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Is ICT a new essential for national economic growth in an information society?

Sangki Jin [a,*], Cheong Moon Cho [b]

[a] Korea Student Aid Foundation, Republic of Korea
[b] National Information Society Agency, Republic of Korea

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ABSTRACT

This paper attempts to empirically verify the theoretical assumption that ICT factors affect national economic development. To this end, this study will use a research model to examine the relationship between ICT and development through statistical evidence. IT infrastructure, IT competence, IT investment and IT trade size will be selected as variables reflecting ICT factors since these are widely used by the balance model of supply and demand. Also, this paper will employ several socio-economic factors such as population size, consumer inflation, national corruption and education as control variables. A panel data analysis was used to statistically verify the impact of national ICT capability on a country's development. Furthermore, this paper tried to find an intervening variable between ICT and national development such as national corruption, consumer inflation and national education that have been highlighted as important elements of national development from political and social perspectives, and improved explanatory power of the analysis model. This result indicates that these variables mediate ICT capacity's effects on each surveyed nation's economic growth. This study verified statistic relevance for the effects that ICT capacity has on economic development.

1. Introduction

Many researchers highlight ICT's role in and impact on the progress of human history after the Industrial Revolution (Northrop, 2000). The ITU (2010) defines ICT as an efficiency parameter of technological advance that revolutionizes production, logistics process and decision making. The effects of the information revolution are reaching a whole range of daily activities, bringing changes in the role and scope that the government, business and individuals play (Jin, 2008).

A diversity of both optimistic and pessimistic views co-exists on the ICT-led paradigm shift in human history.[1] Thus this issue has been subject to intense controversies in academia since 2000. Certain papers made a negative pitch of the digital divide and internet abuse or misuse (Haywood, 1998; Loader, 1998; Perelman, 1998; Schiller, 1966; Wresch, 1996), whereas other papers shed a positive light on ICT-initiated national development and its subsequent improvement in quality of life (Kim, 2013; Kraemer & Dedrick, 2001; Naisbitt, 1982; Negroponte, 1995; Toffler, 1990).

In this regard, other economists have debated whether ICT is a new production value system that can drive national development. Under this circumstance, ICT has become a subject of discussion on how it influences an economy and attests to the need for empirical studies on the effectiveness of the IT revolution since the 1980s. Certain studies on this topic exist, but a more in-depth study is needed because ICT began to impact human history around 30 years ago. Studies have to go into further detail on ICT's effects on national economic development. And another consideration is the unique nature of national policies that includes social context in studying ICT's effect on national development (Lasswel, 1971).

In this vein, this paper attempts to assess the impact of ICT capacity on economic development. To this end, statistical and empirical verification of the ICT sector, which are considered important factors in economy, is performed. Also, a panel data analysis method (which can analyze both longitudinal and cross sectional effects at the same time) is used and examines the issue with time variable on the vertical axis.

2. Theoretical and literature reviews

2.1. Literature review

The literature review finds that two research methodologies are used in examining how ICT development affects national competitiveness and economic growth. One method is a longitudinal approach for time-series analysis. This method considers chronological time flow in

* Corresponding author.
E-mail addresses: wooyul10@gmail.com (S. Jin), cmcho@nia.or.kr (C.M. Cho).

[1] Theological arguments on the information society have been conducted by scholars with both positive (Negroponte, Naisbitt, Toffler, Wurman, Godfly) and negative (Schiller, Loader, Wresch, Perelman, Haywood) perspectives on the matter (Kim, 2013: 14–16).

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examining how a variable is correlated to another. The other method is a cross-sectional approach that involves multiple countries; the major purpose of this method is to target multiple countries to find a cross-country analysis in which ICT progress affects national competitiveness or economic growth.

The typical method of the longitudinal approach is to choose one country as a case study to examine how ICT development is related to economic development over a particular time span. The analysis method used in this approach is usually statistical time series analysis or descriptive case study as illustrated by the following cases.

Cisco (2003) uses time series analysis to explain that investment in ICT has positively affected economic growth in the U.K. (1992–2000). The positive impact of ICT investment was found to be particularly evident on the job market, and was achieved through human capital restructuring. Similarly, Chu (2005) finds that profit generated by New Zealand's IT service sector positively correlated to GDP growth from 1987 to 2001.

The literature review finds that most previous papers use a single country as a case study. Therefore, these prior studies are considered to have a limitation on generalizing the findings to all nations. In this sense, this paper broadens horizons by surveying 128 countries to overcome the limitations of preceding papers, namely the time series study of one case.

The other method is a cross-sectional approach to find a relationship between ICT progress and national development. The major purpose of this approach is to generalize the relationship between these two variables. Therefore, the analysis studies a diversity of nations to examine how ICT development is related to national development. To conduct comparative studies on national ICT levels across countries, Northrop (2000) examines relationships between economic factors, social infrastructure and information infrastructure (Garson, 2000a, 2000b: 256–280). This study has shortcomings, however, in that its coverage is confined to computer penetration and lacks a comprehensive conceptual approach of ICT.[2] But the good point of this study is to use the path model, which uses multiple regression analysis and path analysis in studying factors that affect cross-country differences in computer penetration. The analysis result finds information infrastructure to have the biggest impact on each country's computer penetration, and GDP and social infrastructure have the largest effect on information infrastructure.

Many similar papers have mentioned how an economy can benefit from ICT progress. First, NIA (2011) suggests a positive impact of ICT on national competitiveness through a study on how cross-country ICT status is correlated to WEF's indicator on national competitiveness. Second, the OECD (2008) says in a study of 19 countries that broadband technology penetration is related to GDP growth. Finally, LaRosea and Bauer (2013) emphasize the importance of public investment based on an analysis of the broadband technology opportunities program.

But all of these studies have shortcomings in that the approach narrowly focuses on the relationship between GDP and IT infrastructure (e.g., penetration of broadband and IT hardware) without considering other socio-political factors that might interfere in the relationship between ICT investment and GDP development. Preceding studies have also lacked methodological stringency as they take a time-flat approach while ignoring the chronological time-lag effect. It is common to overlook the time-lag effect in conducting a policymaking purpose research. When a causal factor is brought into consideration, we must consider the time-lag effect since it takes time before an outcome is realized by the introduction of input factor.

Moshe (2010) and Parsons (1996) have already indicated the time order between the precedence and result factors in examining the causal factor of economic development. But this principle has not been widely adopted due to the difficulty of the collection of time series data.

To overcome the limits of preceding papers, this paper utilized panel data that has been stored over a 13-year period, from 1999 through 2012, which measures various ICT and economy related indicators of 128 countries. Therefore, this paper has methodological strength compared to the precedent researches, which enables the consideration of both cross-sectional and time dimensions in examining the causal effect of ICT on nation's economic development.

2.2. Review of theory

2.2.1. National competitiveness and economic growth

The meaning of national competitiveness has been defined from multiple perspectives by various institutions. They include the ECD,[3] EU (Competitiveness Advisory Group), USA (U.S. Competitiveness), U.K. (Competitiveness White Paper), IMD (The World Competitiveness Yearbook), WEF (The Global Competitiveness Report) and UNDP (Human Development Index).

In addition, many studies use it as a conceptual basis that involves an intrinsic concept of evolutionary direction. The following chart shows that each definition of national competitiveness draws out its respective set of measurement factors to be quantified and described. Although many controversies linger over measurement variables, GDP is used as a major variable that represents productivity in assessing a nation's competitiveness.[4]

Porter (1990: 543–573) explains the development process of national competitiveness by dividing the process into four stages. The core message from the development strategies of national competitiveness by Porter (1990) lies in a development process of societal cohesion achieved by undergoing four stages: factor-driven stage, investment-driven stage, innovation-driven stage and wealth-driven stage

Reflecting a similar position, other papers have made theoretical assertions that economic growth drives competitiveness because the former is seen as a core element of enhancing the latter.

Ciccone and Jarocinski (2009) have shown statistically verified factors that influence economic growth.[5] This approach is a departure from the traditional model that focuses solely on economic factors to explain growth. In this model, economic growth is assumed to be a production function of labor, knowledge and technique.[6] Thus Antonio and Marek's theory outlines disciplined labor, capital investment and technological progress to be the key drivers of economic growth (Hicks & Hollander, 1977; Kaldor, 1956; Pasinetti, 1977; Samuelson, 1978).

Meanwhile, an alternative economic growth theory includes socio-economic factors (e.g., regulation, corruption,[7] education and ethics) as new factors to influence growth ($Y = F(L,K,T,S)$). In this alternative model, "S" is offered as a socio-economic factor and the need is stressed to add non-economic factors like socio-economic variables onto the traditional model's economic factors to better explain economic growth (Jalilian, Kirkpatrick, & Parker, 2007: 1–5; Nicoletti & Scarpetta, 2003). In this model, corruption is singled out as a major obstacle to economic

[2] Huntington (1996) considers computer ownership as the most important factor for modernizing a country. Northrop (2000) gets an idea from Huntington and conducts research whose coverage is limited to the number of computers owned.

[3] They define it in long-term perspective as that each country's level of increasing their people's real income by making it possible to produce goods & services as required by the world under free and fair market conditions.

[4] Economic growth factor is the most important gauge of national competitiveness. Besides this, national competence is also stressed as another important factor that leads mental, institutional and technological communication and convergence. To explain it, national corruption, education, and price increase are used in common as measurement variables by OECD, EU, UK, IMD, WEF and UNDP.

[5] In the research, they identified the key elements of economic growth as education, population growth, natural resources, government size, openness to trade, market access, inflation, age structure, war and conflict, and economy size.

[6] $Y = F(L,K,T)$.

[7] Klitgaard (1998) defines corruption as "deviation from official duty or violation of rules to gain monetary and status income". Transparency International (TI) defines corruption as the "abuse of entrusted power for private gain."

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Table 1
Concept of national competitiveness.
Source: IMD (http://www.imd.org/wcc/wcc-factors-criteria/), WEF (http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2012-13.pdf), Human Development Report 2014.

Sources	Conceptualization	Features
IMD	– A nation's capacity to provide an environment in which business activities within its territory can remain competitive both at home and abroad – 4 main factors (Economic performance, Government efficiency, Business efficiency, Infrastructure) including 20 sub-factors	Highlight a nation's ability to support businesses
WEF	– A nation's capacity to sustain a high level of per capita GDP growth, and also a set of institutional and economic policies that supports mid-term economic growth – 3 subindex and 12 pillars (Basic requirements (4), Efficiency enhancers (6), Innovation and sophistication factors (2))	To value survey data on policies
UNDP	– A nation's capacity to grant a decent quality of life for its people – 3 subindex (life expectancy, education, and income indices)	To raise quality of life

growth, and corruption-caused hindering factors have been statistically verified (Pak, 2002; Stiglitz, 2000). Drebek and Payne (2002) assert in their paper that national transparency is a major factor that impacts inbound foreign investment (such as foreign direct investment) and in turn, economic growth. In this regard, Keefer and Knack (1997) stress that economic growth is affected by government efficiency and transparency (Table 1).

2.2.2. ICT and national competitiveness

Two contradictory approaches exist on ICT's effects on national competiveness. The approach that negates ICT's effects on national competiveness emphasizes "the paradox of productivity" (Carr, 2003; Parsons, Gottleb, & Denny, 1990; Solow, 1987) which says that despite a rise in ICT capacity investment, productivity in business, industry and a nation does not increase in proportion to the rise in such investment, or it could even drop. On the other hand, multiple sources assert that ICT investment positively affects economic growth and national competitiveness by improving labor productivity or organizational efficiency.

Johnson (1992) and Kraemer and Dedrick (2001) cite important relationships between ICT and national development or economic growth through their own logical concept called "respectability": "accumulated relationship between ICT investment and economic growth" and a "virtuous circle structure." SERI (2008) also says ICT investment leads to improved productivity through "static economies of scale (e.g., informatization of industries)" and "dynamic economies of scale[8] (e.g., industrialization of information)." Static economies of scale is a reference to the economic effects that benefit each industry and business in the form of reduced cost and increased flexibility to produce high-quality products due to the spread of ICT. NIA (2011) also considers ICT development as a significant technological change that raises efficiency in capital and labor elements, both of which are input elements of productivity.

Meanwhile, the dynamic scale of economies is a reference to improved productivity that benefits business and industry that appears as a result of increased social labor division and know-how accumulation. This position is reflected by the ITU (2010), which calls ICT development as a major factor to increase each industry's productivity by simplifying and improving efficiency for decision-making and production and logistics.

[8] A form of increasing returns to scale in which average cost declines over time as producers accumulate experience, so that the average product rises with total output of a company or industry accumulated over time. It is related to R&D, marketing and training.

3. Research design

3.1. Research scope

In examining the effects of IT development on national development, this paper limits its scope to the impact of IT progress on economic development. Therefore, GDP is set as the dependent variable. In conducting the analysis, this paper seeks to increase the explanatory power of its findings to generalize all circumstances that can be universally applicable to most countries. This method differs from the preceding method that conducted a case study to explain a situation that is applied to a particular country. To this end, this paper has studied 128 countries that belong to the ITU. Considering that 193 nations are United Nations members, the sample size of this paper is substantially large enough to reflect all types of countries.

What this paper attempts to explain is IT development's impact on a nation's level of economic development. Therefore the unit of analysis is a national level characteristic, thus, the outcome of this research should be applied to the explanation of national development, not individual, within a particular country to avoid ecological fallacy.[9] The analytic tool for this paper is the panel data analysis by STATA 12.1 v.

3.2. Research framework

IT progress is highlighted as a core element of major technological advances in all countries moving toward a knowledge and information society in the 21st century (Gómez-Barroso & Pérez-Martínez, 2005; Hicks & Hollander, 1977; Kaldor, 1956; Kim, 2013; Pasinetti, 1977; Samuelson, 1978). But opinions diverge on which factors drive IT development.[10] Northrop (2000) and Huntington (1996) highlight the importance of technology-driven national advancement through laying out the national information infrastructure. Other papers have also presented non-technological and socially driven national development such as the role of policy and the importance of users (Kim, 2013). Furthermore, the supply–demand balance model is suggested as the theoretical framework for explaining ICT development. This model seeks to mutually balance the technological aspect with the social aspect in ICT development, while also stressing the role of government policy to control mutual adjustment of demand and supply (Kim, 2013).

Kim (2013) introduces the supply–demand balance model which integrates the technology deterministic approach of Northrop (2000) and Huntington (1996), who emphasized the supply side of IT, and the socio-economic approach of Masuda (1980), Naisbitt (1982) and Wilhoit (1981), who emphasized the demand side of IT. Furthermore, he added the policy sector as a coordination factor that seeks balance between supply and demand. His main focus lies in the balance of supply and demand, so his model is called the supply–demand balance model (Table 2).

In designing the research model, this paper adopts the aforementioned balance model of supply and demand as the theoretical framework to explain ICT development as the driver of national development.[11] From this perspective, this paper uses both supply and demand of ICT development as an important element in explaining each nation's ICT development.

[9] An ecological fallacy is an error in the interpretation of statistical data in an ecological study, whereby inferences about the nature of specific individuals are based solely upon aggregate statistics collected for the group to which those individuals belong (McGaw & Watson, 1976: 134).

[10] In Korea's case, government-initiated policy support for the developing nation's ICT capacity as comprised by IT infrastructure, competence and productivity is considered a major factor that positively impacted the nation's rise as an IT powerhouse (NIA, 2011).

[11] But the policy factor that Kim (2013) suggests in his stress on the balance model of supply and demand is not directly reflected on this study's research model. As this study covers 128 countries in its research model, it is unable to deeply cover each country's public policy cases. In other words, this study designs a model that gives priority in generalizing the explanatory power of 128 countries instead of detailing the case studies of each country.

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Table 2
Supply–demand balance model.
Source: Kim (2013), pp.: 4–9.

Dimensions	Supply	Policy	Demand
Theoretical background	Technology determinism Technology expansion theory	Policy science	Socio-economic constructionism
Proponents	Northrop (2000), Northrop (2002), Huntington (1996)	Kim (2013)	Masuda (1980), Naisbitt (1982), Wilhoit (1981)
Main focus	Development of technology and product, Infrastructure development	Support for R&D Development of experts Coordination between supply & demand	User capacity Cost to use or purchase IT

First, as the aspect of ICT supply, network infrastructure, computer penetration, mobile subscription, and import of telecommunication equipment were adopted in this paper. ICT infrastructure represents the supply dimension of the balance model of the supply and the demand in this paper. Otherwise put, this factor is the technology aspect and supplier side of this model. So fixed-line networks, the PC adoption rate and mobile phone subscription are employed as leading gauges of ICT infrastructure. Northrop (2002) stresses the PC adoption rate as a key benchmark for ICT development.[12] And mobile phone subscription[13] is used as another indicator to measure the recent rise of wireless networks in light of the global commoditization of mobile networks as well as the rise of mobile networks as mainstream national networks in developing countries.

Second, as the aspect of ICT demand, internet use rate, ICT workers, annual earnings in telecom service, and exports of telecommunication equipment were adopted in this paper. ICT capacity[14] could also be one of the important factors reflecting the ICT demand. However, due to the unavailability of data set to measure ICT capacity directly, proxy indicators such as the internet adoption rate and ICT human capital[15] were adopted in this paper. It can be assumed that ICT capacity and training may lead to high utilization of internet and increase of ICT workers, thus, it can be said that 'internet use rate' and 'ICT workers' may indirectly reflect the nation's ICT capacity and training.

Also, reinvestment of ICT service is seen as an important element to measure each country's ICT demand. Therefore, this paper adopts the telecom service sector's annual profit as another indicator to measure ICT demand. One of the most important activities in ICT is internet use, thus the internet usage rate is deemed an important indicator of ICT demand and capacity (Jin & Hyun, 2010).

Moreover, modern society is seeing a rapid evolution of knowledge and globalization, and new ICT technologies are fast spreading across the world. Especially, globalization widens the spatial concept of supply and demand, so this paper has to reflect this trend in research framework. Therefore, this paper proposes to use the export status of ICT equipment as an external demand and the import status of ICT equipment as an external supply factor to measure the effect of a country's ICT progress on national development.

Thirdly, this paper tried to explain the importance of ICT policy factor with ICT investment and GFCF. The concept of public policy is very complex which include regulation, distribution, and encouragement so it is arguable that ICT investment and GFCF are enough to represent the public policy variable. But this paper focused on the impact of ICT on economic growth, this paper highlighted the promotion aspect which is one of the most important functions of public policy. Researches studying the economic aspects of the ICT development, emphasized the importance of investment in ICT. Therefore, investment in ICT[16] is included in this paper under the assumption that government efforts toward ICT progress will eventually lead to financial investment in the sector, which is also aligned with policy factors in the balance model of the supply and demand. Thus, gross fixed capital formation (GFCF) and annual investment in the ICT sector are used as indicators to measure ICT investment. Finally, this paper employs moderating variables that have an indirect effect on interaction between development of the ICT sector and economy. Population size, consumer inflation, national corruption, educational capacity and time are mediators affecting both ICT development and economic development.

Human capacity is an important mediating factor which enables the utilization of ICT devices and networks for the efficient and productive activities (NIA, 2011). Appropriate indicator for measuring human capacity for ICT utilization is a digital literacy, however, no data set is available to measure digital literacy in the world-wide level. Thus this paper used general human capacity as a proxy indicator of digital literacy since ability to read letters can be seen as a useful index for measuring information literacy (UNDP, 2013). The education index, which the UNDP measures and releases, was adopted as an indicator for measuring human capacity. It is a composite measure including both UNESCO's illiteracy rate and school enrollment.

Next, in studying national development, each country's corruption level is seen as a major obstacle to economic growth, and so corruption[17] has been a popular topic of discussion as a hindrance to growth (Pak, 2002; Stiglitz, 2000). One assertion from Drebek and Payne (2002) says that national corruption greatly influences the flow of FDI into a country, and FDI affects economic growth. Finally, population size and consumer inflation, which have been traditionally mentioned as factors of economic growth, are also used as another mediating variable to examine how ICT development influences economic growth. The research framework can be shown in Table 3.

3.3. Operational definitions of variables

In the research framework, a country's GDP in a given year is used as a dependent variable (GNIi, t), according to the data source, the World Bank. Independent variables (t − 1) consist of ICT infrastructure, capacity, investment in the sector and trade size.

[12] Data for this study was collected from 128 countries for the past 13 years. So it is not easy for us to find a good ICT indicator available in all these countries. Thus, despite that PC adoption is not the best indicator of information society, PC penetration rate was adopted. PC has been a typical ICT instrument (as like an Index fossil) for the early information society of the past decade. And this paper also adopted mobile phone subscription rate as another IT indicator due to the importance of mobile phone in the recent days.

[13] ITU (2010) suggests mobile network as a cost-efficient and time-saving alternative to the existing fixed-line network for developing countries.

[14] Nation's ICT capacity was defined by NIA (2011) as composed of IT infrastructure (SOC), IT competence (ability to use ICT), and IT productivity (ability to make value with using IT).

[15] It means the level of ICT expert manpower which is gauged by ICT workers (no. of ICT full-timers in public and private sectors) in this paper.

[16] Cisco (2003) invites a particular attention to both investment to IT and investment to non-IT when it studies IT influence on national economy, and thereby suggests a research model that considers both variables.

[17] Klitgaard (1998) defines corruption as a deviation from public duties or violation of the rules with the aim of earning private financial profits or a privileged position. TI (Transparency International) defines it as abuse of entrusted power for private gain.

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Table 3
Research framework to study ICT progress and economic growth.

Category	Variable	Definition
Dependent variable (t)	(GDP)i, t	A country's GDP
Independent variable (t − 1)	(Supply)i, t − 1	Fixed-line internet network: no. of fixed-line broadband subscribers per 100 persons
		PC penetration rate: no. of PC owners per 100 persons (both of laptop and desktop PC)
		Mobile phone subscription rate: no. of subscribers per 100 persons
		Imports-telecommunication equipment
	(Demand)i, t − 1	Internet use rate: rate of internet users for the past one year vs. total population
		ICT workers: no. of ICT full-timers in public and private sectors
		Annual earnings in telecom service: annual earnings as posted by mobile and fixed-line telecom service providers in public and private sectors
		Exports-telecommunication equipment
	(Policy)i, t − 1	Gross fixed capital formation
		Total annual investment to telecommunication sector
Moderating variables	(Population size)i, t − 1	Population as officially surveyed and released by a government
	(PI)i, t − 1	Inflation (2000 year = 100)
	(CPI)i, t − 1	Each year's corruption perception index as surveyed and announced by TI
	(Education capacity)i, t − 1	Literacy rates for people above age 15
		Educational index is a composite measure reflecting both the illiteracy rate and school enrollment

First, the supply aspect (ICT infrastructure) is designed as a variable, (Supply)i.t − 1, to assess the level of a country's ICT infrastructure that has been established (t − 1). To measure ICT infrastructure, three indicators are used: the number of fixed-line internet subscribers per 100 persons (fixed-line network), PC owners per 100 persons (PC adoption rate), and the number of mobile phone subscribers per 100 persons (mobile phone subscription rate). These ICT infrastructure variables are analyzed using data from the ITU (International Telecommunication Union, 2013). Import of ICT equipment reflects the influx of technologies and devices, which will function as ICT development infrastructure; therefore, it was included as an indicator of the supply side of ICT development.

Second, three indicators measure ICT capacity, "(Demand)i, t − l," the internet use rate (or the rate of those who have used the Web over the past 12 months) and the number of ICT workers exclusively for ICT work (the number of ICT employees in the public and private sectors) were used. In addition, the telecom sector's annual earnings (US$) were used as posted by public/private telecom service providers in both fixed-line and wireless networks as another indicator for indirectly assessing ICT capacity. All of the data were measured from the World Telecommunication Data surveyed and released by the ITU. Finally, the export of ICT equipment shows a nation's capacity to sell its own technology or products abroad; so it was included as an indicator of the demand side of ICT development.

To measure ICT investment and moderating capacity "(Policy)i, t − 1," this study uses two variables: gross fixed capital formation (GFCF)[18] and total annual investment in telecommunication (US$) as surveyed and released by the ITU. To analyze the effects of trade size on economic growth (Trade size)i, t − 1, this paper uses two indicators under this variable: import and export sizes of ICT equipment (US$).

In addition, a set of mediators, or moderating variables, are included in the analysis model to strengthen the explanatory power of the analysis model. Population size "(Population size)i, t − 1"is the official number of a country's population as surveyed and released by each government. This paper uses these numbers from the World Bank. Consumer prices (PI)[19] are indicated as price increase as variable"(PI)i, t − 1." The corruption perception index "(CPI)i, t − 1" is used as a moderating variable, and surveyed and released by Transparency International (TI) to assess a country's level of corruption.[20] Finally, the UNDP educational index[21] and UNESCO's adult literacy rate are adapted to measure the education capacity (EDUi, t − 1), and these two variables are sourced from the Human Development Report.

4. Panel data analysis and findings

4.1. Fit model analysis

To avoid limitations of the ordinary least squares (OLS) method, this paper used panel data analysis that can control cross-sectional properties such as cultural characters and attributes of individual countries. Panel data analysis requires the selection of the best fit model between fixed and random effect models.[22] Selection of the best fit model was carried out by the Hausman specification test which compares the relevance of the fixed effects model with a random effects model to allow monitoring of set errors (Hausman, 1978). The test result shows that the fixed effects model fit the study more than the random effects model. Another problem in conducting panel data analysis with time series data is autocorrelation, or the correlation of a time series with its own past and future values. This is sometimes called "serial correlation," or the correlation between members of a series of numbers arranged in time. Autocorrelation can also complicate the identification of significant covariance or correlation between time series, so statistical analysis of time series data requires testing if autocorrelation exists (Dunn, 2005). If autocorrelation is detected, certain measures to rectify autocorrelation should be applied.

To test for the existence of autocorrelation, the Wooldridge test was conducted. The result shows that there is first order autocorrelation at one-percent significant level. Therefore, FEAR (fixed effects model with autocorrelation) was chosen as the best fit model in this research.

[18] Businesses replace aging equipment with new ones or build factories and buy machines to maintain production capacity and secure competitiveness. These activities are aimed at securing a future source of revenue over the long term. These resources used over multiple fiscal years are called capital goods, and the purchase of capital goods by the production subject is called the total fixed capital formation (TFCF = Physical capital formation + HR capital formation).

[19] Consumer price index (PI: The conventional acronym is CPI, however, to avoid confusion with the corruption perception index, PI will be used in this paper) measures changes in the prices of consumer goods and services purchased by households (Bureau of Labor Statistics).

[20] Since 1995, Transparency International (TI) has published the corruption perception index (CPI) every year. The organization defines corruption as "the abuse of entrusted power for private gain." A higher score means less (perceived) corruption (TI, 2013).

[21] The educational index is measured by the adult literacy rate and combined primary, secondary, and tertiary gross enrollment ratio. Education is a major component of well-being and used to measure economic development and quality of life, which are key factors determining whether a country is developed, developing or underdeveloped (UNDP, 2013).

[22] The fixed effects model represents observed quantities in terms of explanatory variables that are all treated as if the quantities were non-random.(Christensen, 2002).

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4.2. Impact of ICT on economic growth (1999–2012)

For the analysis of ICT's effects on a country's economic development, this paper included a set of moderating variables[23] assumed to have a relationship with economic growth. This paper assumes that certain variables (e.g., educational capacity, national corruption, consumer price index, and population size) that have been emphasized from the points of view of economists and sociologists could control or intermediate the relationship between ICT progress and economic growth. The missing data of each variable was compensated by linear interpolation.[24]

The analysis result is outlined in Table 4. The effects of ICT development on economic growth remain almost the same even adding moderating variables, resulting in three ICT factors, variables of ICT supply and ICT demand and ICT policy, related to economic growth.

Among the three indicators under the ICT supply dimension, only the mobile network adoption rate is shown to have a significant effect on economic development. The reason can be traced to the rapid shift of mainstream broadband access from fixed line to mobile network since 2000. So the inference is that a more intensive and wider mobile network can have a more positive effect on economic growth. But the analysis of the panel model found no statistically significant effects of the PC adoption rate on economic growth. The inferred reason is that a variety of multiple online interfaces has been made available as alternatives to the PC, which was the main interface in the 1980s and 90s. So the logical inducement is that rather than the simple PC adoption rate, the adoption rate of multiple web-interfacing devices has a positive influence on economic growth.

Next, the analysis result of the panel model on the ICT demand dimension shows that the internet use rate and telecom profit are statistically significant for economic development. No statistic relevance was found, however, for the effect that ICT workers have toward economic development.

The analysis of how the ICT policy dimension (investment) is related to economic growth shows strong statistical relevance for the positive effects of GFCF on economic growth. Finally, ICT trade size is statistically unrelated to economic growth in this model.

4.3. Moderating effects on economic growth (1999–2012)

Next is the analysis of the effects of moderating variables on economic growth. Moderating variables related to human capacity have no statistically significant direct relationship to economic development. It can thus be inferred that the use of technology that fits the information age has a greater impact on economic development than just education or literacy capacity. The panel analysis indicates that the internet use rate has more meaningful influence on economic growth than the educational index or adult literacy rate.

Other moderating variables are national corruption and the consumer price index; both are shown to affect national economic growth positively, with significance levels of 95% and 99%, respectively. The positive effect of CPI (corruption perception index) on economic development is consistent with the assertions that emphasize good governance as a critical factor for economic development. Inflation, however, should not be considered a real cause of economic development. Instead, GDP calculated each year reflects the price level of a particular year, so GDP is highly correlated with inflation.[25]

Table 4
Analysis of ICT's impact on economy with moderating variables (1999–2012).

Model: FEAR		(Fixed effect with autocorrelation)
Variables		GDP
Moderating variables	Educational index	0.242 (0.300)
	Adult literacy rate	0.014 (0.020)
	National corruption	0.344** (0.146)
	PI (consumer price index)	1.215*** (0.395)
Environment	Population size	0.151 (0.130)
ICT policy	Investment in ICT	0.009** (0.019)
	GFCF	0.600*** (0.070)
ICT demand	Annual earnings by telecom service providers	0.151* (0.083)
	No. of ICT workers	0.000 (0.000)
	Internet use rate	1.945***(0.567)
	Export of ICT equipment	0.000 (0.000)
ICT supply	Mobile network adoption rate	0.004** (0.002)
	PC adoption rate	0.004 (0.041)
	Fixed-line network subscription rate	0.000 (0.000)
	Import of ICT equipment	−0.000 (0.000)
Interaction terms	Crosprice (Int_PI) (internet use rate vs price increase rate)	−0.487***(0.121)
	Croscpi (Int_CPI) (internet use rate vs corruption perception index)	0.217***(0.062)
	Crosedu (Int_Edu) (internet use rate vs education index)	0.153* (0.105)
Constant		−0.392***(0.061)
R-Sq (overall)		0.7716
Observations (no. of IDs)		128 (67)

Standard errors in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

4.4. Interaction effects between ICT and economic growth (1999–2012)

This section reviews the interaction effects of ICT factors and moderating variables on economic development. Among all ICT variables, the internet use rate was selected as a leading ICT variable.[26] The interaction effect analysis of the panel model could be used to explain whether moderating variables mediate ICT's effects on economic growth. In other words, it allows the statistical verification of whether moderating indicators (e.g., PI, CPI and the national education index) negatively or positively mediate the internet use rate's impact on economic development.

First, the analysis of the panel model shows that both the consumer price index (PI) and the internet use rate positively affect a country's economic development at 99% statistical significance. And the analysis of "crosprice" terms shows that the interaction effect of consumer price increase (PI) and the internet use rate is negative (−), meaning that inflation tends to diminish the internet use rate's net marginal effects on economic growth.

Second, this study employs the croscpi term to examine the interaction effect of CPI (corruption perception index) and the internet use rate

[23] As a kind of independent variable to systematically change the relationship between independent and dependent variables, moderating variables can adjust the cause-and-effect relationship between independent and dependent variables.

[24] Linear interpolation is often used to fill gaps in a time-series table. Suppose that one table lists a country's population in 1970, 1980, 1990 and 2000, and that the intent is to estimate the population in 1994. Linear interpolation is an easy way to do this (Stata Press, 2009).

[25] This statistical result could be used to show the existence of a relationship between GDP and PI rather than interpreting that PI has a positive impact on national development. In other words, a rise in consumer price leads to higher national production, which causes GDP to rise.

[26] The internet use rate is most often used as a leading indicator by international organizations like the OECD, World Bank and the UNDP in measuring the level of a country's information advancement. The reason is that the ultimate goal of ICT development is the use of ICT (internet), therefore, IT infrastructure or investment should lead to an increase in the number of web users.

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on economic development. National transparency is often stressed as a source of competitiveness (Pak, 2002; Stiglitz, 2000). The previous analysis of direct effects indicated that both the internet use rate and the corruption perception index (CPI) are statistically significant for economic development. The positive coefficient of the interaction between national corruption and internet use rate is shown in the analysis result of the croscpi effect. This attests to a country's corruption rate and internet use rate having a reinforcing effect on economic development. Two variables — national corruption and internet adoption rates — have a mutually boosting effect on one variable's effects on a dependent variable. The inference is that high national transparency tends to raise the net marginal effects of the internet use rate on economic development, whereas a high internet use rate leads to more net marginal effects of national transparency on economic development.

Finally, this study examines whether the national education index moderates the internet use rate's effects on economic development. To do this, the crosedue term is used. Contrary to the previous finding of no direct effect of the national education index on economic development, an interaction term analysis shows that the index has a positive interaction effect with the internet use rate on economic development. This result indicates that a rise in a country's educational index tends to increase the net marginal effect of internet use on economic growth. This attests to the national education index having a mediating effect rather than direct influence on economic growth through the impact of the internet use rate on economic development. This analysis result underscores the importance of the indirect effect that ICT capacity has on economic development.

4.5. Analysis of policy factors on ICT's effects on economic development

While public policy factors, a key component of the supply and demand balance mode, cannot be easily detected by a quantitative study like this paper, there are a few significant effects of policy factors from logical and statistical findings from the panel data model.

This paper argues that ICT policy can be a critical moderator for IT development on economic growth in both the supply and demand dimensions.[27] The findings of the panel data model that "ICT policy" (GFCF and investment in ICT) variables are statistically significant mean that key factors of ICT policy boost ICT demand.

Out of two dimensions of policy, regulation and promotion, this paper focused on promotion aspect of policy since it intended to reveal the impact of ICT on national economic growth.[28] However this paper cannot show how to build ICT policy for the economic development since it does not include a case study of each country's ICT policy.

In Korea's case, policy factors have played a key role in boosting ICT development, so much so that the Korean government raised investment in ICT (i.e., information highway and e-government) to overcome the economic crisis of the late 1990s. This policy has been evaluated as successful and allowing Korea to overcome economic crises and become an information society in a short time (NIA, 2011).[29]

ICT investment impacts not only the supply dimension but also the demand side per panel data analysis. Government investment in ICT education for citizens is a key factor in Korea's ICT success (KOICA, 2009; NIA, 2011). As seen in the panel data model, traditional education has no impact on development but interaction terms with ICT capability do contribute to an information society. So recently, the concept of transliteracy[30] has been highlighted in the ICT education sector. Transliteracy is all about the ability to move across competing literacies, and one way to do this in instruction is emphasis on cross-platform (or "multimodal") research skills. That is, what should be taught is skills and concepts that are transferable between radically different media (Bobish, 2011). So rather than treat library instruction as a class on library skills, information literacy can be handled more broadly and be divorced from a particular information source. Bobish (2011) reinforces this need for transferable information literacy instruction, insofar as he provides great examples for classroom activities that engage students on their own information turf (i.e., Facebook and Twitter), yet still teach the kinds of skills needed in academic research.

This paper adopted panel data analysis to consider time-lag effect between independent and dependent variables in exploring the causal effect of ICT on the nation's economic development. So the values of ICT and other medicating factors were obtained from the data set surveyed 1 year early.

Finally, this paper emphasizes the importance of policy factors in ICT's effects on national development. And this can be called a virtuous circulation of ICT policy in that the latter promotes ICT investment on the supply side (e.g., ICT infrastructure and service provider part), and it increases the demand side and creates the need for another ICT policy.

5. Conclusion

Traditional economists have emphasized the importance of human capital, financial capital and technology as vital elements of economic growth. Since the advent of the information society after industrialization, ICT has been considered a major factor in economic growth. So ICT factors have been theoretically highlighted as a driver of economic growth. This study also seeks to statistically explain whether ICT components affect economic growth.

This paper adopts the balance model of supply and demand, and thus used three components — ICT investment, capacity and infrastructure — that reflect various aspects of ICT development. Furthermore, socio-economic factors such as human capital, national corruption and inflation are also included as moderating variables to show the intermediating effects of these variables in the causal relationship between ICT factors and economic development. Another merit of this study is to conduct analysis of time-series data from 1999 to 2012 (13 years), not only cross-sectional data or only the case studies of one or two nations. This paper can find important results from the panel data analysis.

First, ICT demand, supply and policy among the three components of ICT development turn out to have a positive causal effect on economic development. The effects of these variables remain strong even after controlling socio-economic factors such human capital, national corruption and consumer inflation.

Second, an analysis of moderating variables shows that national corruption and consumer inflation have a direct relationship with economic development. Furthermore, national corruption and inflation have interaction effects with ICT development on economic development. Thus, these two moderating variables could be said to have a reinforcing effect with ICT development on economic development.

Third, human capital, a key moderating variable, cannot find a statistical relationship with economic development but has an interaction effect with ICT development on economic development. Thus a country's human capital has no causal effect on economic development by itself, but could have a significant causal effect when it comes with co-progress in ICT development.

[27] Gómez-Barroso and Pérez-Martínez (2005) say any public intervention in access to advanced telecommunications services should be based on one or more causes that justify state intervention in industrial activities.

[28] The concept of 'Public Policy' is very complex which include regulation, distribution, and promotion.

[29] LaRosea and Bauer (2013) show the impact on and importance of ICT investment to accelerate the deployment of advanced broadband networks and services to unserved and underserved regions of a country.

[30] Transliteracy is the ability to read, write and interact across a range of platforms, tools and media from signing and orality through handwriting, print, TV, radio and film to digital social networks (www.transliteracy.com).

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This paper also finds that public policy factors are a big part of economic development in an information society. ICT policy factors make a virtuous circulation: promotes ICT investment and increases the demand side, then creates the need for another ICT policy.

Furthermore, this paper considered the time-lag issue which is academically discussed by policy science researchers such as Moshe (2010) and Parsons (1996). Thus, in measuring ICT development (ICT policy, ICT demand and ICT supply factors), one-year early ICT level was used in order to enhance the explaining power of panel data model.

Overall, this paper has explained that ICT development is a key factor in economic development, and additional analysis of the effects of moderating variables also shows that higher national transparency, management of consumer inflation and human capital have direct or indirect effects on national development. One policy suggestion derived from this analysis is that ICT development planning as a catalyst for economic development requires not only consideration of ICT factors but also socio-economic factors.

Finally, this research has proven that the balance model of supply and demand is suitable for analyzing the impact of ICT development on economic development.

Despite the contribution mentioned above, the authors have expressed the need for further qualitative case studies to see and explore the internal policy dynamic that mediates IT development and economic growth. Case studies can show the real process of how IT development led to economic growth and the policy process adopted by a nation in pursuing IT development and economic growth.

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Sangki, JIN earned a Ph.D. in Public Administration from Sungkyunkwan University in Seoul and served as principal researcher in the National Information Agency, Seoul, Korea. He currently works as principal researcher in the Korea Student Aid Foundation (KOSAF), Seoul, Korea. He has written many articles on ODA policy, information policy, and performance evaluation in the public sector, and is also co-author of Audit System of Korea Local Government. Email: wooyul10@gmail.com

Cho, Cheong Moon earned Ph D. in Sociology form University of Maryland, College Park and serves as director in national Information Society Agency (NIA) in Seoul, Korea. Email: cmcho@nia.or.kr

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