment. While smart devices innately bring Internet access, our analysis did not separately categorize these new devices, instead including them in the group of mobile cellular subscriptions (MCS100). Thus, future studies conducting an analysis between pre- and post-smart-device eras would be able to show the difference in the impact of smart devices on human progress.

Second, the limited data availability limits the range of this study, especially in low-income countries. We concluded that satisfying basic needs is more important than promotion of ICT diffusion in low-income countries, but different results based on supplementary data might show different results. Further availability of low-income country data will shed light on the impact of ICT diffusion on human progress. It is important to acquire more data from low-income countries, because promotion of ICT to alleviate extreme poverty is actively being continued at the global scale. The most rapid diffusion rate and innovative usage of ICT will also bring new insights to studying the impact of ICT on human progress.

Third, the human progress indicators were restricted to political rights, economic freedom, and civil liberty in this paper. These approaches were based on extending previous ICT studies, which had focused analyses by region or time period. In addition, this paper attempted to assess the impact of ICT on human progress separate from productivity measures or gross domestic products, which are generally accepted indicators for determining the well-being of a nation. In future studies, conducting an analysis of the relationships between the diffusion of ICT and other human progress indicators is suggested. As technology changes lifestyles, the impact of ICT should be examined further given its role of facilitating progress in our everyday lives.

Note

1. Variable description in the SUR Model is as follows:
   EF_t: Economic freedom indicator at time t.
   PR_t: Political rights indicator at time t.
   CL_t: Civil liberties indicator at time t.
   $FBS100_{t-1}$: Fixed-line broadband subscriptions per 100 inhabitants at time $t-1$.
   $FTS100_{t-1}$: Fixed-line telephone subscriptions per 100 inhabitants at time $t-1$.
   $MCS100_{t-1}$: Mobile cellular subscriptions per 100 inhabitants at time $t-1$.

Disclosure statement

No potential conflict of interest was reported by the authors.

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