EFFECTS OF INFORMATION COMMUNICATION TECHNOLOGIES ON ECONOMIC GROWTH, ENVIRONMENTAL QUALITY, AND LABOR PRODUCTIVITY

By

YONG SZE WEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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October 2022

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The first objective of this study is to investigate the impact of ICTs on economic growth, which is dependent on the intelligence threshold level for the 128 countries in 2019. ICTs are key driver of economic growth, and several studies have been conducted with varying perspectives on ICTs. Most research has been conducted on the relationship between ICTs and economic growth. However, research on the relationship between ICTs and intelligence-based economic growth is limited. Specialists in operating, investing, and expanding technology are required to use ICT infrastructure effectively. Employees with a high level of intelligence will ensure that ICT adoption runs smoothly and significantly increase productivity over workers with a low level of intelligence. This study investigates the role of intelligence in moderating the impact of ICTs on economic growth. The threshold regression model provides a more consistent and accurate indication of the intelligence threshold value, which can be used to show how intelligence influences the ICTs and economic growth nexus in both below and above-threshold regimes. Hansen's (2000) threshold regression estimation reveals that ICTs stimulate economic growth when intelligence is below a certain threshold level but not above the threshold value. To improve economic growth, developing-country policymakers should prioritize human capital development through skill-based training, particularly in the digitalization era.

The second objective of this study is to examine the ICTs threshold effect on economic growth and environmental quality nexus. Environmental quality has long been regarded as a critical factor in long-term growth and advancement in many countries. The CO_2 emissions rate in developing countries increased to 63 percent in recent years due to industrialization procedures and significant energy-intensive technologies for national development and progress. According to the United Nation (2015), ICTs help to promote economic growth and address environmental challenges. Therefore, this study employs dynamic panel threshold regression by Seo et al. (2019) to examine the

threshold effect of ICTs on economic growth and environmental quality for 69 developing countries from 2000 to 2019. The empirical results indicate that the ICTs variable is a statistically significant determinant of economic growth and environmental quality. Economic growth improves the environmental quality when the ICTs variable is below the threshold value. When the usage of ICTs exceeds the threshold value, economic growth degrades the environmental quality in developing countries. Thus, ICTs use in these countries to modernize, automate, and digitalize production processes requires close monitoring and legitimate concern from policymakers to ensure that ICTs usage is optimal and not excessive. Excessive ICTs use degrades environmental quality in developing countries.

The third objective of this study is to evaluate the impacts of ICTs on labor productivity in 84 developing countries from 2000 to 2019, using the dynamic panel system generalized method of moments (GMM) and dynamic panel quantile regression estimations. According to ITU (2020), ICTs play a pivotal role in boosting productivity and employment in developing countries, thereby achieving one of the 2030 Agenda's priorities and a component of Sustainable Development Goal 8. This notion is supported by the rapid growth of the youth population in developing countries, as they are active ICTs user and will shape the future labor market. The empirical findings provide new evidence on the moderating effect of ICTs on human capital, financial development, and trade openness in influencing labor productivity in developing countries. ICTs have a positive and statistically significant moderating effect on labor productivity in developing countries through ICTs' interaction with the above three variables. Comparatively, the outcome from dynamic panel quantile regression reveals that ICTs improve labor productivity in the lower and middle quartiles than in the upper quantiles of developing countries. This study can help policymakers develop a long-term strategy for ICTs adoption and usage in developing countries to achieve industrial 4.0 goals.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN TEKNOLOGI KOMUNIKASI MAKLUMAT TERHADAP PERTUMBUHAN EKONOMI, KUALITI ALAM SEKITAR DAN PRODUKTIVITI PEKERJA

Oleh

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Objektif pertama kajian ini adalah untuk mengkaji kesan ICT ke atas pertumbuhan ekonomi, yang bergantung pada tahap ambang kepintaran untuk 128 negara pada 2019. ICT adalah pemacu utama pertumbuhan ekonomi, dan beberapa kajian telah dijalankan dengan pelbagai perspektif. Penyelidikan yang paling banyak telah dijalankan mengenai hubungan antara ICT dan pertumbuhan ekonomi. Walau bagaimanapun, penyelidikan mengenai hubungan antara ICT dan pertumbuhan ekonomi berasaskan kepintaran adalah terhad. Pakar dalam mengendalikan, melabur dan mengembangkan teknologi diperlukan untuk menggunakan infrastruktur ICT dengan berkesan. Pekerja yang mempunyai tahap kepintaran yang tinggi akan memastikan penggunaan ICT berjalan lancar dan akan meningkatkan produktiviti dengan ketara berbanding pekerja yang mempunyai tahap kepintaran yang rendah. Kajian ini mengkaji peranan kepintaran dalam menyederhanakan kesan ICT ke atas pertumbuhan ekonomi. Model regresi ambang memberikan petunjuk yang lebih konsisten dan tepat tentang nilai ambang kepintaran, yang boleh digunakan untuk menunjukkan bagaimana kepintaran mempengaruhi ICT dan perhubungan pertumbuhan ekonomi dalam kedua-dua rejim ambang bawah dan atas. Anggaran regresi ambang Hansen (2000) mendedahkan bahawa ICT merangsang pertumbuhan ekonomi apabila kepintaran berada di bawah tahap ambang tertentu tetapi tidak apabila kepintaran melebihi nilai ambang. Untuk meningkatkan pertumbuhan ekonomi, penggubal dasar negara membangun harus mengutamakan pembangunan modal insan melalui latihan berasaskan kemahiran, khususnya dalam era pendigitalan.

Objektif kedua kajian ini adalah untuk mengkaji kesan ambang ICT ke atas pertumbuhan ekonomi dan perhubungan kualiti alam sekitar. Kualiti alam sekitar telah lama dianggap sebagai faktor kritikal dalam mencapai pertumbuhan dan kemajuan jangka panjang di banyak negara. Kadar pelepasan CO_2 di negara membangun meningkat kepada 63 peratus dalam beberapa tahun kebelakangan ini hasil daripada prosedur perindustrian dan teknologi intensif tenaga yang ketara untuk pembangunan dan kemajuan negara.

Menurut United Nation (2015), ICT membantu menggalakkan pembangunan ekonomi dan menangani cabaran alam sekitar. Oleh itu, kajian ini menggunakan regresi ambang panel dinamik oleh Seo et al. (2019) untuk mengkaji kesan ambang ICT ke atas pertumbuhan ekonomi dan kualiti alam sekitar bagi 69 negara membangun dari tahun 2000 hingga 2019. Keputusan empirikal menunjukkan bahawa pembolehubah ICT adalah penentu pertumbuhan ekonomi dan kualiti alam sekitar yang signifikan secara statistik. Pertumbuhan ekonomi meningkatkan kualiti alam sekitar apabila pembolehubah ICT berada di bawah nilai ambang. Apabila penggunaan ICT melebihi nilai ambang, pertumbuhan ekonomi merendahkan kualiti alam sekitar di negara membangun. Oleh itu, penggunaan ICT di negara-negara ini untuk memodenkan, mengautomasikan dan mendigitalkan proses pengeluaran memerlukan pemantauan rapi dan kebimbangan yang sah daripada penggubal dasar untuk memastikan penggunaan ICT adalah optimum dan tidak berlebihan. Penggunaan ICT yang berlebihan merendahkan kualiti alam sekitar di negara membangun.

Objektif ketiga kajian ini adalah untuk menilai kesan ICT ke atas produktiviti pekerja di 84 negara membangun dari tahun 2000 hingga 2019, menggunakan sistem panel dinamik *Generalized Method of Moments* (GMM) dan anggaran regresi kuantil panel dinamik. Menurut ITU (2020), ICT memainkan peranan penting dalam meningkatkan produktiviti dan pekerjaan di negara membangun, dengan itu mencapai salah satu keutamaan Agenda 2030 dan komponen Matlamat Pembangunan Mampan 8. Tanggapan ini disokong oleh pertumbuhan pesat populasi belia di negara membangun kerana mereka adalah pengguna ICT yang aktif dan akan membentuk pasaran pekerja masa hadapan. Penemuan empirikal memberikan bukti baharu tentang kesan penyederhanaan ICT ke atas modal insan, pembangunan kewangan, dan keterbukaan perdagangan dalam mempengaruhi produktiviti pekerja di negara membangun. ICT mempunyai kesan penyederhanaan yang positif dan signifikan secara statistik terhadap produktiviti pekerja di negara membangun melalui interaksi ICT dengan tiga pembolehubah di atas. Secara perbandingan, hasil daripada regresi kuantil panel dinamik mendedahkan bahawa ICT meningkatkan produktiviti pekerja di kuartil bawah dan pertengahan berbanding kuantil atas negara membangun. Kajian ini boleh membantu penggubal dasar membangunkan strategi jangka panjang untuk penerimaan dan penggunaan ICT di negara membangun untuk mencapai matlamat industri 4.0.

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Date: 8 June 2023

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α	Alpha
β	Beta
AI	Artificial Intelligence
ARDL	Autoregressive Distributed Lag
ATKC	Agriculture Technology Kuznets curve
B2B	Business-to-Business
BRICS	Brazil, Russia, India, China and South Africa
CIS	Commonwealth of Independent States
CO_2	Carbon Dioxide
DEA	Data Envelopment Analysis
DOLS	Dynamic Ordinary Least Squares
DSUR	Dynamic Seemingly Unreal Ted Regression
EKC	Environmental Kuznets Curve
EMDEs	Emerging Market and Developing Economies
EPA	Environment Protection Agency
EU	European Union
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GGEs	greenhouse gas emissions
GMM	Generalized Method of Moments
GPT	General-purpose technology
ICT	Information and Communication Technology
IEA	International Energy Agency
IFs	International Futures

ITU	International Telecommunication Union
I.T.	Internet Technology
I.Q.	Intelligence Quotient
LM	Lagrange Multiplier
MFP	Multifactor Productivity
OECD	Organization for Economic Cooperation and Development countries
PISA	International Student Assessment
QR	Quantile regression
QRPD	panel quantile regression method with non-additive fixed effects
SDG	Sustainable Development Goals
TFP	Total Factor Production
TIMSS	International Mathematics and Science Study
U.N	United Nations
VECM	Vector error correction model
WDI	World Development Indicators
WTO	World Trade Organization (WTO)
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Information and communication technologies (ICTs) have emerged as a powerful new force in today's digital age, reshaping our daily life and the business world in manifold ways. ICTs are defined as the management and communication of information through electronic tools and resources such as computers, the internet and broadcasting technology (Kaware and Sain, 2015). Besides that, ICT is also referring to information science that specifically manages computers and is used to facilitate the communication of expertise in the technological, economic, and social domains (Clement Ola, 2018). ICTs comprise six components: internet access, software, hardware, transaction, cloud computing, communication community, and data. Many researchers believe that ICTs play a role as general-purpose technology and have become an essential part of various industries (Ahmed and Ridzuan, 2013). ICTs are used as a technological advancement parameter in the business world to assist industrialization and economic growth (Niebel, 2018). The development of ICTs has transformed traditional business operations into electronic commerce. ICTs changed the nature of world trade and competition worldwide, as evidenced by successful cases like Alibaba.com, Amazon and eBay. For instance, the Alibaba group transformed China's market into a B2B online marketplace and benefited numerous sellers and buyers worldwide.

Moreover, ICTs are the catalyst for accomplishing the Sustainable Development Goals (SDGs), particularly in environmental quality, social integration, and sustainable growth, the three supports of sustainable development in the SDGs. According to the 2030 Agenda for Sustainable Development, the spread of ICTs and global interconnection is essential for human progress, closing the digital gap, and constructing knowledge societies. The 2030 Agenda also underlined the critical roles of ICTs in achieving the 17 Sustainable Development Goals, including poverty reduction, productivity and growth development, education system enhancement, and healthcare improvement. For instance, ICTs help reduce poverty by increasing the productivity of millions of people, including small producers, by providing accurate and up-to-date information to ensure equal access to economic resources and the appropriate market for their products. To achieve the 2nd SDG, ICTs help reduce hunger and enhance food security by enabling farmers to obtain all sorts of information in the agriculture sector, such as weather forecasts, market information and others to increase their productivity and efficiency. As for the 3rd SDG, ICTs promote healthy lives and well-being by delivering extensive benefits to the healthcare system globally and connecting health workers to the latest health information and diagnostic services.

ICTs assist the United Nations in achieving the 4th SDG by improving the current education system through online learning. People could access the learning material online regardless of geographical constraints and achieve the objective of providing educational opportunities. Besides that, ICTs have significant prospects to improve energy efficiency and reduce carbon emissions through smart grids, smart buildings and

other economic sectors to reduce energy consumption to achieve the 7th SDG. Furthermore, ICTs enhance economic growth and employment globally, as stated in the 8th SGD, by transforming traditional business methods into online platforms and changing conventional employment sectors into new online industries. Despite the aforementioned SDGs, ICTs are crucial in achieving all goals. In addition, ICTs will assist in constructing and maintaining sustainable infrastructure, encouraging sustainable and inclusive industrialization, and enhancing innovation in emerging information and knowledge societies. Thus, this study aims to shed light on the roles of ICTs in achieving the SDGs by investigating the impact of ICTs on economic growth, environmental quality, and labor productivity in developing countries and presenting new insights based on empirical evidences.

ICTs have become part of globalization for information processing. The Internet has been widely used as one of the ICTs standard tools since the I.T. experts created the World Wide Web in 1983. High-speed internet streamlines business operations, company strategy, innovation and transformation. Considering the rapidly expanding youth population in most countries, ICTs can potentially become a major driver of economic growth and development (ITU report, 2021).

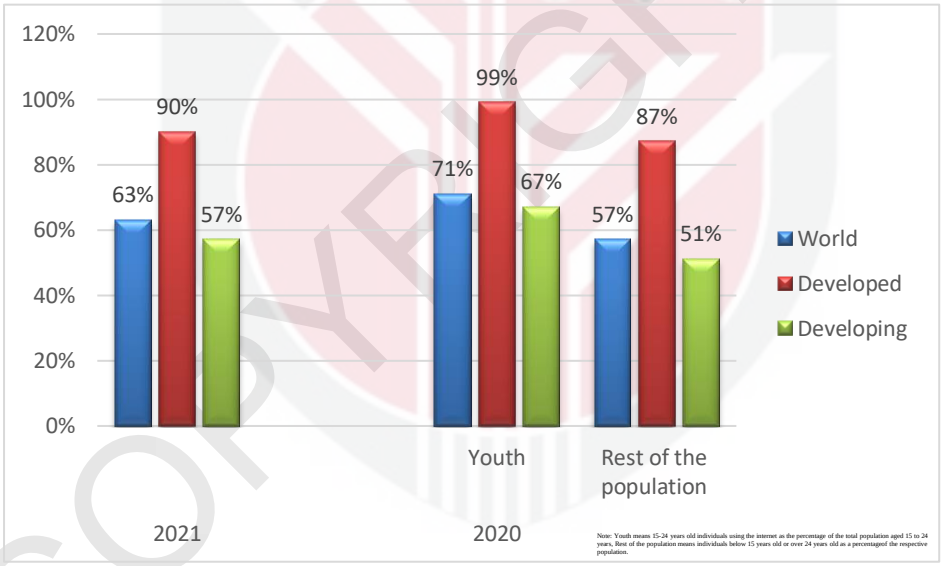

Figure 1.1 : Percentage of individuals using the internet in 2020 and 2021
(Sources : *Fact and Figures 2021*, International Telecommunication Union ITU)

As shown in figure 1.1, about 71 percent of internet users are between the ages of 15 and 24, indicating that the younger generation has a significant need for internet usage. In contrast, the percentage of youthful internet users in developed nations is over 99 percent, whereas it is just 67 percent in developing countries. There are vast disparities between developed and developing countries. The low percentage of young internet users in developing countries compared to developed countries will be an intriguing

topic and motivation to investigate the impact of ICTs on economic growth in developing countries.

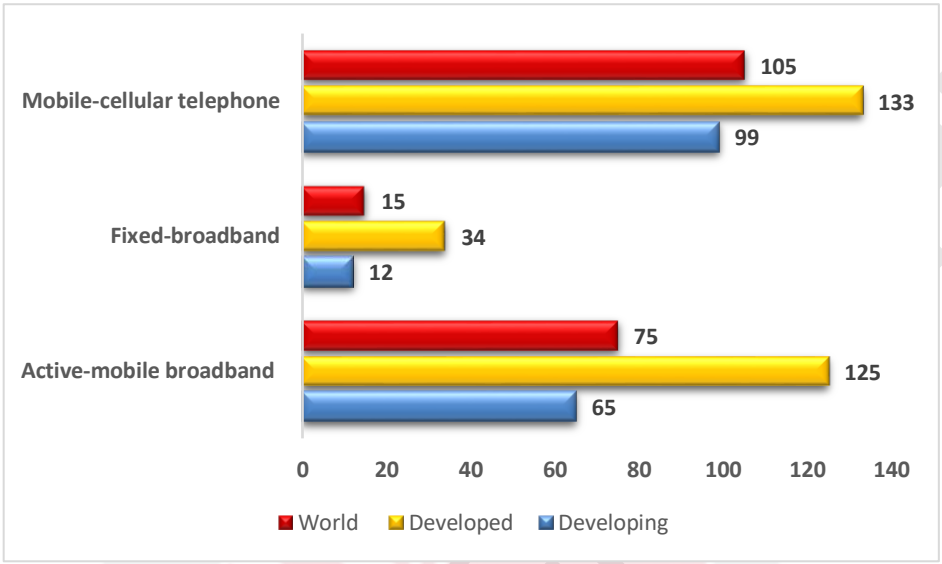

Figure 1.2 : Mobile-cellular, fixed-broadband and active-mobile broadband telephone subscriptions per 100 inhabitants, 2020
(Sources : *Fact and Figures 2020*, International Telecommunication Union ITU)

Figure 1.2 indicates that active-mobile broadband, fixed broadband, and mobile-cellular telephone are three essential ICTs components. The graph demonstrates that mobile-cellular telephone subscriptions are more prevalent than other subscriptions worldwide. This is followed by active-mobile broadband with 75 subscriptions per 100 residents in 2020 and fixed broadband with only 15 subscriptions per 100 residents. Moreover, the statistics show that developed and developing regions have the most mobile-cellular telephone subscribers compared to other subscriptions. Mobile broadband services drive the development of ICTs in the contemporary world. Statista's Digital Market Outlook (2020) revealed there are three times as many mobile internet users as desktop internet users. Social networking, watching an online movie or video, reading online news or an e-book, and online shopping are the most popular mobile internet activities. In the 2000s, the internet successfully altered people's lifestyles and purchasing habits, and smartphones are currently the preferred online purchasing method for metropolitan residents.

Over the decades, several longitudinal studies have investigated the macroeconomic effects of ICTs on economic growth and productivity for developed countries such as the United States and OECD countries (Australia, New Zealand, and Canada). ICTs are the key contributor to the country's productivity and economic growth, as highlighted in the literature. (Albiman and Sulong, 2016; Hwang and Shin, 2017; Chung, 2018; Cheng et al., 2020; Appiah-Otoo and Song, 2021; Nchofoung and Asongu, 2022). It is indisputable that developed countries surpass developing countries in innovation due to

the heavy usage of advanced technology (Yousefi, 2011). Compared to developed countries, developing countries have only partially experienced the benefits of ICTs in stimulating national productivity and economic growth in recent decades. The International Telecommunication Union indicates that only 57 percent of people in developing countries use the internet compared to 90 percent of the population in developed nations. As a result, it is critical for policymakers in developing countries to be aware of the gap and strategize effectively to reap the full benefits of ICT usage, particularly in-country development. However, the disparity between ICTs in developed and developing countries has lately narrowed due to increased ICT usage and penetration in developing countries, particularly following the Covid-19 epidemic.

The significant contribution of ICTs to established growth in developed countries serves as a model for developing countries to emulate and follow. With the adoption of new technology, developing countries have entered a new "window" of re-specialization in specific areas. Furthermore, developing countries can seize new chances to boost their growth performance, such as the emergence of e-commerce in China and the software industry in India. Most importantly, ICTs adoption will provide developing countries with benefits such as improved product and service quality through innovation, market penetration through e-commerce, business opportunities with technologies, increased access to information and knowledge in various sectors, and cost savings due to increased efficiency. However, developing countries still require advanced ICT infrastructure to enable their development and achieve long-term economic growth. Integrating developing countries into the rest of the world through ICTs will allow them to compete more effectively.

Many scholars believe ICTs can help poor and underserved communities access information, break down communication barriers, and promote information exchange. (Thapa and Sæbø, 2014; Zhang et al., 2018; Zheng et al., 2018). In developing countries, ICTs contribute to rural development by abolishing the digital divide, reducing the poverty gaps and improving the equality between urban and rural areas (Venkatesh and Sykes, 2013; Song et al., 2020). Besides that, ICTs also assist rural citizens, especially those relegated villagers left behind become active participants in interconnecting the world (Bailey and Osei-Bryson, 2018).

There are several reasons developing countries benefit less from the advancement of ICTs. A lack of human resources, telecommunications infrastructure, and experience effectively managing I.T. or successfully implementing organizational and process changes are factors (Dewan, 2000; Pohjola, 2001). According to Niebel (2018), developing countries benefit less from ICT investment than developed countries due to a lack of absorptive capacities such as insufficient human capital or R&D spending. He advocated investigating if the investment has begun to yield a return and increase productivity in developing countries. However, many developing countries have improved their ICTs development over time. Developing ICTs, mainly Internet Technology (IT), will likely produce additional benefits for developing countries. For instance, China had 1 million internet users in 1997, which increased to 854 million in 2019 (Internet World Statistics, 2020). Despite that, some countries with significant economic growth, such as Eastern Europe, India, Latin America, and Southeast Asia, have revolutionized the ICT environment in developing countries. Nevertheless, most

prior research focused on developed countries rather than developing countries. Insufficient high-quality micro-and macro-level data sets on ICTs for developing countries are the source of uncertainty.

1.1.1 ICTs, Economic Growth and Intelligence Nexus

There is a growing concern regarding the roles of ICTs in boosting national GDP. (Wang, 1999; Sassi and Goaied, 2013; Jin and Cho, 2015; Stanley et al., 2018; Cheng et al., 2020). For the past two decades, several researchers have studied the impact of ICTs on various fields or sectors, especially in developed and OECD countries. A considerable number of literature discussed the ICTs and economic growth nexus from the macroeconomic point of view (Latif et al., 2018; Pradhan et al., 2018; Cheng et al., 2020) or firm-level and productivity from a microeconomics view (Canarella and Miller, 2018, DeStefano et al., 2018). Widespread and heavy usage of ICTs impacts production potential and efficiency and leads to economic growth (Cardona et al., 2013). Several studies have suggested that long-term investment in ICTs and R&D is essential for economic growth (Brynjolfsson and McAfee, 2014; Griliches, 1991; Nelson, 1959; Schumpeter, 1942). High investment in ICTs reduces production costs, enhances productivity, and improves living standards (Murakami, 1997). Meanwhile, the indirect effect of ICTs generated from the massive foreign direct investment and the spillover effect of technology transfer will increase the countries' competitiveness (Haseeb et al., 2019).

Numerous studies have investigated the direct impact of ICT on economic growth and contributed to contradictory results. Additional factors that moderate the relationship between ICT and economic growth may account for the variability of the results. This type of inquiry has gotten little consideration in the previous studies of ICTs and economic growth nexus. However, factors such as human capital and education were identified in the research conducted by Dedrick et al. (2013) and Jin and Cho (2015) but intelligence was not considered. This study will analyze the relationship between ICTs and economic growth in 128 countries from the perspective of intelligence to distinguish itself from previous research by considering intelligence as a significant factor in boosting the influence of ICTs on economic growth in a country. Intelligence or Intelligence quotient (I.Q.) is the general driving force that leads humanity towards economic well-being. Intelligence or I.Q. is described as an intellectual aptitude related to comprehending, combining, and learning. It should not be confused with concrete performance or education. For example, education does not reduce a person's IQ; instead, the person who can attain the same level of education with less work is considered more intelligent. Intelligence becomes an essential element not only for personal development but also for a nation's economic growth (Burhan et al., 2014a; Hafer et al., 2017). Some researchers (Hanushek and Kimko, 2000; Jones and Schneider, 2010) suggested that group intelligence level or cognitive ability is more crucial than individual cognitive ability. This suggestion is based on the perception that small changes in an individual's cognitive ability will only cause a slight difference in their salary. However, the same changes in the group will lead to a massive difference in labor's private marginal product across countries.

Intelligence is one of the critical factors in supporting the effective use of ICTs. The ICTs infrastructure needs experts in operating, investing, and extending the technology to utilize the technology efficiently. Workers equipped with a high level of intelligence will ensure the ICT adoption is performing at the optimal level and make huge changes in productivity compared with workers with a low level of intelligence. Researchers have defined intelligence over the past years. According to Meisenberg (2004), intelligence closely linked to critical thinking is crucial for national prosperity and a contemporary, unconventional worldview. On the other hand, intelligence is defined by 52 psychologists as a standard mental capability that includes reason, planning, problem-solving, thinking abstractly, comprehending complicated ideas, learning effectively, learning from experience, and so on.

Intelligence can be measured at the individual level or country level. Few famous researchers study intelligence at the country level or refer to it as national I.Q. (Lynn and Vanhanen, 2002, 2006). According to Burhan et al.(2014b), national I.Q. refers to the human aptitude for success in competitive economies, reasoning, and problem-solving. In other words, national I.Q. represents the capability of a country. Jones and Klenow (2016) stated that national I.Q. predicts those economic outcomes better than I.Q. prediction among individuals because national I.Q. produces a "positive spill-overs" effect. The authors recognized it as a "hive mind," which refers to a thriving hive due to many individual efforts. Furthermore, Lynn and Vanhanen (2002, 2006) suggested that national I.Q. is the reason for the dissimilarity between per capita gross domestic product (GDP) and economic outcomes at the country level.

Adam Smith (1776) claimed that personal gain would transfer to the well-being of the entire economy. If intelligence promotes personal achievement by holding others equal, the economic outcomes will be more impressive in countries with a high intelligence level than in those with low intelligence. Several empirical studies supported this statement. They observed that countries with higher levels of intellect experience greater growth than countries with lower levels of intelligence (e.g., Burhan et al., 2014a; Meisenberg, 2012; Rindermann, 2012; Rindermann and Thompson, 2011; Weede and Kämpf, 2002 Jones and Schneider, 2006; Lynn and Vanhanen, 2002, 2006, 2012). Moreover, some research suggests improving the national income by increasing intelligence productivity. Individuals working in a group with similar degrees of cognitive ability will be motivated to perform through favorable assortative matching, leading to extravagant per capita productivity. (Jones, 2011; Kremer, 1993). Some literature indicates that the effect of intelligence on productivity is more prominent at the international level than at the individual level (Hanushek and Kimko, 2000; Jones and Schneider, 2010).

Figure 1.3 illustrates the top eight countries with a high I.Q. score and the real GDP per capita of the country in the year 2022. The study done by Lynn and Vanhanen (2002) yielded the average I.Q. score. According to the graph, Singapore and Hong Kong had the highest average IQ at 108, followed by Japan and China at 105. Similarly, Iceland, Mongolia, and Switzerland all have an average IQ of 101. However, Japan has a lower real GDP per capita than Singapore, despite both countries having the highest average I.Q. Even if Mongolia and Switzerland have the same I.Q., these two countries' real GDP per capita is vastly different. As demonstrated by China and Mongolia, high intelligence

is not always associated with a high real GDP per capita. The IQ score did not support the claim that high intelligence contributes to a high GDP. The link between Intelligence and economic progress deserves examination.

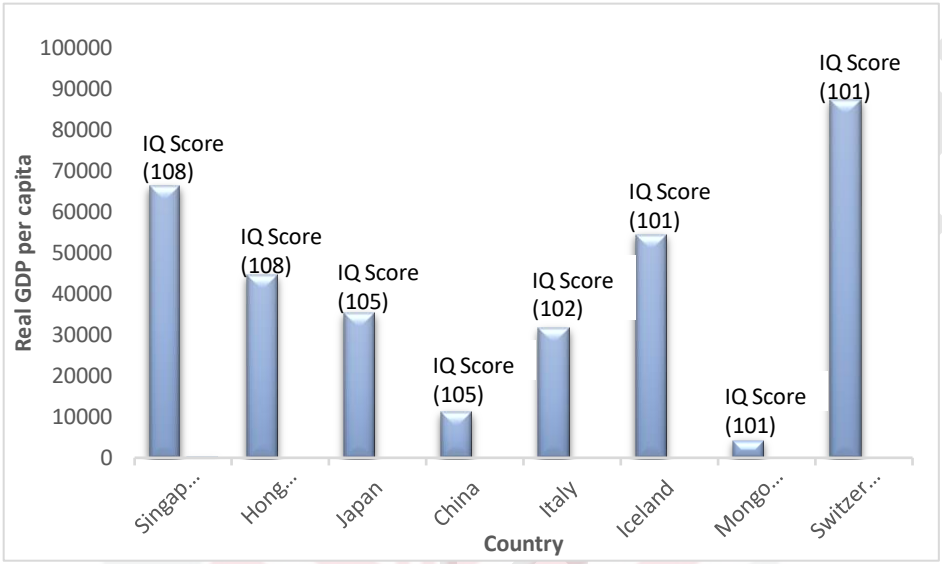

Figure 1.3 : Top Average IQ score by selected countries
(Sources : World ranking of countries by their average IQ. Access from https://brainstats.com/average-iq-by-country.html Feb, 2022)

On the other hand, numerous studies have been on ICTs and economic growth nexus over the past decades. Some earlier studies indicated that ICTs negatively affected economic growth in the past decades. (Baily, 1986; Schneider, 1987; Strassmann, 1985; Roach, 1987; Parsons, 1990; Roach, 1988). In contrast, some researchers are optimistic about the role of ICTs on the economic growth. (Dewan and Kremer, 2000; Cardona et al., 2013; Ishida, 2015). Apparently, the previous literature's outcomes are somewhat controversial and there is no general agreement about the contribution and effect of ICTs on economic growth. Thus, the direct impact of ICTs on economic growth still has many uncertainties. On the other hand, numerous studies focus on the impact of intelligence on individual development and a country's economic growth but limited quantitative analysis to examine the effect of ICTs on economic growth from other perspectives, such as added in the influential factor-like intelligence quotient or national I.Q. that might enhance the effect ICT adoption on economic growth in term of intellectual aptitude.

Hence, this study will examine these three variables by investigating how the intelligence quotient or national I.Q. will affect the relationship between ICTs and economic growth through the threshold analysis. The threshold determination of intelligence and investigation of the intelligence effect on ICTs and economic growth nexus for selected 128 countries will offer some fresh evidence to fill up the gap in the literature. The threshold regression model provides a more consistent and accurate indication of the intelligence threshold value, which can be used to demonstrate how intelligence affects

the ICTs and economic growth nexus in both below and above-threshold regimes. This finding will provide a useful indicator how the effect of different intelligence levels in maximizing the impact of ICT on economic growth.

1.1.2 ICTs, Economic Growth and Environmental Quality Nexus

Environmental quality commonly refers to the natural environment and the built environment (He et al., 2020; Dong et al., 2019), for instance, air and water purity or pollution, noise, or any potential effects that might harm physical and mental health that caused by the human activities. (Wesseh and Lin, 2020; Arthur and Yamoah, 2019). Environmental quality is the primary concern of policymakers in many countries as a critical factor in achieving sustainable development and growth (Asongu and Nwachukwu 2016). Subsequently, environmental quality became the point of discussion in the 2015 United Nations (U.N.) Sustainable Development Agenda. The agenda urged that it is vital to improve environmental quality globally in sustaining economic growth and development. All nations are endeavoring to attain the 2030 clean energy and climate goals of the United Nations by upgrading their environmental quality. In conjunction with this, monitoring greenhouse gas emissions (GGEs) is one of the effective strategies to enhance environmental quality. GGEs are produced due to human activities such as burning fossil fuels (coal, natural gas, and oil), solid waste, trees, other biological materials, and certain chemical processes (Aluko and Obalade, 2020).

Several international agreements, including the Kyoto Protocol and the Paris Climate Agreement, were formed to combat the global climate change issue and lessen GGEs. Among GGEs, carbon dioxide (CO_2) emissions are the leading cause of climate change. Besides, CO_2 emissions are the most destructive to the living environment and individual welfare (IPCC, 2019). Figure 1.4 depicts the types of global greenhouse gas emissions (GGEs), with CO_2 emissions accounting for 74 percent of GGEs as the largest contributor compared to other gases such as methane (CH4), nitrous oxide (N2O), and fluorinated gases (F-gases). The majority of CO_2 emissions shown in Figure 1.4 support the claim that CO_2 emissions are the primary driver of environmental degradation.

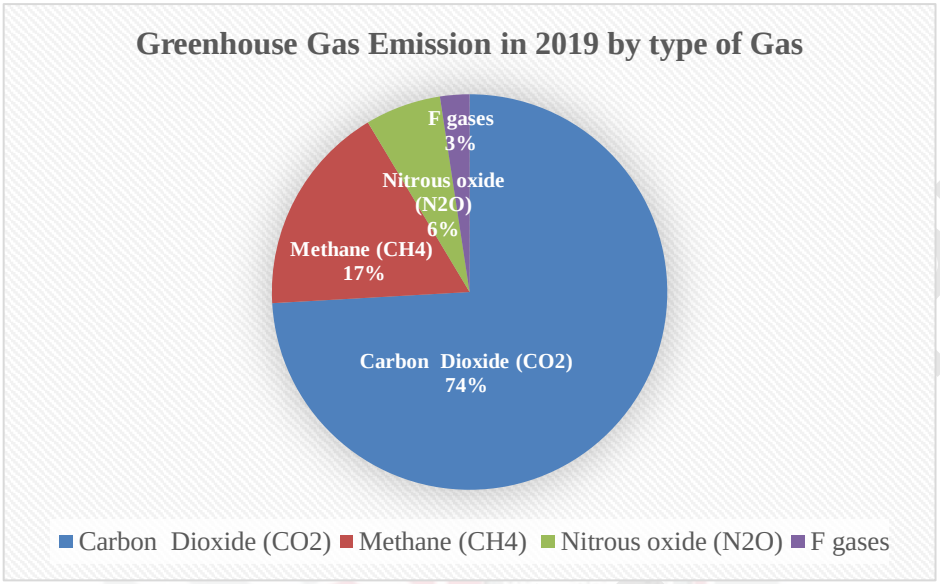

Figure 1.4 : Greenhouse Gas Emission in 2019 by Type of Gas
(Sources : Climate Watch, based on raw data from IEA (2021), GHG Emissions from fuel Combustion,www.iea.org/statistics)

Furthermore, the Center for Global Development report 2015 highlighted that developed countries were labeled as the primary contributor to CO_2 emissions and climate change over the past decades. Previously, developed countries were responsible for 79 percent of the emissions between 1850 and 2011 due to their high energy consumption. However, developing countries have accelerated the emissions rate to 63 percent in recent years caused of industrialization processes and heavy energy-intensive technologies for the country's development and growth. The rising emissions in developing countries is a severe issue that demands more focus from policymakers and scholars to combat environmental degradation and meet the United Nations Sustainable Development Goals by 2030. Nonetheless, according to Dalhammar and Richter (2019), developing and least developing countries failed to meet the goals due to their poor adaptation to environmental change. Hence, the validity of this statement still requires more shreds of evidence to prove the truth. For this reason, there is a strong urge to have a more in-depth study on this issue, particularly in developing countries.

Observing the yearly increase in environmental degradation problems, some academics have proposed that shifting from physical resources to information resources in the digital age is one way to reduce resources and pollution throughout the economic growth process (Toffel and Horvath, 2004). For instance, to protect the environment from excessive tree cutting, all documentation has been converted to digital format instead of stored in physical files. All communications are sent via email or social media websites. The heavy usage of ICTs in this era of globalization has contributed to productivity improvement and energy efficiency in various economic sectors over the past decades (Haseeb et al., 2019). ICTs have also improved organizational structure, productivity,

financial development, foreign direct investment (FDI), human interactions, socioeconomic development, and income disparities, all contributing to economic growth (Tchamyou et al., 2019). The substantial evolution of ICTs in economic sectors amplified the role of ICTs in promoting economic growth through innovation and investment activities such as e-commerce and online banking that will indirectly affect the environmental quality.

Generally, ICTs and environmental quality have a complicated relationship because they positively and negatively affect environmental degradation issues. ICTs may positively impact the environment by implementing various strategies such as increasing energy efficiency in production consumption and improving the production process through emissions reduction by building smarter cities, intelligent transportation systems, electrical networks, etc. For instance, smart cities use digitalization to collect data to promote energy efficiency and effectively manage resources, services, and assets. When it comes to intelligent transportation, cutting-edge apps allow for optimal coordination between transportation and traffic management to guarantee a safer and more effective use of the transportation network.

Secondly, ICTs can help mitigate environmental deterioration through online distribution and dematerialization, recycling, mode substitution, and energy efficiency in manufacturing and consumption (Haseeb et al., 2019). In comparison, traditional distribution channels have higher overhead and operating costs and a slower processing time. On the other hand, ICTs presented the negative impacts associated with higher pollution levels via the massive demand for energy utilisation, particularly in the production that uses non-renewable energy for the operation, production resources, e-waste from the non-functioning or obsolete electronic appliance, and ICTs equipment diffusion (Houghton, 2010).

The ICTs and environmental quality nexus are receiving more attention due to the literature's contradictory claims. Two strands of research explain conflicts over the impact of ICTs on environmental quality. The first strand of the study suggests that environmental deterioration can be minimized through ICTs, such as increased energy efficiency, increased productivity in renewable energy utilization, and renewable energy production. (Moyer and Hughes 2012; Al-Mulali et al. 2015a; Salahuddin and Gow 2016; Ozcan and Apergis, 2017; Avom et al., 2020; Zafar et al., 2022). On the other hand, another line of research suggests that extensive use of ICTs through multiple channels, such as greater industrial output, massive energy use and a more robust economic structure, will increase pollution levels or CO_2 emissions (Sadorsky 2012; Lee and Brahmasrene 2014; Belkhir and Elmeligi 2018).

Besides studying the ICTs and environmental quality nexus, numerous studies have been conducted to examine the relationship between economic growth and environmental quality (Alam et al., 2016; Sarkodie, 2018; Wang and Dong, 2019; Kacprzyk and Kuchta, 2020). The economic growth and environmental quality nexus have been widely studied over the past few decades due to the enormous impact of economic development on environmental quality. Hence, the issue of environmental quality should not be

ignored, as the effects of environmental degradation will impact their own countries and the rest of the globe.

Theoretically, the economic growth and environmental quality nexus study is commonly related to the Environmental Kuznets Curve (EKC) Hypothesis. EKC hypothesis illustrated an inverted U-shaped curve between CO_2 emissions and the economic growth nexus (Kuznets, 1955). In other words, the EKC hypothesis assumed that income would reduce the environmental quality at the initial stage; however, when it exceeds a specific threshold level, it ultimately improves environmental quality. The EKC hypothesis' validity has been verified in previous literature based on different regions, for instance, developed countries or Organization for Economic Cooperation and Development (OECD) countries (Bilgili et al., 2016), developing countries (Narayan and Narayan, 2010), BRICS (Brazil, Russia, India, China and South Africa) countries (Dong et al., 2017) and others. Unlike others, the novelty of this study is to examine the relationship between economic growth and environmental quality, which depends on the ICTs threshold level. Different ICTs threshold levels might contribute to the various effects on economic growth and the CO_2 emissions nexus. It is crucial to know which ICTs threshold level will impact the economic growth and CO_2 emissions nexus. This finding will provide new insight to policymakers and apply it as a guideline to monitor environmental degradation issues and improve environmental quality in a country.

1.1.3 ICTs and Labor Productivity Nexus

The economic growth rate for every country in this world has a different pace and magnitude. Generally, the wealth of nations and economic growth are determined by productivity. High productivity in a country can stimulate the national product's aggregate demand and improve its living standard. Furthermore, technological advancement and innovation, the accumulation of human capital and knowledge, research and development activities, as well as spillover effects are the main causes of the rising productivity growth rate.

According to the International Labor Organization's 2020 report, productivity is crucial for increasing firm profitability and growth, lowering consumer costs, and raising labor wages at the industry level as well as stimulating economic growth and increasing living standards at the national level. Meanwhile, some academicians suggested that a country's ability to raise living standards is contingent on enhancing labor productivity and efficiency growth (Bagley, 2010; Sniukiene and Sarkene, 2014). Thus, one of the priorities of the United Nations' 2030 Agenda and Sustainable Development Goals is to promote productive employment and increase production.

Generally, labor productivity refers to how effectively people, businesses, and economies use resources in producing goods and services to maximize economic advantages over a specific period (International Labor Organization, 2020). Labor productivity has been proposed as the measurement to reflect the state economy's wellness. The efficiency of the employed labor force can indicate the progress of a state or sector (industry) economy. Furthermore, labor productivity provides information about the efficiency and quality of human capital in the manufacturing process and other

complementary input and innovation. Thus, human resources, technological advances, and financial development are all inextricably tied to increase in labor productivity. Financial development is the equipment used by labor to produce goods. Meanwhile, technological advances such as ICTs transform inputs into outputs through production lines or automation, and lastly, human resources denote the level of education and labor specialization. More research is needed to identify how factors like human resource development, financial development, and technological improvement affect labor productivity, which later contributes to the investigation on the interaction term effect between ICTs and three moderators (human capital, financial development and trade openness) in this study.

Figure 1.5 shows the global labor productivity growth in percentage change from 1995 to 2021. According to the Conference Board Total Economy report 2021, global productivity decreased in 2020 but recovered through 2021. Global labor productivity growth has been trending down, from an average yearly rate of 2.6 percent between 2000 and 2007 to 1.7 percent between 2011 and 2019. The growth in output per worker fell about 0.9 percent in 2020 and it increases to 2.9 percent growth in 2021.

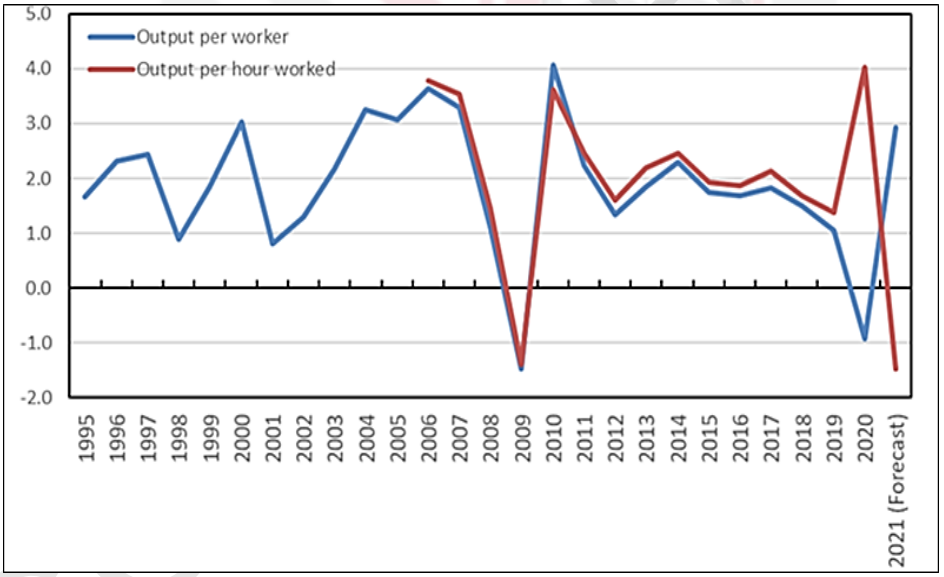

Figure 1.5 : Global Labor Productivity Growth (% change)
(Source : The Conference Board Total Economy Database™, April 2021)

Covid-19 pandemics have a devastating impact on global economies, leading to a decline in growth and productivity. The pandemic has several negative repercussions, including investment depletion, unemployment, education loss, and interruption of global trade and supply systems. These severe implications erode productivity and hamper countries' long-term ability to expand real incomes. Meanwhile, emerging market and developing economies (EMDEs) are experiencing the steepest, longest, and broadest deceleration in recent decades in terms of productivity growth. From 2010-to 2018, labor productivity

in low-income countries was only 2% of the average for advanced economies. After the initial pandemic wave subsides, economists and policymakers will refocus their attention on productivity. During 15 years of slow productivity development, the globe entered the Covid-19 crisis. On the other hand, widespread adoption of new technologies such as information technology skills acquired during the epidemic – and intense reallocation pressures will produce a self-sustaining boost to productivity as the country exit the crisis (Di Mauro and Syverson, 2020).

There are several studies indicate that labor productivity in a country can be enhanced through technology and capital accumulation (Laddha et al., 2022; McMillan et al., 2014). One popular technology is ICTs, commonly known as general-purpose technology (GPT) is widely adopted in various industries globally. ICTs define competitiveness in the knowledge economy and include the technologies that support the digital transformation of the economy and society (Mas et al., 2018).

As the backbone of the fourth industrial revolution, ICTs are essential in influencing the labor market, productivity and growth (OECD, 2016; Cardona et al., 2013). Some proposed that ICTs significantly impact the firm's productivity (Skorupinska and Torrent-Sellens, 2014). For instance, the computer-based system has altered manufacturing processes in different areas of the economy as they facilitate robotization and automation, indirectly improving labor productivity. In smart manufacturing, Internet-connected machinery monitors the production line, enabling machines to communicate via the Internet, enhancing labor productivity and reducing errors.

According to Cardona et al. (2013), ICTs contribute to productivity in two aspects. The first aspect is where the ICTs contribute to reducing cost and product prices through innovation (Jorgenson et al., 2005). Cost reduction can be attained via ICTs by improving product design and enhancing production processes more efficiently and flexibly. Secondly, ICTs serve as the "enabling technology" that provides new opportunities and solutions, such as digital marketplaces and platforms linking demand and supply to productivity (Bresnahan and Trajtenberg, 1995).

ICTs' contribution to labor productivity at the national level has been widely discussed over the decades. Some researchers suggested that mobile ICTs have enhanced firms' labor productivity (Bertschek et al., 2016), customer relationships (Bresnahan and Yin, 2017), and employee autonomy (Viete and Erdsiek, 2020). However, the mixed findings led to extensive discussion among academicians and scholars. This study intends to analyze the interaction effect of ICTs with human capital, financial development and trade openness on labor productivity in developing countries as most studies on ICTs and labor productivity are conducted in the OECD or developed countries. The interaction effect of ICTs with three moderators reveals how human resources, financial development, and trade openness indirectly influence the impact of ICTs on labor productivity. The interaction of ICTs and human capital can significantly increase labor productivity by allowing workers to work more effectively, efficiently, and flexibly while actively evolving their skills and knowledge. Meanwhile, the interaction of ICTs and financial development can improve labor productivity by increasing access to finance, facilitating transactions, fostering communication and collaboration,

streamlining daily activities, and improving decision-making. Lastly, the interaction between ICTs and trade openness will positively impact labor productivity by improving access to new technologies, stimulating competitiveness and knowledge spillovers, and encouraging specialization.

Furthermore, this study also intends to reconfirm the findings of Dewan and Kraemer (2000), who discovered that the productivity paradox existed in developing countries but not in developed countries. Current global trends, such as the increasing importance of technology, urbanization, and the globalization of the value chain, have altered the demand for jobs and skills in the labor market. The labor market of the twenty-first century requires more complete talents, such as cognitive skills, social-emotional skills, technical skills, and digital abilities. Skills development contributes to structural transformation and economic growth by improving employability and labor productivity (The World Bank Report, 2021).

1.2 Problem Statement

1.2.1 ICTs, Economic Growth and Intelligence Nexus

The first part of this study is to analyze the relationship between ICTs and economic growth using intelligence level or national I.Q. as a threshold variable. ICTs are the critical engine for increasing output and productivity growth, enhancing product quality and promoting innovation to improve economic growth when all other factors remain constant. Some studies indicate that the extended growth and rise in productivity caused by ICTs may occur in some countries, such as the United States or OECD countries, but may not apply to others, such as developing countries (Yousefi et al., 2011; Dedrick et al., 2013). Accessibility to ICTs is highly influenced by the expansion of the countries and a variety of other factors, including human capital, economic variables, geographic variables, and infrastructure variables. Furthermore, several research studies on the ICT on economic growth nexus have produced inconsistent conclusions. Other factors, such as education and human capital that affected the relationship between ICTs and economic growth have been conducted by Dedrick et al. (2013) and Jin and Cho (2015). However, intelligence was not evaluated in prior studies of ICT and economic growth nexus.

The relationship between ICTs and economic growth has been the subject of numerous research. However, only a few research have investigated the link between ICTs, intelligence, and economic growth concurrently. Intelligence is one of the criteria associated with human capital and development, and countries' development relies not only on massive production but also on human capital development. In general, the theory stated that a high level of intelligence would contribute to a high level of national growth. There is no consensus achieved in the finding of previous literature to verify this statement. Furthermore, studies reveal that high-IQ individuals contribute more to social-economic growth than normal citizens (Herrnstein and Murray, 2010; Rindermann and Thompson, 2011). Countries with high intelligence may experience higher economic growth, as the intellectual class is more efficient and may raise

productivity than the non-intellectual class. Another school of thinking states that low-IQ countries will have faster economic growth.

In the mid-20th century, East Asian countries had slightly higher I.Q. scores. This is shown by the world ranking list of countries based on average national I.Q., which includes China, Mongolia, and some of the eastern countries. This statement contradicted the belief that high-income countries should have greater cognitive levels than medium and low-income countries. There are a few questions that drag the attention and will be investigated in this study. Will high intelligence improve the ICTs-economic growth nexus, or will it have the reverse effect? What degree of intelligence will influence the ICTs and economic growth nexus? There is a limited research focus on the impacts of ICTs on economic growth in terms of intelligence perspective. Thus, investigating the relationship between ICTs and economic growth based on the intelligence level or national IQ is essential. The empirical result on this issue will shed light on the literature when the ICTs and economic growth nexus are examined from the intelligence threshold level's perspective in this study for 128 countries.

1.2.2 ICTs, Economic Growth and Environmental Quality

The second part of this study is to address ICTs' impact on developing countries' ecology and economy. In recent decades, environmental degradation has become a global concern. World Health Organization (WHO) reports that many developing countries fail to manage industrial waste by dumping toxic sewage into the soil, air, and water. In developing nations, this unethical behavior causes pollution, health difficulties, and environmental damage. According to a Centre for Global Development study (2015), developing countries account for 63 percent of global industrialization and energy consumption emissions. Statistics show that 98 percent of the population lives in contaminated areas. The dependence of developing countries on natural resources as a source of revenue is impacted by unsustainable resource use. Environmental challenges are more intense in developing countries than in developed countries, and environmental neglect will exacerbate economic growth, poverty, and income inequality.

The WHO stated that environmental hazards impact impoverished and vulnerable populations in developing countries. The SDGs of the United Nations (UN) have devoted increased attention to climate change as the fuel footprint in developing countries (U.N. 2018) and urge all countries to commit to the 17 Sustainable Development Goals (SDGs), particularly SDGs 9, 11, 12, and 13 for sustainable production and climate change mitigation (U.N. 2015). European emerging countries have shown increased interest in sustainable production and consumption (Anser et al., 2021). Air pollution and CO_2 emissions can be reduced by monitoring greenhouse gas releases (GGEs). Meanwhile, the UN reports that ICTs can assist with sustainable growth and climate change (U.N., 2015). Thus, the relationship between ICTs, economic growth, and environmental quality is reciprocal.

There are two views on how ICTs affect economic growth and environmental quality. ICTs minimize CO_2 emissions and industrial waste through digitalized and technology-based management, contributing to economic growth. Another school of thought

suggests that extensive use of ICTs and technology in production will increase energy consumption and pollution during economic expansion. The discrepancy in the statement motivated this study to evaluate ICTs' impact on environmental quality and economic growth in developing countries. This study will evaluate the threshold level of ICTs that affect environmental quality and economic growth to distinguish themselves from others. The ICTs threshold level will provide more specific information on their impact on the economic growth and CO_2 emissions nexus.

1.2.3 ICTs and Labor Productivity Nexus

The third part of this study focuses on the relationship between ICTs and labor productivity. The world has recently undergone a digital transition. ICTs, such as computer-based systems through the internet are extensively used to enhance productivity and effectiveness, where ICTs drive innovation and labor productivity in many developed countries. According to the International Telecommunication Union (ITU) report for 2020, 98 percent of 15- to 24-year-olds in developed countries and 66 percent in developing countries are internet users. This study indicated that many developing countries are underutilizing ICTs, and they are behind in terms of the ICTs sector size, industrial integration, and environment. This also indicated that ICTs adoption in developed countries has almost reached the fullness point while developing countries still have low penetration rates.

Furthermore, ITU (2020) indicated that ICTs would become a critical productivity accelerator for developing countries to accomplish one of the 2030 Agenda priorities and part of Sustainable Development Goal 8 in enhancing productivity and employment. The fast youth demographic increase in developing countries supports this notion, and they are the most engaged ICT users and will shape the future work market. Using ICTs, the expanding youth population may transform labor productivity into a digital platform. This motivates the author to examine ICTs' impact on labor productivity, where developing countries confront hurdles to boosting their per capita economic output. ICTs could be a complementing strategy in encouraging developing countries' productivity. Covid-19 has forced some firms to use digitization, robots, and algorithmic process control to enhance labor productivity by eclipsing human labor (World Economic Forum, 2021).

Some research shows that the extended expansion and improvement in labor productivity through ICTs may not be generalizable to emerging or developing countries (Yousefi et al., 2011; Dedrick et al., 2013). Human capital, financial development, and geography could also cause variances. ICTs' effects may differ across developed and underdeveloped countries, requiring investigation and evidence. Scholars debate the existence of the I.T. productivity paradox caused by ICTs' failure to boost worker productivity in some developed countries. There is literature stated that ICT had benefited the economic growth of developed countries. Meanwhile, A study by Dewan and Kraemer (2000) suggested that the productivity paradox doesn't apply to developed countries but does to developing countries. However, ICT's contribution to developing countries remains questionable. Will I.T. productivity paradox exists, or will the adverse

outcomes in developing countries? Thus, there is a need to investigate ICTs' implications on economic growth in developing countries based on the issues mentioned.

1.3 Research Questions

1.3.1 Does the intelligence threshold level exist and affects the ICTs and economic growth nexus

1.3.2 How the ICTs moderate the economic growth - environmental quality nexus

1.3.3 What is the moderating effect of ICTs on labor productivity in developing countries

1.4 Objectives of Study

1.4.1 General Objective

This study generally examined the impacts of ICTs on economic growth, environmental quality and labor productivity.

1.4.2 Specific Objectives

1.4.2.1 To investigate the impact of intelligence threshold level on the ICTs and economic growth nexus

1.4.2.2 To analyze the effect of ICTs in moderating the economic growth – environmental quality relationship

1.4.2.3 To examine the effect of ICTs on labor productivity in developing countries

1.5 Hypothesis Development

Hypothesis 1:

H_0 = There is no relationship between ICTs and economic growth nexus when above threshold level of intelligence.

H_1 = There is a relationship and significant impact on ICTs and economic growth nexus when above threshold level of intelligence.

Hypothesis 2:

H_0 = There is no relationship between economic growth and environmental quality nexus when the ICTs usage is high in developing countries.

H_1 = There is a relationship between economic growth and environmental quality nexus when the ICTs usage is high in developing countries.

Hypothesis 3:

H_0 = There is insignificant effect of ICTs on labor productivity in developing countries.

H_1 = There is a significant effect of ICTs on labor productivity in developing countries.

1.6 Significance of Study

1.6.1 ICTs, Economic Growth and Intelligence Nexus

This first study examines the impact of intelligence threshold level on ICTs and economic growth nexus for 128 countries. For the previous research, various econometric methods have been adopted to examine the relationship between ICTs and economic growth at the national level. Researchers widely use two popular methods: growth accounting techniques and cross-country regression techniques. However, this study investigates the relationship between ICTs and economic growth from different aspects by adding intelligence as the threshold variable through the threshold regression method.

Firstly, there are very minimal studies that examine the ICTs and economic growth nexus from other perspectives. Thus, the conclusions of this study will be novel, as opposed to earlier research which is only focused on the impact of ICTs on economic growth from other perspectives but not intelligence. Second, the study's findings indicate that the threshold regression method proposed by Hansen (2000) may precisely identify the intelligence threshold point as a predictor of the intelligence level that will influence the relationship between ICTs and economic growth. In addition, this study shows how intelligence affects ICTs and economic growth nexus depending on whether they are below or above the threshold of intelligence. This will better explain how intelligence affects the relationship between ICT and economic growth in the above- and below-threshold regime.

By examining the threshold impact of intelligence on the ICTs and economic growth nexus, this new finding will provide additional information to those countries regarding the effect of intelligence and the precise threshold point of intelligence in monitoring ICTs usage. This study presents policymakers with a novel suggestion to examine

additional aspects, such as intelligence, in a country's economic growth and to be aware of the influence of intelligence threshold level on economic growth through ICTs.

1.6.2 ICTs, Economic Growth and Environmental Quality Nexus

The second study examines the impact of the ICTs threshold on economic growth and environmental quality nexus. Firstly, the environmental quality problem and its effect on socioeconomic is a contentious topic of discussion globally. In the preceding decades, numerous research has investigated the relationship between ICTs, economic growth, and environmental quality. However, previous empirical studies had inconsistent findings on the ICTs, economic growth and environmental quality nexus. Developing countries need more attention to environmental quality as CO_2 emissions are likely to increase due to the countries' ongoing economic development. On the other hand, digitalization, modernization, and production process automation are anticipated to promote ICT adoption, thus increasing real concerns about their impact on the environment. The outcomes of this study assist the governments and policymakers in developing countries in formulating short-term and long-term policies in mitigating the CO_2 emissions issue as well as promoting the ICTs industries.

The second contribution of this research is to examine the effects of ICTs on economic growth and environmental quality nexus, where the dynamic panel threshold regression method will be utilized. This study focuses on the ICTs threshold effect on growth and environmental quality nexus. Unlike previous research, most previous studies only examined the causal relationship or direct impact of ICTs on environmental quality or economic growth. The threshold method will determine the specific threshold value of ICTs and illustrate the different effects of ICTs on economic growth and environmental quality nexus when above and below the threshold value in developing countries. This study will provide new insight into the literature and bridge the gaps by analyzing the growth and environmental quality nexus from ICTs' perspectives. The different methods applied in this study will provide a more robust and accurate indication of the ICTs threshold level and their effect on the growth and environmental quality nexus.

1.6.3 ICTs and Labor Productivity

The third study investigates the effect of ICTs on labor productivity in developing countries. First, most literature discussed the ICTs and productivity nexus from the microeconomic perspective at the firm level in the 1990s. There is minimal research on the macroeconomic level, such as national productivity. This study explains the relationship between ICTs and labor productivity from the macroeconomic level. Studying the ICTs and labor productivity nexus at the macroeconomic level will provide a broader picture of the ICTs and labor productivity nexus at the aggregate level. The macroeconomic conclusions of this study will complement the firm-level findings of the ICTs and labor productivity nexus.

Second, prior research on the relationship between ICTs and labor productivity has taken techniques and has mainly focused on developed countries during the 1990s and 2000s.

Following the 2000s, research into the nexus between ICTs and labor productivity in emerging and developing economies gained pace. To date, there is a paucity of empirical information about the influence of ICTs on labor productivity in developing nations, and the conclusions remain vague (Laddha et al., 2022; Niebel, 2018). Empirical evidence from this study can fill research gaps in developing nations and be used as a reference point by policymakers when establishing ICTs investment policies in developing countries.

Third, this analysis incorporates a few country-level control variables, such as human capital, financial development, and trade openness to obtain significant findings on the ICTs and labor productivity nexus. Besides examining the direct impact of ICTs on labor productivity, this study employs model estimates with interaction effects between ICTs and potential moderators such as ICTs and human resources, ICTs and financial development, and ICTs and trade openness. The interaction effect of ICTs with three moderators provides findings on how human resources, financial development, and trade openness will indirectly affect the impact of ICTs on labor productivity. Next, the dynamic panel quantile regression adopted in this study will investigate the relationship between ICTs and labor productivity at different quantile levels in developing countries, including countries with lower labor productivity (lower quantile), countries with average labor productivity (middle quantile) and countries with high labor productivity (upper quantile). These two analyses differ from previous literature that mostly applied methods such as panel cointegration and Vector Error Correction Model (VECM). The findings of this study will close the research gap and provide new insight into the literature.

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