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Erasmus

Did Information and Communication Technology Mediate the Macroeconomic Effect of the COVID-19 Pandemic? Evidence from Indonesian Districts

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List of Acronyms

ICT	Information and Communication Technology
COVID-19	Coronavirus Disease 2019
FEM	Fixed Effect Model
GDP	Gross Domestic Product
HDI	Human Development Index
OLS	Ordinary Least Squares
ILSSR	Indonesia Large-Scale Social Restrictions
ECAR	Enforcement of Community Activity Restrictions
REM	Random Effect Model

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Abstract

The role of Information and Communication Technology (ICT) in the economy continues to be a topic of discussion. Numerous works have addressed the topic, but no consensus has emerged. When the Coronavirus Disease 2019 (COVID-19) pandemic happened, this discussion entered a new phase, as the pandemic pushed many offline activities to go online. It is interesting to examine whether ICT can play a role in increasing economic resilience during a pandemic. The COVID-19 pandemic is relatively recent, and most previous studies have studied the impact of ICT on economic resilience during the pandemic using data at the country level. Then, using district-level data in Indonesia, this research aims to contribute to the existing knowledge. In addition, this study employs several proxies for ICT penetration (internet penetration, mobile phone penetration, and internet speed), which can enhance the role of this research in prior studies. Using a panel data regression, this analysis revealed that the COVID-19 pandemic and the restriction policy negatively impact economic performance. Moreover, it was discovered that ICT could be disruptive to the economy. Nonetheless, districts with more advanced ICT have greater economic resilience in dealing with the COVID-19 pandemic. In addition, policymakers can use the findings of this study to consider policies or other methods to alleviate the economic disruption caused by ICT and encourage ICT to contribute more positively to the economy. Furthermore, the Government can concentrate on enhancing the districts that remain below the threshold regarding internet penetration, mobile phone penetration, and internet speed as development's priority areas.

Relevance to Development Studies

The COVID-19 pandemic has recently become one of the biggest concerns affecting many development sectors. This condition prompted a significant shift from online to offline activities, necessitating digital infrastructure support, such as ICT readiness. Based on that, this research wants to analyze whether ICT positively influences the economy, especially in helping districts to be more economically resilient in the face of COVID-19. The results of this research can be used as a consideration for policymakers in making policies related to digital infrastructure. Moreover, for developing countries where digital infrastructure readiness is still a challenge, the findings of this study can influence the area that needs to be prioritized by policymakers to accelerate development.

Keywords

ICT; economic resilience; COVID-19 pandemic; internet penetration; mobile phone penetration; internet speed; Indonesia, districts data, panel data, fixed effect.

Chapter 1
Introduction

In this technological era, Information and Communication Technology (ICT) might stimulate the global economy to enter a new generation of the digital economy (Paradise, 2019). The relationship between ICT and economic performance has been widely discussed. Some say ICT has a favorable relationship with economic performance (Vu, 2011; Pradhan, Arvin and Hall, 2016; Palvia, Baqir and Nemati, 2018). Nevertheless, some argue that the impact of ICT on economic performance is not always positive (Parsons, Gotlieb and Denny, 1993; Gordon, 2000).

The discussion reaches a new phase as the Coronavirus Disease 2019 (COVID-19) pandemic prompts a shift in human behavior regarding the use of technology. Many online activities, such as online learning (e-learning), online shopping (e-commerce), and online health services (e-health), have been increased by the implementation of social distancing to minimize the transmission of the COVID-19 virus. It contributes to a roughly 30% increase in global internet traffic (Katz and Jung, 2021). Furthermore, according to a survey undertaken by Asosiasi Penyedia Jasa Internet Indonesia (2022), internet penetration in Indonesia has risen from 64.80% in 2018 to 77.02% in 2022 during the COVID-19 pandemic.

This condition adds to the new questions, such as whether this pandemic has altered ICT's function in the economy and whether ICT can make the country/region more economically resilient during the pandemic. These are the questions that we hope to address through this research. This pandemic is relatively new, and few studies have examined ICT's contribution to economic performance throughout this situation. Therefore, it is the contribution of this research to the existing knowledge. In addition, this study contributes by doing research at the regional level, whereas most earlier literature examining the connection between ICT and economic development at the national level (Hong, 2017; Hwang and Shin, 2017; Adeleye and Eboagu, 2019; Laitsou, Kargas and Varoutas, 2020). Moreover, as far as we know, no research uses Indonesian district-level data. Besides that, this study also contributes to the existing knowledge by considering several proxies for ICT penetration. This study will utilize internet penetration, mobile phone penetration, and internet speed. The variety of proxies used enhances this research's role in contributing to existing knowledge.

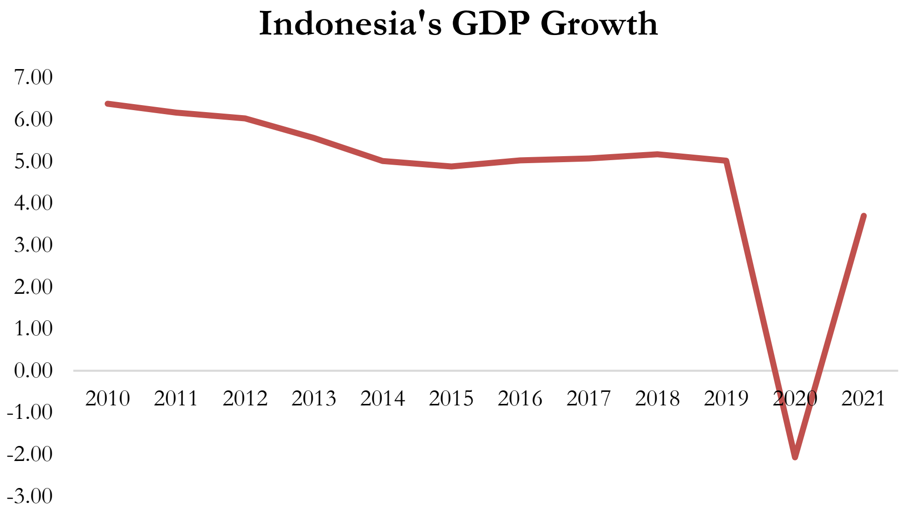
This study will employ panel data from the Central Bureau of Statistics, the Ministry of Health, the Ministry of Communication and Information, the Audit Board of the Republic of Indonesia, and the Local Government of 496 districts in Indonesia. The annual data from 2010 – 2019 are used to assess the economic impact of ICT prior to the pandemic, while the data from 2020 to 2021 are used to determine the contribution of ICT to economic performance through the pandemic. Then, data from 2020 to 2021 will also be used for a more in-depth evaluation of ICT's impact on economic pandemic resilience. In addition, we will utilize the Fixed Effect Model (FEM) to estimate panel data in this study. It is thought that this strategy can control unobserved individual heterogeneity. Besides that, the FEM is believed can control time fixed effect by controlling factors that may influence the result in specific districts and specific time or time-varying district effect (Cameron & Trivedi, 2005).

Moreover, this study intends to assess the influence of ICT on economic performance in Indonesia through the COVID-19 pandemic. There are two approaches to answering this query. First, it will determine whether or not the impact of ICT on economic expansion has remained constant between before and during the pandemic. In addition, it assesses the ICT's role in enhancing economic resilience to the pandemic. This paper contains six chapters. Chapter 1 is an introduction that explains the study's background, novelty, and scope. The second chapter is a context of Indonesia that describes Indonesia's economic condition, COVID-19 status, and digital infrastructure readiness. The third chapter provides a theoretical framework and empirical evidence for COVID-19 and economic performance, ICT and its relationship to economic performance, and ICT during the pandemic. In addition, Chapter 4 will describe the data and methodology utilized in this paper. The fifth chapter presents the study's findings regarding the impact of ICT on economic performance and the impact of ICT on economic resilience during the COVID-19 pandemic. Then, Chapter 6 is the conclusion, which summarizes the study, its policy implications, and recommendations for future research.

Chapter 2
Context of Indonesia

According to the Central Bureau of Statistics (2022), Indonesia's real Gross Domestic Product (GDP) growth has shown a less than 6% trend since 2013. Unfortunately, the COVID-19 pandemic has worsened this condition. The GDP growth fell to -2.07% in 2020.

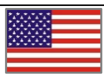
Figure 1. Real GDP Growth of Indonesia in the Year 2010 – 2021



Source: Central Bureau of Statistics (2022)

The coronavirus that attacked at the beginning of 2020 has become a global pandemic. In terms of mortality, Indonesia has become one of the worst countries. According to the World Health Organization (2022), Indonesia has a total of 6,732,179 cases and 160,855 deaths as of 10 February 2022. This is the tenth-highest number of deaths in the world.

Table 1. Spread of COVID-19

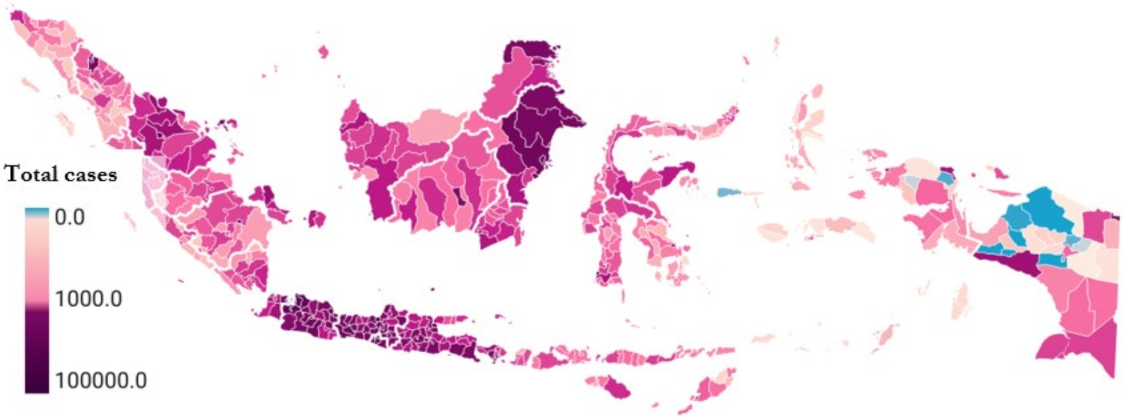
No.	Country		Deaths Cumulative Total	Cases Cumulative Total
1.	United States of America		1,100,421	101,211,478
2.	Brazil		697,533	36,887,991
3.	India		530,748	44,683,748
4.	Russian Federation		395,447	22,035,133
5.	Mexico		332,483	7,390,902
6.	Peru		219,214	4,482,852
7.	The United Kingdom		204,898	24,293,752

8.	Italy 	187,272	25,488,166
9.	Germany 	166,526	37,879,714
10.	Indonesia 	160,855	6,732,179

Source: World Health Organization (2022)

Looking into detail at the country level, Indonesia, an archipelago with 38 provinces and 514 cities, exhibits regional variation in COVID-19 cases. According to the below distribution map, as of 18 September 2021, nearly all cities/regencies on the island of Java tend to have a high number of cases (KawalCOVID-19, 2021). Then, outside of Java (East Kalimantan, North Kalimantan, West Kalimantan, North Sumatra, and Riau) also have a high incidence of total cases, while other regions tend to have fewer cases.

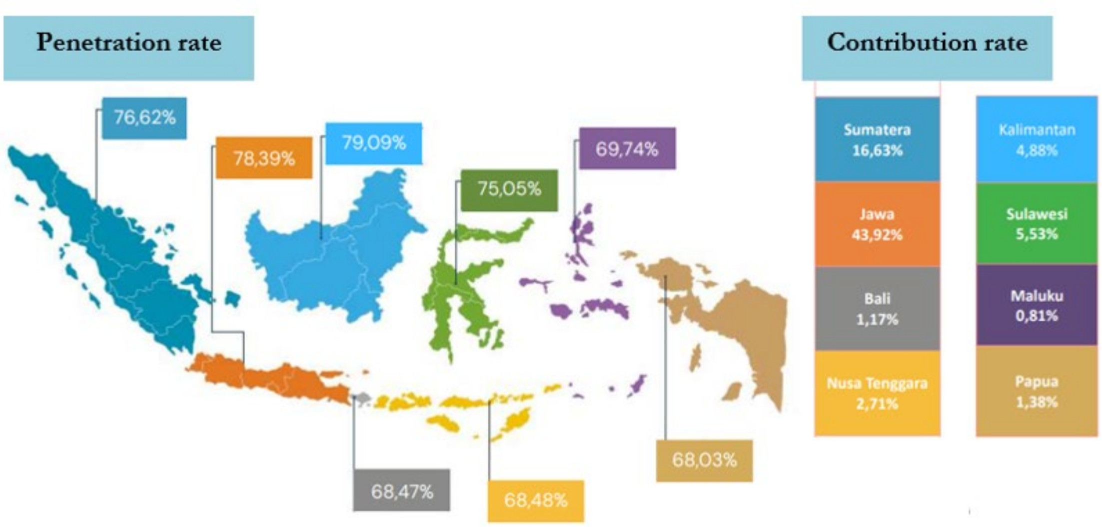
Figure 2. Indonesia's COVID-19 Cases



Source: KawalCOVID-1919 (2021)

Pandemic conditions have also altered the behavior of individuals, such as at work and school. The social distancing policy in Indonesia has shifted a substantial amount of work to be completed at home, and many schools have implemented distance learning policies. Nonetheless, this policy poses a challenge that varies by region due to the varying digital infrastructure readiness. It is demonstrated by the fact that, according to Asosiasi Penyelenggara Jasa Internet Indonesia (2022), the penetration of internet in Kalimantan and Java islands is almost 80%, while Nusa Tenggara, Sulawesi, and Papua are still less than 70%. Moreover, for the contribution rate, 43.92% of internet users come from Java Island, 16.63% from Sumatra, and the rest from other islands.

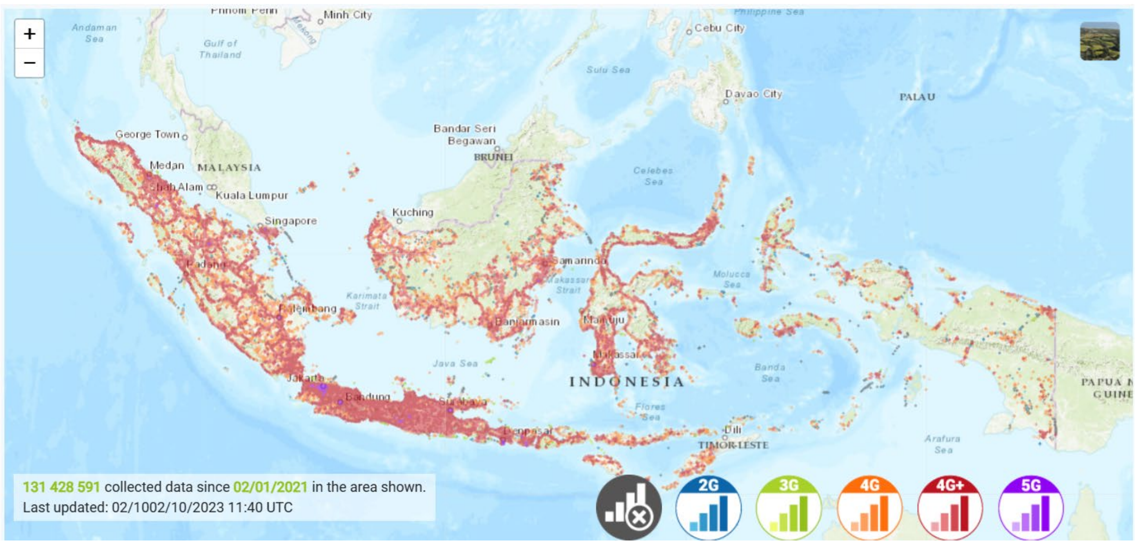
Figure 3. Internet Penetration in Indonesia



Source: APJII (2022)

Moreover, the disparity in internet access speed remains a challenge. According to data from one of the telecommunications providers in Indonesia, Java and parts of Sumatra have the fastest internet speeds, while other islands have slower connections (nPerf, 2023). This inequality has also impacted the region's ability to adapt during the pandemic.

Figure 4. Internet Speed in Indonesia



Source: nPerf (2023)

Chapter 3
Theoretical Framework and Empirical Evidence

3.1 Theoretical Framework

3.1.1 COVID-19 and Economic Performance

Regarding the economic effects of the COVID-19 pandemic, historical epidemics and pandemics can shed light on the situation. However, in doing the research, we cannot necessarily be regarded as identical due to virus type and severity differences, which produce various economic disruptions. Epidemic cases (Influenza, SARS, and Ebola) and pandemic cases (Spanish flu, Asian flu, Hongkong flu, and Swine flu) have shown that these conditions can cause panic buying, a shortage in supply, inflation, and an increase in unemployment, all of which have a negative effect on the economy (Hanna and Huang, 2004; Smith *et al.*, 2009; World Bank, 2020; Flomo, Papyrakis and Wagner, 2023).

In addition, the COVID-19 pandemic can contribute to economic disruption through several channels. First, it can lower economic demand, particularly for activities requiring physical interaction. The decline in aggregate demand in the goods market can prompt businesses to reduce wage or labor demand (Gali, 2012). If many people lose employment, their consumption will be reduced (World Bank, 2020). The pandemic has also made individuals pessimistic about the future, so they tend to preserve money and restrict their consumption to protect themselves from future uncertainty. This increasing pessimism also causes inflation (Binder, 2020). Obviously, the price rise diminishes people's purchasing power, especially amidst a declining income.

In addition to reducing home consumption, COVID-19 has compelled the Government to cut its spending due to decreased Government revenue. This may be the result of a drop in Government tax revenue. The income taxes can be reduced due to reducing public and corporate income, and the sales taxes can be reduced due to falling public consumption (Clemens and Veuger, 2020). Moreover, Kaplan, Moll and Violante (2020, as cited in Murshed, 2022) have developed a model that considers the economic effects of COVID-19 disruption. According to the model, the intensity of a COVID-19 infection might negatively affect economic output, as it decreases household income, causing a reduction in consumption, and negatively affects investment. Then, it leads to a decline in national income. The model is characterized as follows:

$$Y(R) = \sum_{i=1}^{n} C_i\left(Y_i^D\right) + I(r, R) + G + T \quad (1)$$

$$\text{Where, } Y_i^D = (1-t)w_i L_i(R) + B_i \quad (2)$$

In equation (1), Y represents national income, which can be influenced by the severity of infection (R). It is assumed that national income will accrue to households (from 1 to n). C denotes consumption as a function of disposable income (Y_i^D). This disposable income, as demonstrated by equation (2), is equal to earnings from employment (wage (w) minus tax (t)), where employment (L) is a function of the infection rate (R). The relationship between liquid assets (B) and disposable income is positive. Moreover, the infection rate can have a negative influence on wages, particularly for those who are unable to work from home. However, those who can change their job from offline to online from home will not be much impacted, and the impact on highly skilled occupations may be favorable. Besides that, the impact of the infection rate on labor employment may be negative, as it may lower labor due to illness or fear of infection, leading to decreasing income. The infection rate can then increase liquid assets due to reduced consumption.

On the supply side, the COVID-19 pandemic may impair the flow of raw materials since the distribution of commodities has been hampered due to restrictions on outdoor activities imposed by the COVID-19 pandemic. According to Goel, Saunoris and Goel (2021), the current COVID-19 situation has stressed supply chain operations. The pandemic can also lead to a shortage of raw resources, which raises production costs. All of these disturb the production process, decreasing the ability to generate the final product. In addition, the COVID-19 pandemic affects the labor market due to worker deaths and sickness/symptoms, lowering the number of the labor force and the intensity of work. Moreover, the severity of COVID-19 also aligns with the tendency of lockdown or restriction policies that shut down components of the economy where the worker's physical presence is essential in production for several sectors. This circumstance can reduce production output as a supply-side disruption (International Labor Organization, 2020).

In addition, Government regulations such as bans and lockdown can affect the intensity of COVID-19's impact on the demand and supply sides. According to Kaplan, Moll and Violante (2020), lockdown can affect the economy in two ways. First, lockdown can restrict economic activity in social goods by prohibiting restaurants from opening other than takeaways and non-essential businesses from opening physically, where the extent of restrictions affects the output of production. In addition, the policies limit the availability of work hours by requiring employees to stay home. Therefore, the policy will affect household labor supply. In general, lockdown have a similar impact as the pandemic, whose economic impact is dependent on the level of restrictions. Following is a description of the production function during the lockdown:

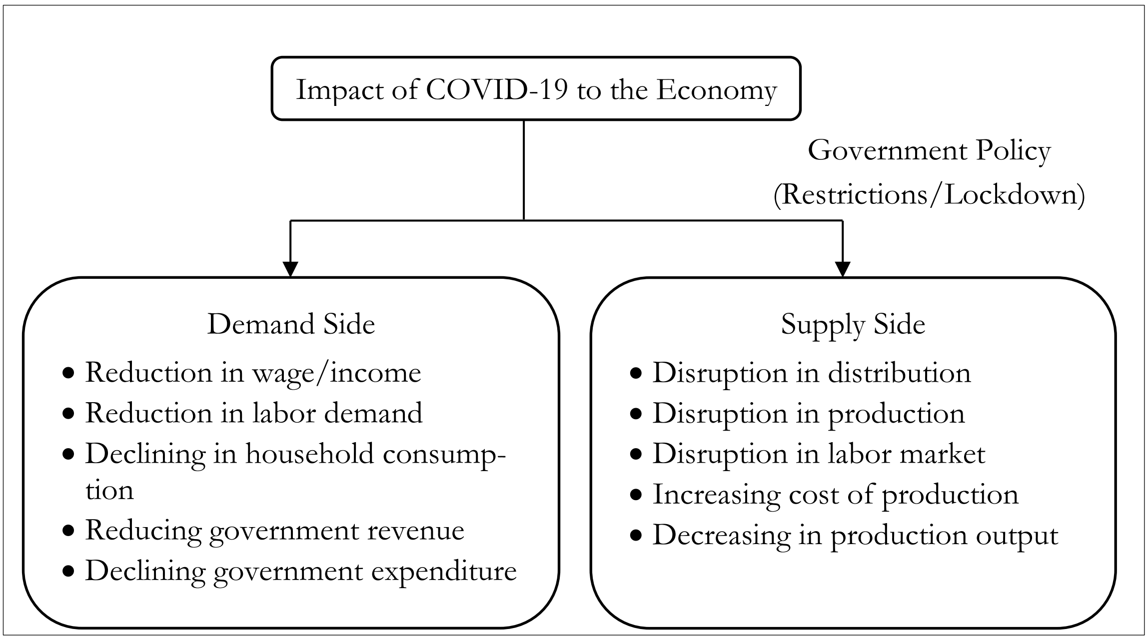
$$Y_s = Z_s(k_s K_s)^{\alpha_s} N_s^{1-\alpha_s} \text{ with } 0 \leq k_s \leq 1$$

Where k_s represents the permitted level of capital usage by the Government. In addition, during the pandemic, this equation can be used to describe the constraint-related household labor supply.

$$l_w^j \leq k_l^j (l_w^j + l_r^j) \; with \; 0 \leq k_l^j \leq 1$$

Where k_l^j depicts the maximum proportion of work that can be accomplished in the workplace. Then, if $k_s = k_l^j = 0$, there is a complete lockdown, whereas if $0 < k_s, k_l^j < 1$, there is a partial lockdown. Both sorts of lockdown slow the pandemic spread. Denoting important professions by j = E, it is assumed that $k_l^E = 1$ means vital occupations can continue functioning in the workplace even during a lockdown.

Figure 5. Theoretical Framework on the Relation of COVID-19 and Economic Performance

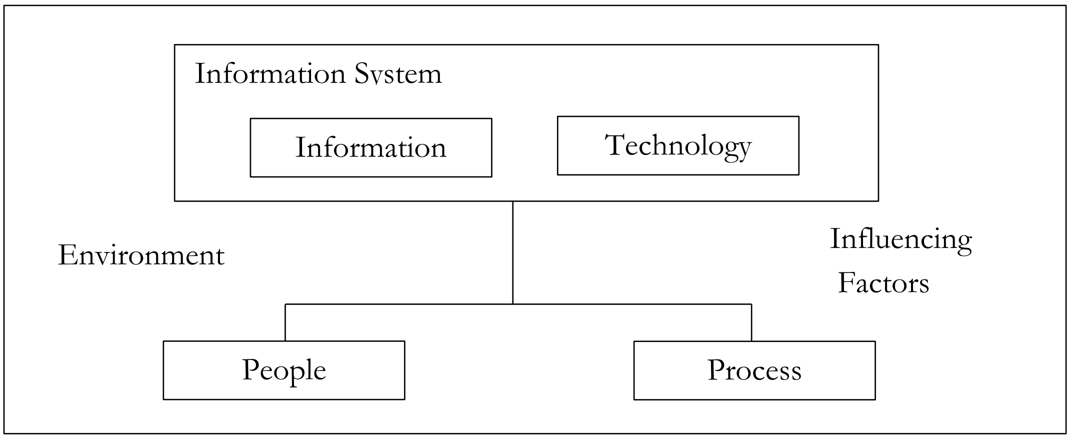


Source: Author's construction

3.1.2 Information and Communication Technology (ICT)

ICT can be defined as any artifact, technology, or body of knowledge employed for information capture, storage, processing, and dissemination (Mbuyisa and Leonard, 2017). According to Stanley (2018), ICT encompasses a wide range of technologies, such as landlines, cell phones and other mobile communication, computing, and internet access. Prior to that, Heeks (1999) had already presented ICT as a model with two components: the existence of information and technology, such as networks, software, and hardware. It becomes beneficial when there are systems of purposeful action and individuals to carry out those processes. All of those are called information systems. This information system is influenced by political, economic, sociocultural, and legal variables and institutions, markets, and organizations. Figure 6 depicts the relationships of them. According to the same source, accessing ICT-carried information requires a number of overt resources, such as a telecommunications infrastructure to offer network access, an electrical infrastructure to make ICTs function, a skills infrastructure to maintain all the technology, money to purchase or access ICTs, usage skills to utilize ICTs, and literacy abilities to read the information.

Figure 6. Theoretical Framework on ICT



Source: Heeks (1999)

3.1.3 ICT and Economic Performance

Some dispute the claim that ICT contributes to economic growth. This is because technological advancement can be disruptive to the economy. It can be related to the concept of disruptive innovation, which has been well recognized since Christensen (1997) published his book describing why technology can cause incumbents in the hard disk drive business to lose market share to new entrants. Moreover, this concept is also supported by a number of factors, including the belief that technology is a labor market disruptor since automation can diminish demand for human work (Brynjolfsson and McAfee, 2011). It is consistent with the Harrod and Domar paradigm, which assumes that technological progress is an endogenous element. In this concept, as capital or machines become more efficient, it will necessitate less labor; hence, the number of jobs required will decrease more slowly than the capital stock (Stiglitz, 2009). This disruption in the labor market can harm the economy, as layoffs can lower income and aggregate demand.

Moreover, looking at sectoral data, such as the manufacturing sector, a labor-intensive sector that is one of the sources of labor absorption, the utilization of sophisticated machines in this area has significantly reduced the demand for human labor, particularly middle-skill labor (OECD, 2019). In addition, recent advances in artificial intelligence pose a threat not only to the manufacturing sector but also to the service industry (Huang and Rust, 2018). Besides that, many existing business sectors are disrupted by online competition, where the destructive impact on some of these traditional sectors may be greater than the positive benefit gained by the online sector, resulting in a net negative effect on the economy. Individually, technology might foster a sedentary lifestyle characterized by increased time spent at home viewing movies, playing online games, or using social media (Mohammed, Tesfahun and Mohammed, 2020). This sedentary lifestyle aligns with the increase in non-productive activities, which can lead to reduced work performance (Vithayathil, Dadgar and Osiri, 2020; Falk *et al.*, 2022).

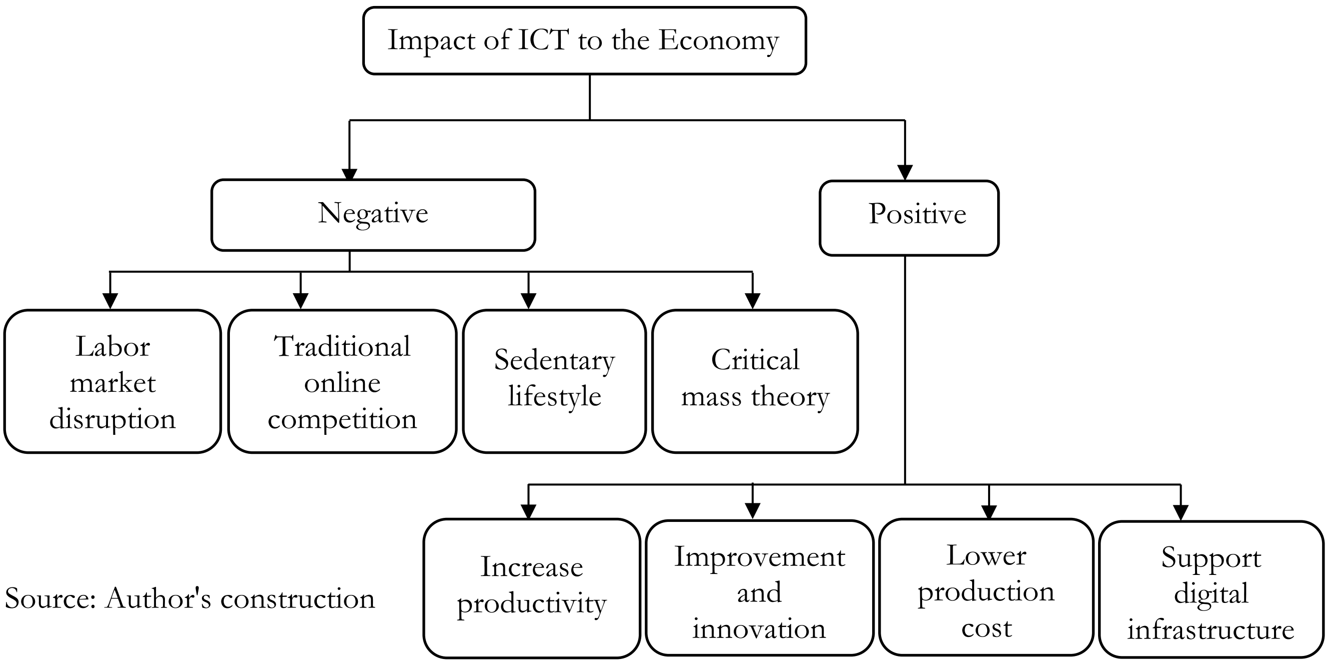
Furthermore, the argument about ICT's negative economic impact exists when significant ICT investments do not accompany increased economic growth (Brynjolfsson, 1993). This phenomenon can be explained by the notion of critical mass, which suggests that the impact of ICT on economic growth may not become significant since its adoption achieves a high degree of penetration. The effect of telecommunications infrastructure on economic output experiences a diminishing return to scale after reaching a critical mass (Katz, 2012). Additionally, others claim that the influence of ICT varies between locations and is not always positive. The regions with a greater proportion of low-skilled labor or a smaller ICT-producing industry typically do not have a favorable effect of ICT investment on economic growth (Bresnahan, Brynjolfsson and Hitt, 2002; Dimelis and Papaioannou, 2011).

On the other hand, there is growing optimism about the role of ICT in boosting economic performance. For example, the positive influence of ICT on the economy can be described using the neoclassical economic model. According to Solow growth model, technology benefits economic production since it augments physical capital and labor to produce more output, resulting in greater economic expansion (Mankiw, 2012). According to the same source, ICT can also counteract diminishing returns to capital. In addition, looking at the endogenous growth model, technological advancement is believed can influence economic growth as it is a key driver in improvement and innovation (Romer, 2012). So, it encourages capital and labor to produce higher output in the economy. Then, assuming that technology is independent (Solow model) or dependent (endogenous growth model), both state that technology positively influences economic growth.

Moreover, according to Katz (2012), ICT can enhance economic performance by encouraging the adoption of more effective business processes. Work previously performed manually and requiring a lengthy processing time can now be automated and completed more quickly. ICT can also contribute to digital infrastructure, favouring economic growth (Jones and Vollrath, 2013). This is because better infrastructure can lower production costs, increase profitability, and drive investment. Like roads and other forms of infrastructure, ICT is now an essential element of the infrastructure required for development (Mack and Faggian, 2013).

The existence of ICT also facilitates the development of digital infrastructure that promotes the use of financial technology to grow the financial system, consequently facilitating greater credit for borrowers and enhancing output and welfare. Digital finance can potentially increase the GDP by promoting access to various financial goods and services for individuals as well as small, medium, and large firms, which can increase aggregate spending, hence increasing GDP levels (Ozili, 2018). Therefore, the employment of ICT in the financial system contributes to economic expansion (Appiah-Otoo and Song, 2021).

Figure 7. Theoretical Framework on The Relation of ICT and Economic Performance



Source: Author's construction

3.1.4 ICT in the Middle of Pandemic

Previously, amid the pandemic, we discussed the negative impact of COVID-19 on the economy through aggregate demand and supply channels. Then, in this section, we will discuss how ICT can alleviate the detrimental effects of COVID-19. On the demand side, we have already discussed how the COVID-19 pandemic can reduce aggregate demand by causing numerous job losses, decreasing household income and consumption, and decreasing Government revenues and expenditures. Moreover, ICT can lessen that economic disruption in several ways. For example, the loss of employment, which is one of the causes of decreased consumption during the pandemic, can be mitigated because many occupations still allow for the transition from offline to online. By enabling work from home, ICT assists people can still work remotely during a pandemic. Consequently, it is still possible for individuals to obtain a sufficient salary to sustain their consumption.

Moreover, during the lockdown or social distancing policy, it is harder for individuals to leave their houses and do business at the market or shopping centre. Then, ICT can support e-commerce and online retail channels that are beneficial during the pandemic. The existence of those platforms allowing online transactions can still be carried out during a pandemic, which has also driven the economic sector. The economic sector that is still moving can also encourage businesses to continue operating while maintaining spending by enterprises and individuals so that the severity of disruptions can be controlled. The operation of this business also helps the Government to receive tax revenue; besides, during a pandemic, they can still collect sales tax from online transactions of goods and services. It can minimize tax deductions, enabling the Government to maintain its revenue and spending levels. Obviously, ICT support is required for this endeavor. Then, through this channel, ICT can help economic resilience (OECD, 2020).

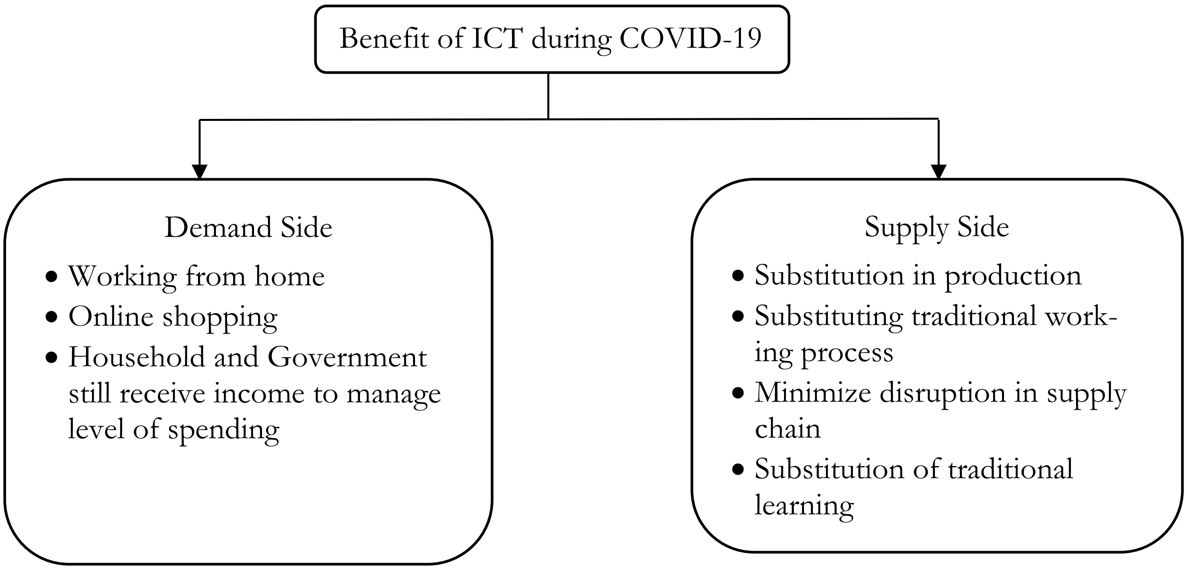
On the supply side, we have already addressed how the COVID-19 pandemic can disrupt the production process by disrupting the supply chain, leading to a lack of raw materials. It also encourages disturbance in the labor supply. Both of them can increase production costs and reduce economic output. Then, based on this, ICT may effectively mitigate the negative effects of the COVID-19 pandemic since it may allow for greater factor substitution in the production function. This is because, with the implementation of lockdown or restriction policy, many businesses were forced to transition to a remote work configuration, which requires support from ICT, such as the internet, video conferencing, mobile devices, and computer software. Moreover, ICT enables people to work from home, substituting traditional working processes. Besides, ICT can reduce or eliminate the need for travel or commuting, as virtual meetings can substitute conventional in-person meetings. It helps to maintain business relationships and collaboration. This condition contributes to the economy's survival (Shahiduzzaman, Layton and Alam, 2015).

Moreover, considering distribution disruptions, ICT enables suppliers and manufacturers to conduct business online. Using technology, inspecting products before delivery and tracking products while delivery can be performed remotely. It can help alleviate supply-side disruptions caused by COVID-19 as ICT can offer digital solutions substituting manual processes. Moreover, when there is a shock and a company's supply chain is disrupted, ICT competence is essential to provide effective communication and coordination between its many divisions, promote resource sharing of its respective supply chains, and facilitate the flow of information to minimize supply chain disruptions (Zhou *et al.*, 2022).

Regarding education, ICT enables educational institutions and businesses to provide online learning and virtual training so that people can continue to study via virtual classes. ICT plays a role by allowing the substitution of traditional classrooms, which are difficult to organize due to restrictions imposed during the COVID-19 pandemic. ICT enables students who cannot attend school to continue their education from home, as school activities can be undertaken online via distance learning during a pandemic. In this instance, ICT positively influences human capital development as a crucial factor in economic production (Olakulehin, 2008).

The impact of the pandemic on demand or supply is also determined by the extent of restrictions enforced by the Government, in which ICT can help to mitigate the negative effects of these restrictions on the economy. This is because the Government's restriction policies or lockdown drive individuals to reduce their outdoor activities, hence influencing the demand and supply side effects of the severity of COVID-19. This condition encourages online activities that use ICT. Consequently, ICT can aid in mitigating the detrimental effects of Government restrictions on both the demand and supply sides.

Figure 8. Theoretical Framework on ICT in The Middle of the Pandemic COVID-19



Source: Author's construction

Based on the theories above, this study has two hypotheses: ICT's impact on economic performance will rise during the COVID-19 pandemic, and ICT will increase economic resilience to the COVID-19 pandemic (**Hypotheses**).

3.2 Empirical Evidence

3.2.1 COVID-19 and Economic Performance

Some empirical evidence suggests that COVID-19 is detrimental to economic performance. Amewu *et al.* (2020) discovered that a three-week lockdown in Ghana led to a 27.9% decrease in GDP. Moreover, based on a simulation by Fernandes (2020), the COVID-19 impact on the economy during a three-month shutdown in 30 countries decreases GDP by 6.2% on average, while a 4.5-month shutdown reduces GDP by 10.4%. COVID-19 also poses a threat to the global supply chain, according to a study of 130 nations (Goel, Saunoris and Goel, 2021). Moreover, Chudik *et al.* (2021) assert that the COVID-19 pandemic would result in a considerable and long-lasting decline in global output, with highly heterogeneous results across countries and regions. While the consequences on China and other growing Asian economies are projected to be less severe, the United Kingdom and other industrialized economies may see more profound and persistent effects. Emerging markets outside of Asia stand out for their susceptibility. Then, structural issues, such as decreased economic dynamism, inflation, and other disruptions to critical industries due to the COVID-19 pandemic, could trigger a recession in G20 nations (Taylan, Alkabaa and Yılmaz, 2022). Another study by Deaton (2021) in 169 countries indicated that the COVID-19 death rate harmed national income per capita between 2019 and 2020. The relationship between OECD and non-OECD nations and the association within the non-OECD reveals that countries with higher death rates experience more significant economic performance reductions.

In the case of Indonesia, Olivia, Gibson and Nasrudin (2020) stated that the Indonesian economy decreased by 2.4% by the end of March 2020. This is primarily attributable to a decrease in consumption from 5% in 2019 to only 2.8% in the first quarter of 2020. Moreover, investment growth dropped below 2%. On the production side, the yearly growth rate of agricultural production fell abruptly from 4.3% to 0%. The mining and quarrying industry's growth slowed to 0.4% in the year's first quarter. Other industries, such as tourism, also suffered a decline in growth in March 2020, as the number of international visitors fell by 64%. In addition, growth in the construction industry dropped to less than 3%, down from 5.8%. It is consistent with Sparrow, Dartanto and Hartwig (2020) conclusion that the pandemic has severely impacted the Indonesian economy, which had a 5.3% decline in GDP in the second quarter of 2020, the worst economic downturn since 1998. According to the same source, the industries most affected by the pandemic are those most susceptible to mobility limitations, a decline in international trade, and supply chain disruptions.

3.2.2 ICT and Economic Performance

Some studies have found that ICT has no positive effect on economic growth, such as because of the existence of disruptive innovation. A number of studies have identified the disruptive impact of ICT on the economy. Regarding job displacement, Ayhan and Elal (2023) evaluated the effect of technology development using panel data from 30 OECD nations and showed that technological change could be labor-destructive. This is because replacing laborers with machines has resulted in a rising unemployment rate. According to the OECD (2019), this increasing unemployment rate will particularly happen in middle-skill labor and disappearing not just due to the shrinking manufacturing sector, but also within almost every industry. The estimates of job polarisation between 1997 and 2007 in Austria and Canada vary by 9 and 2 percentage points, respectively, and are substantially correlated with ICT penetration within sectors (OECD, 2019).

In addition, Yang, Kim and Choi (2022) assert that innovation can disrupt conventional incumbents. They analyzed how traditional companies' rigid business models made them more susceptible to internet retail competition in South Korea. Moreover, Meng, Ng and Tan (2022) discovered that the technology could result in digital attrition and harm the incumbent firm through their research using China's modern and traditional taxi industry as a case study. The study by Duke and Montag (2017) also supports the notion of ICT disruption. Using primary data from 262 respondents, they discovered a negative association between SAS score and work hours, indicating that smartphones may reduce work performance.

Moreover, ICT can negatively impact the economy through diminishing return-to-scale channels. For example, Parsons, Gotlieb and Denny (1993), who examined the relationship between ICT and economic performance from 1974 to 1987, found that ICT investment did not always increase production output, as the improvement was only modest from 1974 to 1979. Furthermore, a study in 113 countries over 20 years by Torero and Braun (2005) found that the economic impact of ICT will not be maximized if only certain groups with a certain income or level of education can utilize it. The available labor skills and the number of ICT-producing industries in a region also influence the positive impact of ICT investment on economic expansion. According to Bresnahan, Brynjolfsson and Hitt (2002), skilled labor complements a company's level of information technology. In addition, Dimelis and Papaioannou (2011) discovered, using panel data from 1980 to 2000 from the United States and the European Union, that the effect of ICT on economic performance is most pronounced in industries that are ICT producers or heavy ICT users.

On the other hand, numerous studies have demonstrated the positive impact of ICT on economic development. For instance, Adeleye and Eboagu (2019), using data from 54 countries from 2005 to 2015, discovered that ICT development has a statistically significant positive correlation with economic performance. Other research focusing on Europe during the period 1996-2006 found that ICT capital is a factor of increasing importance that contributes positively to Europe's economy during the economic crisis (Laitsou, Kargas and Varoutas, 2020). Moreover, Hwang and Shin (2017) investigated the role of ICT in Korea's past and future and concluded that ICT investments are necessary for continued, sustainable growth.

Besides that, Stanley (2018) conducted a meta-regression analysis of 59 econometric studies that investigated the Solow model and concluded that ICT has, on average, contributed positively to the economy. Then, Vu (2011) conducted three empirical exercises on 102 countries to analyze the function of ICT as a source of economic growth between 1996 and 2005. They discovered that ICT penetration has a strong causal relationship with growth, where the influence of ICT is statistically favorable on growth. This is consistent with the conclusion of a study conducted by Pradhan, Arvin and Hall (2016) in 21 Asian nations from 1991 to 2012, which found that investment in telecommunications infrastructure positively influences economic growth in several Asia subregions.

3.2.3 ICT in the Middle of the Pandemic

Talking about the role of ICT in the middle of the pandemic, Katz, Jung and Callorda (2020) examined the role of digitization during SARS in 2003. They employed 178 countries as the study object between 2000 and 2017 and discovered that countries with greater broadband access were able to alleviate some of the economic losses caused by the pandemic. In Latin America, Ramirez-Asis *et al.* (2022) also discovered that nations with stronger connectivity infrastructure could avert 75% of the economic losses caused by the SARS pandemic. This empirical evidence outlines the relationship between ICT and other forms of pandemics, such as the COVID-19 pandemic, although thorough research is required to determine the exact nature of this association.

Furthermore, in more detail regarding the role of ICT during the COVID-19 pandemic, it is also believed that ICT can strengthen economic resilience. Kim *et al.* (2022) conducted a cross-country study in 117 countries and discovered that economies with better internet access were more resilient. This result is consistent with the conclusion of another cross-country study by Katz and Jung (2021) that broadband positively impacts the GDP growth of developing nations and regions. Besides that, Abdelkafi, Ben Romdhane and Mefteh (2022) conducted a study in 14 MENA countries to examine the function of ICT before and after COVID-19, revealed that digital infrastructure has a significant impact on the economic resilience of MENA during the pandemic crisis.

In addition, Mefteh and Ben Romdhane (2022) also discovered that ICT positively promotes economic growth during COVID-19 in four North African countries, as many activities rely on digital technology during the crisis. Another study by Abidi, Herradi and Sakha (2022), wants to determine the effect of digitalization on the resilience of businesses during the COVID-19 pandemic. Using a difference-in-difference technique, this study analyzed firm-level data from the Middle East and Central Asia and indicated that digitally enabled businesses experienced a four percentage point smaller sales decrease during the pandemic than digitally-restricted businesses. It suggests that ICT can make the company more economically resilient during the COVID-19 pandemic.

Moreover, Katz, Callorda and Jung (2020) evaluated the digital resilience of developing nations during COVID-19 by utilizing broadband speed. In analyzing them, a digital resilience index was created. They concluded from the analysis that digital technology might be crucial in reducing the pandemic's impact. However, how individuals utilize the internet can impair their ability to mitigate the pandemic's effects. In most developing nations, the internet is still used mainly for social media and networking. These non-productive activities can diminish the capacity of digitization to combat the pandemic. Moreover, on the production side, the low digitization of enterprises, primarily SMEs, and supply chain bottlenecks impede creating resiliency to confront COVID-19.

Looking into detail through which channel ICT can help economic resilience during the COVID-19 pandemic, Zhou *et al.* (2022) evaluated data collected from 216 Chinese enterprises and determined that information technology competence substantially influenced supply chain resilience during the COVID-19 pandemic. This indicates that ICT can facilitate the continuity of supply and demand between a business and its suppliers and customers. Therefore, if information technology can contribute to a more resilient supply chain, it can contribute to a more resilient economy from the supply side during the COVID-19 pandemic. Furthermore, on the demand side, Oikonomou, Pierri and Timmer (2023) performed research in the United States and discovered that the impact of restriction policy in regions where enterprises had used more IT before the pandemic, unemployment rose less. Consequently, this confirms that the use of IT had a causal effect on bolstering labor market resilience during the COVID-19 pandemic. In this instance, it has been demonstrated that ICT can strengthen the economy's demand-side channel by keeping people employed and earning income.

Chapter 4
Data and Methodology

4.1 Data

This study will utilize panel data of 496 districts in Indonesia compiled from the Central Bureau of Statistics, the Ministry of Health, the Ministry of Communication and Information, the Audit Board of the Republic of Indonesia, and the Local Government. In 2023, there are 514 districts in Indonesia. Nonetheless, a few of them are new districts created by regional expansion. To maintain consistency, this analysis will therefore exclude districts that did not exist at the study's inception (Penukal Abab Lematang Ilir, Musi Rawas Utara, Pesisir Barat, Pangandaran, Malaka, Mahakam Ulu, Banggai Laut, Morowali Utara, Kolaka Timur, Konawe Kepulauan, Muna Barat, Buton Tengah, Buton Selatan, Mamuju Tengah, Pulau Taliabu, Manokwari Selatan, and Pegunungan Arfak). Moreover, this study also will exclude Ndunga regency as this district is a conflict-prone district with separatist troops, which causes several survey periods not to be carried out in the area. Therefore, 496 districts will be the focus of this study. The descriptive statistics of the data used are shown in the following table.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP per Capita	5,672	17.062	0.799	7.261	20.039
GDP	5,672	29.765	1.196	25.620	33.762
HDI	5,667	4.221	0.085	3.659	4.468
GDP per Capita Growth	5,142	0.034	0.055	-0.799	1.214
GDP Growth	5,142	0.045	0.044	-0.792	0.963
HDI Growth	5,138	0.008	0.008	- 0.202	0.219
Internet Penetration	5,672	0.257	0.182	0.020	0.859
Mobile Phone Penetration	2,477	0.725	0.129	0.052	0.942
Internet Speed	496	0.175	0.092	0.018	1.138
Poverty Rate	5,672	0.123	0.070	0.013	0.475
Education Level	5,672	0.246	0.069	0.074	0.505
Audit Result (1-5)	5,589	4.013	1.187	1	5
COVID-19 Cases (0-1)	992	0.038	0.088	0	1
COVID-19 Deaths (0-1)	992	0.054	0.102	0	1
COVID-19 Policy (dummy)	992	0.324	0.468	0	1

Source: Author's calculation

From the table above, GDP per capita represents GDP per capita in its natural logarithm form. It has 5,672 observations with a mean of 17.06 and a standard deviation of 0.80, indicating that the data are quite close to the mean. It has the lowest value 7.26, and a maximum value of 20.04. Moreover, GDP (GDP in its natural logarithm form) has 5,672 observations with a mean of 29.76 and a standard deviation of 1.19, suggesting that the data differ from the mean by 1.19 points. The minimum GDP data value is 25.62, and the maximum is 33.76. In addition, the Human Development Index (HDI), in its natural logarithm form, comprises 5,667 observations with a mean value of 4.221 and a standard deviation of 0.085. The HDI data distribution is quite close to the mean. HDI has a minimum value of 3.659 and a maximum value of 4.468.

Moreover, GDP per capita growth represents the difference in the natural logarithm of GDP per capita. It has 5,142 observations with a mean of 0.03 and a standard deviation of 0.06. It indicates that the data distribution is quite near to the mean. In addition, the maximum value is 1.21 and the minimum value is -0.79. Then, GDP growth depicts the difference in the natural logarithm of GDP. The average value of GDP growth is 0.04, with a standard deviation of 0.04. The lowest data value for GDP growth is -0.79, and the greatest is 0.96. Furthermore, HDI growth is calculated from the difference in the natural logarithm of HDI. It consists of 5,138 observations with a mean value of 0.008 and a standard deviation of 0.008. It means that the data is distributed around the mean. HDI growth has a minimum value of - 0.202 and a maximum value of 0.219.

In addition, internet penetration includes 5,672 observations with a mean value of 0.257 (25.67%) and a standard deviation of 0.182 (18.24%). It implies that internet penetration data is widely distributed. The minimum internet penetration is 0.020 (2.01%), and the maximum penetration is 0.859 (85.92%). This makes sense because internet connection is still problematic in many places in Indonesia, especially before 2018 when the digital infrastructure development project (Palapa Ring) was not yet operational. In terms of mobile phone penetration, there are 2477 observations. The number of observations for mobile phone penetration differs from the number of observations for internet penetration since mobile phone penetration data was available beginning in 2017, whereas internet penetration data was available beginning in 2010. Because of the inconsistency of survey questions related to mobile phone penetration before 2017, we cannot use data before 2017. The mean value of internet penetration is 0.725 (72.47%) and a standard deviation of 0.129 (12.91%). It indicates that the data distribution is quite far from the mean. In addition, the maximum value is 0.942 (94.2%), and the minimum value is 0.052 (5.2%). Then, with a total of 496 observations, the number of observations for internet speed is only available for the year 2020. The data are in Mbps. Then, for display purposes, it is divided by 100. It has a mean of 0.175 and a standard deviation of 0.092. In addition, the minimum speed is 0.018 and the highest speed is 1.138.

The poverty rate comprises 5,672 observations with a mean of 0.123 (12.26%), a standard deviation of 0.07 (7.03%), a minimum of 0.013 (1.33%), and a maximum of 0.475 (47.53%). In addition, the education level comprises 5,672 observations with a mean of 0.246 (24.57%) and a standard deviation of 0.069 (6.94%). 0.074 (7.36%) is its minimum value, while 0.505 (50.53%) is its maximum. In addition, the audit result contains 5,589 observations, as there are some missing values, particularly for districts in the province of Jakarta. As the national capital, districts in Jakarta are less independent than those in other provinces. This leads the regional revenue and expenditure budget to only exist at the provincial level so that audit results reach the provincial level. The mean result of the audit is 4.01 and has a standard deviation of 1.19. The audit result has a minimum value of 1 and a maximum value of 5. This data utilizes a Likert scale where 5 represents good audit results.

In terms of the COVID-19 cases variable, we applied maximum scaling to standardize data by dividing the value of COVID-19 cases in each district per year by the maximum number of COVID-19 cases per year. Then, there are 992 observations for the period 2020-2021 for that variable, with a mean value of 0.04 and a standard deviation of 0.09. The minimum value is 0 for districts without COVID-19 cases, while the maximum value is 1 for the district with the largest number of COVID-19 cases. In addition, for the COVID-19 deaths variable, we also applied maximum scaling to standardize the data. COVID-19 deaths has 992 observations with a mean value of 0.05 and a standard deviation of 0.1. The minimum value is 0 for districts without COVID-19 deaths, while the maximum is 1 for the district with the highest number of COVID-19 deaths. Then, for the COVID-19 Policy variable, there are 992 observations with an average value of 0.32 and a standard deviation of 0.47.

The COVID-19 policy variable is represented as a dummy variable where districts that implement strict policy restrictions or lockdown have a value of 1, while the districts with less or no restriction have a value of 0.

4.2 Methodology

This study employs panel data because it can control unobserved individual heterogeneity that varies across individuals but not over time and can control omitted variable bias (Cameron & Trivedi, 2005). In addition, this study has to account for unobserved individual heterogeneity, as geographical conditions vary across regions and positively correlate ICT penetration (Poushter, 2016). Considering this, we require a technique for controlling unobserved individual heterogeneity in panel data. Pooled Ordinary Least Square (OLS) estimation, a straightforward OLS technique applied to panel data, cannot be used in this instance because it disregards unobserved individual heterogeneity, leading to a biased result (Cameron & Trivedi, 2005). Based on that, this study will employ FEM that can control unobserved individual heterogeneity. Besides, the FEM is believed can control time fixed effect by controlling factors that may influence the result at specific districts and specific time or time-varying district effect (Cameron & Trivedi, 2005). Furthermore, the following equations will be used in the first scheme to address the research question.

The contribution of ICT to economic performance:

$$\Delta lnY_{it} = \beta_0 + \beta_1 PR_{it} + \beta_2 X_{it} + \alpha_i + \delta_t + \varepsilon_{it}$$

Where: i describes district, and t is time, ΔlnY_{it} denotes GDP per capita growth, PR_{it} describes the ICT penetration rate, X_{it} are control variables, α_i is district fixed effects, δ_t is the time-fixed effects, and ε_{it} is an error term assumed to be independent and identically distributed (i.i.d) over the whole sample. For the period before the pandemic, t is from 2010 to 2019, while the period including the pandemic, t is 2020 – 2021. Then, compare these results to determine the differences in impact before and during the pandemic.

Moreover, the second scheme aims to discover whether ICT enhances economic resilience to the pandemic. To consider the pandemic COVID-19 disruption, we include the degree of COVID-19 spread per district and the interaction between COVID-19 and ICT penetration as regressors. This research will employ the following model:

$$\Delta lnY_{it} = \beta_0 + \beta_1 PR_{it} + \beta_2 C_{it} + \beta_3 (C * PR)_{it} + \beta_4 \gamma_{it} + \beta_5 X_{it} + \alpha_i + \delta_t + \varepsilon_{it}$$

Where: i describes district, and t is time, ΔlnY_{it} denotes GDP per capita growth, PR_{it} describes the ICT penetration rate, C_{it} represents the number of COVID-19 cases, $C * PR$ is the interaction amount of COVID-19 cases and ICT penetration rate, γ_{it} is a dummy variable representing provinces specific policy during COVID-19, X_{it} are control variables, α_i is district fixed effects, δ_t is the time-fixed effects, and ε_{it} is an error term assumed to be i.i.d over the whole sample. It uses annual data from 2020 to 2021. Actually, the greater the number of periods included, the more accurate the analysis. Nevertheless, this study employs this period because of the availability of data. In addition, annual statistics are selected because the survey is only conducted yearly.

In both models, we use GDP per capita growth as the dependent variable, calculated from the difference in the natural logarithm of GDP per capita. The GDP per capita data are obtained from the Central Bureau of Statistics. We need to take the natural logarithm form of the value as according to Kim et al. (2018), the transformation can handle the highly skewed data to a more normalized dataset. So, in this model, we transform the GDP per capita into a natural logarithm to normalize the data. Then, we used difference value as it is claimed that change value is more capable than the level value of describing variations in

GDP per capita resulting from explanatory variables. As a result of a district's natural tendency to have a higher income per capita, level values are susceptible to bias. In Indonesia, residents of districts on the island of Java, such as cities in Jakarta, tend to have a higher income than those of other tiny and underdeveloped cities. This is exemplified by the fact that Jakarta has consistently higher per capita income than Papuan cities. Numerous factors may not be able to be controlled. Thus, if we utilize the level value as the dependent variable, it will have a greater potential to be biased. In contrast, we will lessen the bias toward this when we use difference value in per capita income compared to the prior year.

Moreover, we employ ICT penetration as a variable of interest in the first model. This study will use internet penetration as a proxy for ICT, as internet penetration might indicate a country's internet connectivity. Connectivity is an essential aspect of utilizing digital services. Annually, the Central Bureau of Statistics conducts a nationwide survey to collect data on internet penetration. The study inquired whether the respondent had used the internet within the previous three months. A depiction of internet penetration in a district was derived from these questions by computing the proportion of total respondents who replied "yes" to the total number of respondents, taking into consideration the weight factor used to characterize the entire population of Indonesia.

The number of COVID-19 cases used in the second equation indicates COVID-19 disruption. This variable is included because it can characterize the severity of COVID-19 in the area, which influences limits on people's activities outside the home, affecting ICT usage and economic performance. We obtained COVID-19 data from the Ministry of Health. The data is presented per 100 thousand population. This data is the source of reference for the Government in determining the severity of COVID-19 in an area. Furthermore, this becomes the basis for the Government to implement restriction policies in an effort to reduce the spread of the COVID-19 virus.

In addition, data for 2020 is only available from June to December due to the detection of the first new COVID-19 in March 2020. The Government only has access to formal statistics beginning in June 2020 regarding the spread of COVID-19. Meanwhile, for 2021, COVID-19 statistics are accessible from January to December. Based on this, we calculate an average value to obtain information on each district's annual spread of COVID-19. For instance, for COVID-19 cases in Surabaya in 2020, we use the average value from June 2020 to December 2020, but for the data for 2021, we use the average value from January 2021 to December 2021. In addition, we apply maximum scaling to standardize data by dividing the value of COVID-19 cases in each district per year by the maximum number of COVID-19 cases per year.

The interaction between the number of COVID-19 cases and ICT penetration was used as an explanatory variable to measure the effect of ICT on economic resilience during the COVID-19 outbreak. In addition to internet penetration and COVID-19 cases, this is also a variable of interest for the second model. Moreover, the district-specific policy dummy variable is designated as an independent variable. It is required because during COVID-19, regional restrictions on social interaction may differ. We assign districts a score of 1 if they have strict restrictions and 0 if they have no or light restrictions. In 2020, a score 1 is given to districts that implement Indonesia Large Scale Social Restrictions (ILSSR); in 2021, districts that implement Enforcement of Community Activity Restrictions (ECAR) Level 3 and Level 4 received a score of 1. Despite having distinct policy names, ILSSR and ECAR levels 3 and 4 feature relatively similar policies.

According to the Instruction of The Minister of Home Affairs Number 22 of 2021 (Ministry of Internal Affairs, 2021), the restriction policy during ECAR Level 3 and Level 4 includes 100% work from home for non-essential work, 100% online teaching and learning activities, the restaurant being closed and only serving take-out/delivery, the shopping center being closed, the prohibition of holding religious activities in a place of worship, the temporary closure of public facilities, and prohibition of engaging in crowd-generating activities such as wedding receptions. These policies also applied to ILSSR under Government Regulation Number 21 of 2020 (Ministry of State Secretariat, 2020). In light of this, we combine them as panel data 2020 -2021 as a proxy for COVID-19 policy.

Then, as control variables, both the first and second models use three variables: level of education, poverty rate, and audit result. Level of education is used to proxy education as it can influence each province's economic performance (Erlando, Riyanto and Masakazu, 2020). In this case, we utilize the level of education of senior high school as the number of people with high school education can affect the level of internet penetration because high school students interact a lot with ICT. Also, high school graduates dominate the Indonesian workforce, so we utilize the senior high school's education level in this study. We obtained these data from the Central Bureau of Statistics.

This study also controls the poverty rate as the poverty rate can affect people's ability to use the internet because people need to pay to access the internet. Poor people who have difficulty meeting their basic needs, such as food, have a tendency to find it difficult to buy data packages to access the internet (West, 2015). In addition, the poverty rate also has a relationship with the per capita income of the community. So, we need to control them. We obtained data on the poverty rate from the Central Bureau of Statistics.

Besides that, we also attempt to manage institution variables since, according to Acemoglu, Johnson and Robinson (2005), institutions are among the essential growth determinants. Then, to serve as a proxy for it, this study utilizes audit results from an independent state auditor institution analyzing state financial management and accountability. This audit can be used as a stand-in for the institution because it describes its quality (Avis, Ferraz and Finan, 2018). We obtain data on audit results from the Audit Board of the Republic of Indonesia. This independent state auditor institution examines state finances' management and accountability. The result is divided into five Likert scales (unqualified opinions, unqualified opinions with explanatory paragraphs, qualified opinions, adverse opinions, and disclaimers opinions).

The auditor will issue unqualified opinions when financial statements are presented accurately and appropriately, with no exceptions noted, and under widely accepted accounting principles. An unqualified opinion emphasizing the matter paragraph occurs when auditors find no major misstatements in the financial statements. Still, they consider that extra information is necessary for users' comprehension of financial statements. A qualified opinion is an auditor's view that the financial statements are presented fairly, except for one or more identified areas. An adverse opinion is a professional opinion made by an auditor indicating that a company's financial statements are misrepresented, misstated, and do not accurately reflect its financial performance and health. A disclaimer of opinion is considered a significant adverse opinion, as it indicates that the auditor has serious concerns about the reliability of the financial statements. Accordingly, the unqualified opinion represents superior governance to other opinion findings. Therefore, the results of this audit can be used as a proxy for the institution because it can describe the quality of the institution.

Then, we use cluster robust standard error for district-level clustering. According to Cameron and Trivedi (2005), the error term can be connected with a given individual. Hence, it is essential to undertake the analysis. Implementing cluster robust standard error can thereby resolve the problem. Furthermore, to measure the validity and reliability of the results, we conducted several robustness tests. For example, we will try to run additional regressions with the random effects estimator. Besides that, we will add other variables as dependent or independent variables. We will use GDP growth, HDI growth, and GDP growth per sector as the dependent variables in the robustness test.

Moreover, we utilize mobile phone penetration and internet speed in the robustness test as an alternative to internet penetration to proxy ICT. The mobile phone was selected because it is a device that can be used to access information and technology, whilst internet speed can indicate the quality of an internet connection. We obtained mobile phone penetration data from a national survey by the Central Bureau of Statistics. The survey inquired whether the respondent had used the mobile phone within the previous three months. A depiction of mobile phone penetration in a district was derived from these questions by computing the proportion of total respondents who replied "yes" to the total number of respondents, taking into consideration the weight factor used to characterize the entire population of Indonesia. Then, we get internet speed data from the Ministry of Communication and Information. The speed data is the average download and upload speed. Therefore, they can represent ICT. Moreover, related COVID-19 variable, for the robustness test, apart from using COVID-19 cases, this research will also use COVID-19 deaths. Both of them can represent COVID-19 severity.

Then, as another robustness test, we add the lagged value of the dependent variable as the independent variable. This is because the preceding period's economic performance can affect the current period's economic performance (Malik *et al.*, 2021). The lagged value can also capture the persistence of growth patterns influenced by the unobservable factors that are not fully captured by the region-specific and time-fixed effect (Vu, 2011). In addition, we attempted to adjust the pandemic period from 2020-2021 to 2010-2021 for the alternative regression specification of the first equation. Besides that, to verify the validity of the results, we conduct an additional robustness test by eliminating not only new districts generated through regional expansion, but also the original district from which the new district originated. So, this analysis exclude new districts that did not exist at the study's inception (Penukal Abab Lematang Ilir, Musi Rawas Utara, Pesisir Barat, Pangandaran, Malaka, Mahakam Ulu, Banggai Laut, Morowali Utara, Kolaka Timur, Konawe Kepulauan, Muna Barat, Buton Tengah, Buton Selatan, Mamuju Tengah, Pulau Taliabu, Manokwari Selatan, and Pegunungan Arfak), Ndunga regency (conflict-prone district which causes several survey periods to not be carried out in the area), and also exclude district of origin which was later split to minimize bias affecting the district after regional expansion (Muara Enim, Musi Rawas, Lampung Barat, Ciamis, Belu, Kutai Barat, Banggai Kepulauan, Morowali, Kolaka, Konawe, Muna, Buton, Mamuju, Kepulauan Sula, Manokwari). So, there are 481 districts in this case.

Table 3. Summary of the Method

	Main Model	Robustness Test
Model	• Fixed effects	• Random effect
Dependent variable	• GDP per capita growth	• GDP growth • HDI growth • GDP growth per sector
Independent variable	ICT penetration: • Internet penetration	ICT penetration: • Mobile phone penetration • Internet speed
	COVID-19 variable: COVID-19 cases	COVID-19 variable: COVID-19 deaths
		The lagged value of the dependent variable

Control variable	• Education level • Poverty rate • Audit result • COVID-19 policy	• Education level • Poverty rate • Audit result • COVID-19 policy
Period study	Before pandemic: 2010 – 2019 Through pandemic 2020 – 2021	Before pandemic: 2010 – 2019 Through pandemic 2010 – 2021
Data	Exclude new districts created by regional expansion.	Exclude new districts and the original district from which the new district originates.

Chapter 5
Results

5.1 Impact of ICT on the Economic Performance

5.1.1 Impact of Internet Penetration on GDP per Capita Growth

From the regression utilizing FEM and set GDP per capita growth as the dependent variable, we obtain the following result in Table 4. According to the findings, internet penetration, at a 0.1% significance level, negatively affected the dependent variable during COVID-19 (2020 - 2021). Moreover, as the relationship is ln-linear, it can be understood that increasing internet penetration by 1 unit will result in a 10.6% (0.106 * 100%) decrease in the GDP per capita growth. In contrast, prior to COVID-19, the impact of the internet was insignificant. In addition, addressing the control variables, the poverty rate negatively influences the GDP per capita growth for 2020-2021 at a 5% significant level. This indicates that a rise in the poverty rate will result in a decline in the GDP per capita relative to the prior era. Moreover, the impact of education level and audit result are insignificant. Then, the time variable or seasonal influence is negative and significant in 2012 and 2020.

Table 4. Impact of Internet Penetration on GDP per Capita Growth

	2020-2021 GDP per Capita Growth	**<=2019 GDP per Capita Growth**
Internet Penetration	-0.106***	-0.026
	(0.029)	(0.022)
Education Level	-0.136	0.001
	(0.101)	(0.035)
Poverty Rate	-0.953*	-0.116
	(0.396)	(0.075)
Audit Result	-0.002	-0.000
	(0.002)	(0.001)
2012.Year		-0.005**
		(0.002)
2013.Year		-0.007
		(0.003)
2014.Year		-0.007
		(0.004)
2015.Year		0.009
		(0.006)
2016.Year		-0.001
		(0.004)
2017.Year		0.000
		(0.004)
2018.Year		-0.000
		(0.007)
2019.Year		-0.001

		(0.008)
2020.Year	-0.057***	
	(0.003)	
2021.Year	0.013	
	(0.007)	
_cons	0.232***	0.063***
	(0.066)	(0.010)
N	1445	4103
p	0.000	0.000
r2	0.447	0.008

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

The negative significant impact of internet penetration on the dependent variable during COVID-19 is observed, contrary to the first hypothesis. It can result from internet disruptions to the economy. There are several reasons for this, including the fact that many regions are in shock from COVID-19, necessitating a rapid adaptation to the internet. People in areas unfamiliar with the internet will encounter difficulties and view it as an obstacle. According to a survey by the Association of Indonesian Internet Service Providers in 2021, some of the barriers that will prevent people from using the internet include the high cost of internet quota, a lack of information about how to use internet-connected gadgets and a lack of access devices (APJII, 2022). In addition, a possible additional cause is the COVID-19 shock, which compelled everyone to begin shifting online and incurring significant costs. For example, people must invest in devices, and companies have to change their business processes and purchase equipment supporting online activities. These factors can negatively impact output due to the enormous costs involved. Several studies, such as Sadare (2017) and Si and Chen (2020), have demonstrated that the short-term impact of technology on businesses will be detrimental, one of the reasons for this being the high initial expenses that companies must invest in implementing the technology.

In addition, according to the report by APJII (2022), internet use is still dominated by less productive activities such as social media (89.15%) and online chatting (73.86%). As for productive activities, just 21.26% engage in online purchasing, 11.98% in news searches, 7.23% in e-mail, 4.05% in online meetings, 2.81% in online learning, and 1.37% in e-wallets. Moreover, the purpose of using the internet for various types of activity might have varying effects on the economy. According to Vithayathil, Dadgar and Osiri (2020), using the internet for non-productive activities, such as social media, decreases productivity and has a tenuous relationship with project success.

Another possible explanation is that the disruption caused by the internet to conventional sectors/sectors that do not rely heavily on the internet can be larger than the benefits reaped by sectors that are highly dependent on internet use. This argument can be supported by running other regressions on a particular sector, wherein certain sectors experienced a beneficial influence from the internet while others suffered a negative impact. In Appendix 1, the internet penetration regression findings for Information and Communication sector and Business sector have a positive sign, although neither result is statistically significant. Moreover, the impact of internet penetration on the Health sector is positive and statistically significant. Nonetheless, as indicated in Appendix 2, the internet harmed a variety of other areas. For sectors where typical work requires physical presence, such as Agriculture, Forestry, and Fishing, Manufacturing, and Accommodation and Food Services, although statistically insignificant, the relationship between internet penetration and GDP growth is negative. Then, for the Transportation sector that also requires physical presence, internet penetration has a statistically significant detrimental influence.

5.1.2 Impact of Internet Penetration on GDP Growth and HDI Growth

When testing the validity using another dependent variable (GDP growth), the regression results in Appendix 3 indicate that the results when using GDP growth are similar to those when using GDP per capita growth, where internet penetration during 2020 – 2021 had a statistically significant negative impact. Then, as another robustness test, we attempted to use the growth of the HDI as a dependent variable. In this instance, we eliminate education level as a control variable to avoid a circular relationship that could lead to biased results, considering that the HDI calculation already includes the education dimension. The results in Appendix 4 show little change where the internet has a positive and statistically significant impact on increasing HDI growth both before and after COVID-19. During COVID-19, the relationship between internet penetration and the increase in HDI growth is stronger. Before a pandemic, an increase of 1 unit in internet penetration will cause the growth rate of HDI to rise by 0.7%, while, during a pandemic, the increase of 1 unit in internet penetration will cause the HDI growth to climb by 0.8%. As additional regression, we include education level as a control variable in which the results did not show a significant difference when including or excluding education level as a control variable as in Appendix 4.

The positive impact of internet penetration on HDI growth may be because the HDI includes not only monetary variables such as per capita income but also education and health. Due to the disruption it produces, the internet can have a detrimental impact on the economy, but in the health sector, for example, the availability of e-health that utilizes the internet can assist individuals in getting health care. According to Nugraha and Aknuranda (2017), e-health can help address the issue of distance in Indonesian health services. As archipelago nations with thousands of islands, health services are inadequately spread. Using e-health, individuals can get health services from their homes. Besides, the use of e-health has increased during the pandemic, and this helps people get health services amidst the limitations of health care used by COVID-19 patients. In addition, the majority of households' consumption during the pandemic was concentrated in the health sector, such as vitamins, food supplements, etc., and due to the restrictions, they purchased these items online. It is demonstrated in Appendix 1 that the internet has a positive and significant influence on the Health sector. Besides, in the Education sector, during the COVID-19 pandemic, the use of e-learning has increased due to restriction policies that prevent students from studying offline. Consequently, internet penetration can have a positive correlation with HDI growth.

5.1.3 Impact of Internet Penetration on GDP per Capita Growth (Period Change) and Impact of Mobile Phone Penetration on GDP per Capita Growth

Then, as another robustness test, we change the period of study. We compare the regression result during COVID-19 (2020-2021) and the whole period before and through COVID-19 (2010-2021). The results in Appendix 5 show that internet penetration's impact on the GDP per capita growth rate is negative and significant in both periods. It means that the results are similar to the main model.

In addition, we attempt to shift the proxy for ICT penetration from internet to mobile phone penetration while maintaining the specifications for the remaining variables. This mobile phone penetration can be an alternative proxy for ICT penetration. Then, the results are displayed in Appendix 6. The results show that before and during the COVID-19 pandemic, the impact of mobile phone penetration was insignificant.

5.2 Impact of ICT on the Economic Resilient During COVID-19 Pandemic

5.2.1 Impact of Internet Penetration on GDP per Capita Growth During COVID-19 Pandemic

Using the second equation, we evaluate ICT's effect on whether it makes districts more economically resilient during the COVID-19 pandemic. At a significance level of 0.1%, Table 5 demonstrates that internet penetration negatively affects GDP per capita growth. Moreover, at a significance level of 1%, COVID-19 cases negatively influence GDP per capita growth. However, when we examine the coefficient for the interaction term between internet penetration and COVID-19 cases, we observe a positive sign and statistical significance at 1%. It might be interpreted that internet penetration can mitigate the detrimental impact of COVID-19 on economic performance, or in other words, it makes districts more resilient during the COVID-19 pandemic. It is in line with the second hypothesis.

Moreover, the COVID-19 policy negatively impacts the GDP per capita growth rate at a significance level of 5%, as indicated by a negative coefficient (-0.008). It means that, on average, the economic performance of districts with strong policy restrictions during COVID-19 is 0.8% inferior to districts with less restrictive or no policy restrictions. Then, the coefficient for 2021.Year indicates that the GDP per capita growth in 2021 will be 8.4% greater than it was in 2020 (reference year). This is possible, given that the economy began to revive in 2021. According to the World Bank (2021), local demand improvement and the positive effect of a stronger global economy underpinned Indonesia's economic recovery in 2021. Moreover, no control variables (education level, poverty rate, and audit result) had a statistically significant relationship with the dependent variable.

Table 5. Impact of Internet Penetration on GDP per Capita Growth Considering COVID-19 Cases

	GDP per Capita Growth
Internet Penetration	-0.244***
	(0.047)
COVID-19 Cases	-0.583**
	(0.210)
Internet Penetration * COVID-19 Cases	0.914**
	(0.303)
Education Level	0.117
	(0.174)
Poverty Rate	-1.085
	(0.784)
Audit Result	-0.004
	(0.004)
COVID-19 Policy	-0.008*
	(0.004)
2021.Year	0.084***
	(0.008)

_cons	0.193*
	(0.092)
N	962
p	0.000
r2	0.589

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

In addition, by analyzing the COVID-19 impact on the GDP per capita growth, we may determine the internet penetration required to mitigate the negative effects of the COVID-19 pandemic.

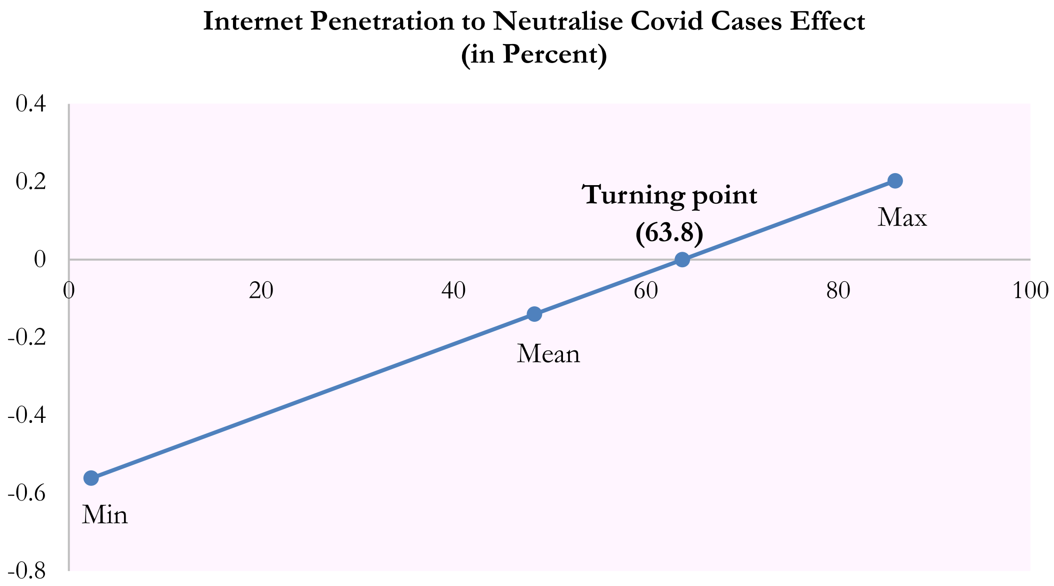
$$\frac{d(GDP\ per\ Capita\ Growth)}{d(Covid\ Cases)} = -0.583 + 0.914 * \text{Internet Penetration}$$

$$0 = -0.583 + 0.914 * \text{Internet Penetration}$$

$$Internet\ \text{Penetration} = \frac{0.583}{0.914} = 0.638 * 100\% = 63.8\%$$

Therefore, based on the preceding computation, districts' internet penetration must be at least 63.8% to mitigate the harmful effects of the COVID-19 pandemic. The districts with internet penetration more than or equal to 63.8% will be resilient during COVID-19, whereas the districts with internet penetration below this threshold will be unable to withstand its detrimental effects. The detailed relationship is depicted in the graph below.

Figure 9. Internet Penetration and COVID-19 Cases Effect



Then, we obtain the following results, as shown in Table 6, when we replace COVID-19 cases with COVID-19 deaths as the COVID-19 proxy. Internet penetration negatively affects GDP per capita growth at a significance level of 0.1%, and COVID-19 deaths negatively influence GDP per capita growth. However, when examining the coefficient for the interaction term between internet penetration and COVID-19 deaths, a positive sign and statistical significance of 5% are observed. It might be argued that internet penetration makes districts more resistant to the COVID-19 pandemic. Moreover, statistically, the COVID-19 policy has a negative effect on the GDP per capita growth at 5% significance level represented by a negative coefficient (-0.009). It means that the districts that implement strict policy restrictions during COVID-19 have lower economic performance by 0.9% than those with less restrictive or no policy restrictions. Then, the coefficient for the 2021 year dummy is positive and significant, similar to the main model result.

Table 6. Impact of Internet Penetration on GDP per Capita Growth Considering COVID-19 Deaths

	GDP per Capita Growth
Internet Penetration	-0.241***
	(0.048)
COVID-19 Deaths	-0.180
	(0.095)
Internet Penetration * COVID-19 Deaths	0.313*
	(0.140)
Education Level	0.117
	(0.175)
Poverty Rate	-1.014
	(0.802)
Audit Result	-0.004
	(0.004)
COVID-19 Policy	-0.009*
	(0.004)
2021.Year	0.085***
	(0.008)
_cons	0.184
	(0.094)
N	962
p	0.000
r2	0.587

Notes: “*” indicates the estimation is significant at the 5%, “**” at the 1% level, and “***” at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

In addition, by calculating the impact of COVID-19 fatalities on the GDP per capita growth, we may determine the internet penetration required to mitigate the negative effects of the COVID-19 pandemic.

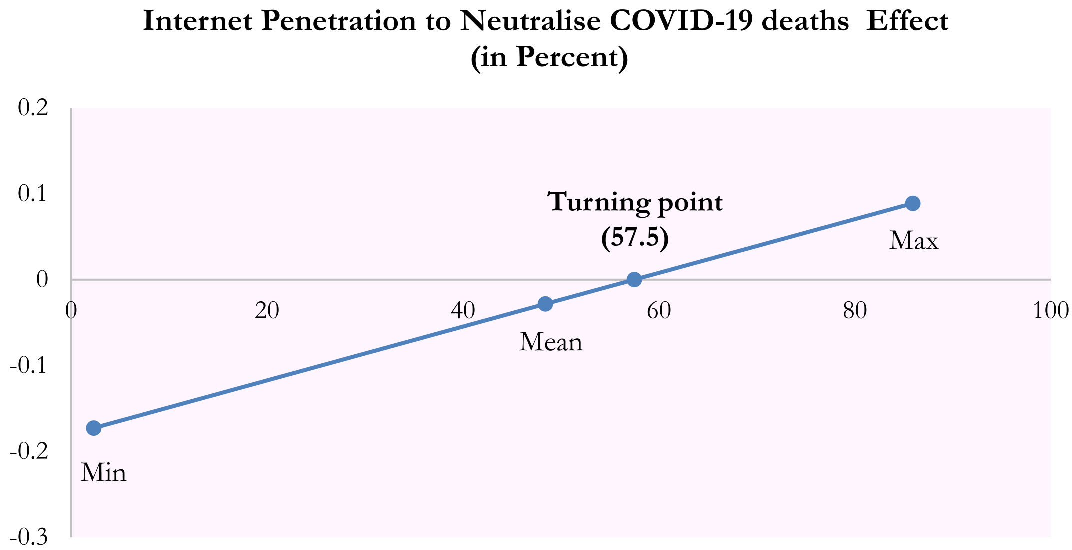
$$\frac{d(GDP\ per\ Capita\ Growth)}{d(Covid\ Deaths)} = -0.180 + 0.313 * \text{Internet Penetration}$$

$$0 = -0.180 + 0.313 * \text{Internet Penetration}$$

$$Internet\text{ Penetration} = \frac{0.180}{0.313} = 0.575 * 100\% = 57.5\%$$

Therefore, based on the previous computation, the minimal internet penetration required for districts to combat the harmful effects of COVID-19 deaths is 57.5%. Districts with internet penetration of more than or equal to 57.5% will be resilient during COVID-19, but districts with internet penetration of less than 57.5% will not be able to withstand the harmful effects of COVID-19 deaths. Moreover, compared to the results using COVID-19 cases, the internet penetration threshold required to neutralize the COVID-19 deaths effect is lower. It implies that the deaths from COVID-19 are less disruptive than the cases of COVID-19. The detailed relationship is depicted in the graph below.

Figure 10. Internet Penetration and COVID-19 Deaths Effect



5.2.2 Impact of Mobile Phone Penetration on GDP per Capita Growth During COVID-19 Pandemic

In addition, we replace internet penetration with mobile phone penetration as an alternative ICT penetration proxy for robustness testing. Using GDP per capita growth as the dependent variable, the regression yields similar results as shown in Table 7: the coefficient of mobile phone penetration has a negative sign and is statistically significant at the 1% significance level, COVID-19 cases have a negative sign and are statistically significant at the 5% significance level, the interaction between mobile phone penetration and COVID-19-cases has a positive influence at the 5% significance level, and the COVID-19 policy negatively influenced the dependent variable at 5% significance level. Therefore, the results are reliable.

Table 7. Impact of Mobile Phone Penetration on GDP per Capita Growth Considering COVID-19 Cases

	GDP per Capita Growth
Mobile Phone Penetration	-0.143**
	(0.053)
COVID-19 Cases	-1.027*
	(0.413)

Mobile Phone Penetration * COVID-19 Cases	1.306*
	(0.506)
Education Level	0.110
	(0.173)
Poverty Rate	-0.885
	(0.773)
Audit Result	-0.005
	(0.004)
COVID-19 Policy	-0.008*
	(0.004)
2021.Year	0.068***
	(0.005)
_cons	0.174
	(0.095)
N	962
p	0.000
r2	0.574

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

In addition, by analyzing the influence of COVID-19 on GDP per capita growth, we can determine the mobile penetration required to mitigate the negative effects of COVID-19 cases.

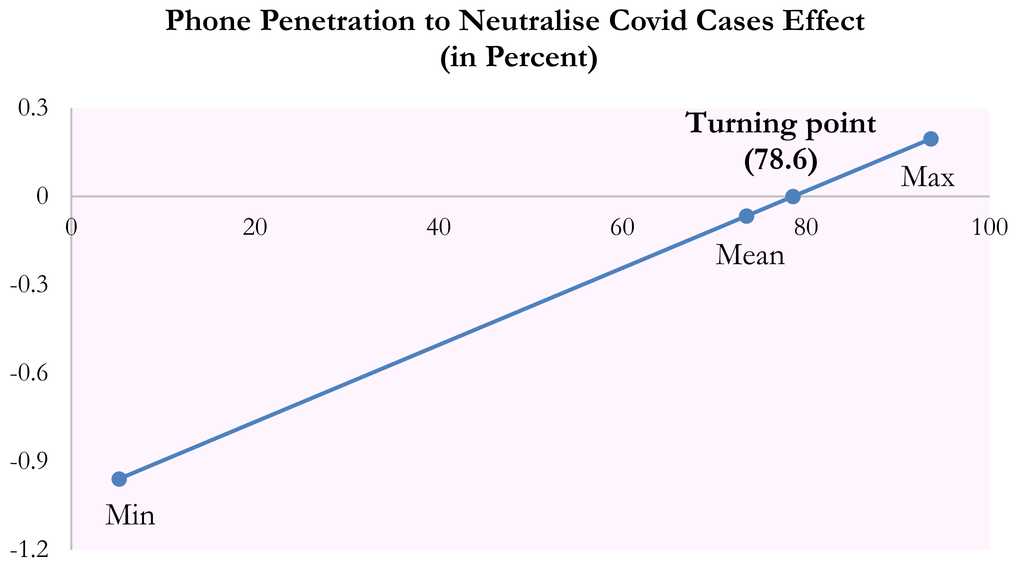
$$\frac{d(GDP\ per\ Capita\ Growth)}{d(Covid\ Cases)} = -1.027 + 1.306 * \text{Mobile Phone Penetration}$$

$$0 = -1.027 + 1.306 * \text{Mobile Phone Penetration}$$

$$\text{Mobile Phone Penetration} = \frac{1.027}{1.306} = 0.786 * 100\% = 78.6\%$$

Therefore, based on the preceding computation, the minimal mobile phone penetration required for districts to combat the harmful effects of COVID-19 cases is 78.6%. The districts with a mobile phone penetration more than or equal to this percentage will be resilient during COVID-19, whereas those with an internet penetration below 78.6% will not be able to withstand the detrimental effects of COVID-19. Moreover, compared to the results obtained by using internet penetration as a proxy for ICT penetration, the mobile phone penetration threshold required to neutralize the COVID-19 cases impact is larger. So, to counteract the negative impact of COVID-19 cases, the districts require a higher mobile phone adoption rate. The relationship can be observed in the graph below.

Figure 11. Mobile Phone Penetration and COVID-19 Cases Effect



5.2.3 Impact of Internet Penetration on GDP Growth and HDI Growth During COVID-19 Pandemic

When attempting to test the validity using another dependent variable (the growth of GDP and HDI growth), the regression results (Table 8) indicate that the GDP growth results are comparable to those when using GDP per capita growth. Internet penetration statistically harms GDP growth at a 0.1% significance level, while COVID-19 cases have a negative effect at a 1% significance level. The interaction between internet penetration and COVID-19 instances positively affected the dependent variable at a significance level of 1%. Then, the year dummy for 2021 has a statistically significant positive impact. Moreover, when HDI growth is used as the dependent variable, the influence of internet penetration is positive but statistically insignificant; the direction is the same as when we use HDI growth in the first equation. Moreover, the sign of coefficient COVID-19 cases shows that it has a negative effect on HDI growth, although statistically insignificant. Then, the interaction between internet penetration and COVID-19 cases has a positive influence on the dependent variable at a significance level of 5%, while the COVID-19 policy has a statistically significant negative impact on HDI growth at a significance level of 5%. These results support the main model's findings.

Table 8. Impact of Internet Penetration on GDP Growth and HDI Growth Considering COVID-19 Cases

	GDP Growth	HDI Growth
Internet Penetration	-0.158***	0.003
	(0.041)	(0.005)
COVID-19 Cases	-0.500**	-0.040
	(0.183)	(0.021)
Internet Penetration * COVID-19 Cases	0.786**	0.076*
	(0.269)	(0.031)
Education Level	0.202	
	(0.163)	

Poverty Rate	-1.186	-0.040
	(0.626)	(0.066)
Audit Result	-0.001	-0.000
	(0.003)	(0.000)
COVID-19 Policy	0.005	-0.001*
	(0.003)	(0.000)
2021.Year	0.062***	0.003***
	(0.007)	(0.001)
_cons	0.144*	0.007
	(0.070)	(0.008)
N	962	962
p	0.000	0.000
r2	0.592	0.298

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

5.2.4 Impact of Internet Penetration on GDP per Capita Growth During COVID-19 Pandemic (REM)

In this part, we employ the Random Effect Model (REM) as another robustness test. The outcome is displayed in Table 9, where at a significance level of 5%, the data indicate that internet penetration negatively influences GDP per capita growth. Then, COVID-19 cases have a negative effect on GDP per capita growth. However, this influence is insignificant. In addition, the interaction term coefficient between internet penetration and COVID-19 cases exhibits a positive sign impact. In other words, internet penetration makes districts more robust during the COVID-19 pandemic. Moreover, at a significance level of 1%, the poverty rate negatively influences the GDP per capita growth. Then, the influence of the COVID-19 policy is negative but statistically insignificant.

Table 9. Impact of Internet Penetration on GDP per Capita Growth Considering COVID-19 Cases (REM)

	GDP per Capita Growth
Internet Penetration	-0.092*
	(0.036)
COVID-19 Cases	-0.153
	(0.112)
Internet Penetration * COVID-19 Cases	0.250
	(0.149)
Education Level	0.065
	(0.062)
Poverty Rate	-0.104**
	(0.034)
Audit Result	0.001
	(0.002)
COVID-19 Policy	-0.008
	(0.004)

2021.Year	0.069***
	(0.007)
_cons	0.006
	(0.012)
N	962
p	0.000
r2	

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

In addition, when using COVID-19 fatalities as a proxy for ICT penetration, Table 10 indicates that internet penetration negatively affects the GDP per capita growth at a significant level of 1%. Then, the sign of coefficient COVID-19 deaths shows that it has a negative effect on GDP per capita growth, although statistically insignificant. The coefficient for the interaction term between internet penetration and COVID-19 deaths is positive and statistically significant at the 5% level. It might be interpreted that internet penetration can mitigate the detrimental impact of COVID-19 on economic performance, or in other words, it makes districts more resilient during the COVID-19 pandemic. Moreover, the poverty rate negatively impacts the GDP per capita growth at 1% significance level. Moreover, the coefficient of the COVID-19 policy confirms the main model's conclusion that the impact on GDP per capita growth is negative and statistically significant at the 5% level.

Table 10. Impact of Internet Penetration on GDP per Capita Growth Considering COVID-19 Deaths (REM)

	GDP per Capita Growth
Internet Penetration	-0.094**
	(0.035)
COVID-19 Deaths	-0.075
	(0.046)
Internet Penetration * COVID-19 Deaths	0.141*
	(0.068)
Education Level	0.066
	(0.062)
Poverty Rate	-0.105**
	(0.035)
Audit Result	0.001
	(0.002)
COVID-19 Policy	-0.009*
	(0.004)
2021.Year	0.069***
	(0.006)
_cons	0.006
	(0.012)
N	962
p	0.000
r2	

5.2.5 Impact of Internet Speed on GDP per Capita Growth During COVID-19 Pandemic (OLS)

We substitute internet penetration with internet speed as an alternative ICT proxy for robustness testing. In this case, we employ the OLS method as there is only one year of data. Table 11 reveals that the influence of internet speed on the GDP per capita growth is negative but insignificant. Moreover, the impact of COVID-19 cases on the dependent variable is negative and statistically significant at the 0.1% significance level. Furthermore, at a significance level of 5%, the interaction term between internet speed and COVID-19 cases favorably affects the GDP per capita growth. It is possible to interpret internet speed as making districts more economically resilient during the COVID-19 outbreak.

Table 11. Impact of Internet Speed on GDP per Capita Growth Considering COVID-19 Cases

	GDP per Capita Growth
Internet Speed	-0.051
	(0.027)
COVID-19 Cases	-0.180***
	(0.052)
Internet Speed * COVID-19 Cases	0.480*
	(0.189)
Education Level	-0.030
	(0.021)
Poverty Rate	0.022
	(0.019)
Audit Result	-0.000
	(0.002)
COVID-19 Policy	-0.002
	(0.006)
_cons	-0.007
	(0.012)
N	483
p	0.000
r2	0.051

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

In addition, by analyzing COVID-19's effect on the GDP per capita growth, we may determine the internet speed required to mitigate the negative effects of the COVID-19 pandemic.

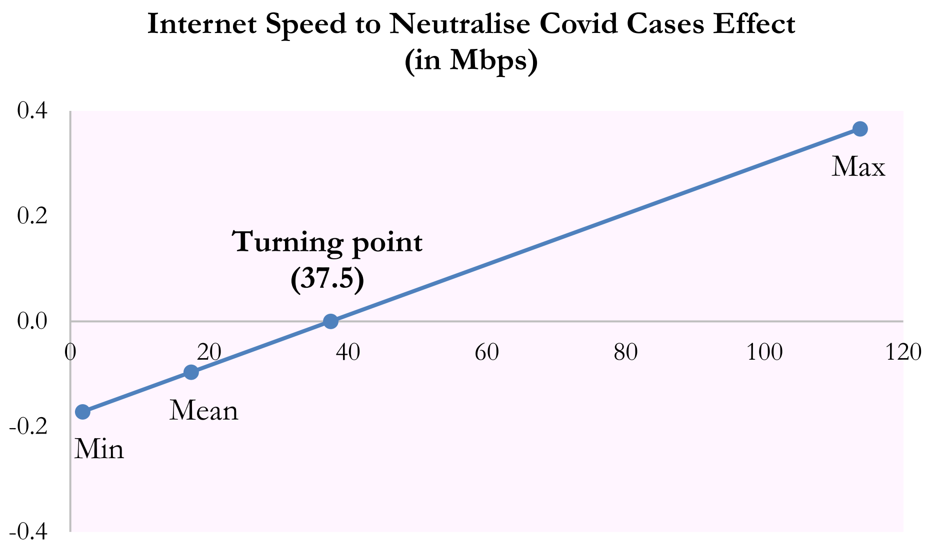
$$\frac{d(D.lGDP\ per\ Capita)}{d(Covid\ Cases)} = -0.180 + 0.480 * \text{Internet Speed}$$

$$0 = -0.180 + 0.480 * \text{Internet Speed}$$

$$Internet\ Speed = \frac{0.180}{0.480} = 0.375 * 100 = 37.5\ \text{Mbps}$$

In the calculation above, the result is multiplied by 100 because previously, when regressing the data for display purposes, it was divided by 100. Therefore, according to the calculation, the districts require a minimum average internet speed of 37.5 Mbps to combat the harmful effects of COVID-19 cases. Based on the Federal Communications Commission, a suitable internet speed is at least 25 Mbps (FCC, 2022). So, 37.5 Mbps is enough for the majority of online activity. Districts with speeds greater than or equal to 37.5 Mbps will be more resilient during COVID-19 than those below 37.5 Mbps. The detailed relationship is depicted in the graph below.

Figure 12. Internet Speed and COVID-19 Cases Effect



5.2.6 Impact of Internet Penetration on GDP Growth per Sector During COVID-19 Pandemic

In this section, as an additional robustness test, we attempt to use sectoral data (GDP growth per sector) as the dependent variable, whereas others employ variables with the same specification. From the regression result in Appendix 7, most of the effects of internet penetration, COVID-19 cases, and the interaction of those variables on the economy are insignificant. The statistically negative significant impact of COVID-19 on the economy is shown in Electricity and Gas sector and Transportation sector. In Electricity and Gas sector, the impact of internet penetration is negative and insignificant, whereas the effect of COVID-19 cases is negative and statistically significant at the 1% significance level, and the effect of the interaction term between internet penetration and COVID-19 cases is positive and significant at the 1% significance level. Moreover, in Transportation sector, the impact of COVID-19 cases is negative and statistically significant at the 5% significance level, and the effect of the interaction term between internet penetration and COVID-19 cases is positive and significant at the 5% significance level. Therefore, we can say that those sectors are the most affected by COVID-19. Then, from the calculation below, where the value of internet penetration is calculated using the average value for 2020-2021 (0.484), we obtained that the negative impact of COVID-19 on the Transportation sector (-0.81) is more severe than on Electricity and Gas sector (-0.50), it means that Transportation sector is the sector that experienced the worst impact of COVID-19 pandemic. This is reasonable because during COVID-19, there were many restrictions on people traveling and requiring people to stay home, greatly affecting the transportation sector.

The impact of COVID-19 on the Electricity and Gas sector is =

$$\frac{d(GDP\ Growth\ per\ Sector\ )}{d(Covid\ Cases)} = -2.112 + 3.319 * \text{Internet Penetration}$$
$$= -2.112 + 3.319 * 0.484 = -0.50$$

The impact of COVID-19 on the Transportation sector is =

$$\frac{d(GDP\ Growth\ per\ Sector\ )}{d(Covid\ Cases)} = -2.176 + 2.827 * \text{Internet Penetration}$$
$$= -2.176 + 2.827 * 0.484 = -0.81$$

Moreover, it is somewhat remarkable that the effect of internet penetration on the Information and Communication sector is insignificant. However, the sign indicates that internet penetration positively impacts this sector, as depicted by the positive sign of the internet penetration variable's coefficient. The insignificance of this sector's impact may be attributable to several factors, such as the increase in internet demand from this sector may not be all that significant, given that this sector already had a high demand for the internet because its core business is ICT-related. In addition, ICT preparedness in this industry has been well-established for quite some time, suggesting that a further improvement in internet usage may not significantly affect performance. Then, this sector was already ICT-based before the introduction of COVID-19, which could be another reason why COVID-19 may not significantly impact the business processes of this industry related to internet use. Furthermore, besides Information and Communication sector, although insignificant, other sectors such as Wholesale and Retail sector, Financial and Insurance sector, Business sector, Education sector, and Health and Social sector also show positive signs coefficient of the internet penetration variable. It can be caused that the activities of these sectors can shift from offline to online during COVID-19, such as through e-commerce, e-learning, e-health, and virtual meetings, so that these can get a lot of benefits from the internet.

5.2.7 Impact of Internet Penetration on GDP per Capita Growth During COVID-19 Pandemic by Adding Lagged Value of the Dependent Variable as Explanatory Variable

With GDP per capita growth as a dependent variable, we conducted another robustness test by adding the lagged value of the natural logarithm GDP per capita as an independent variable, while maintaining a similar specification for all other variables like the primary model. From the regression result below in Table 12, we can see that the coefficient of the lagged value is not statistically significant. This indicates that the main model's specification is better. Therefore, we may exclude the lagged variable from the model. In addition, the sign of the lagged variable is negative, and this negative sign actually supports the notion that there is convergence, in which districts with a higher initial GDP per capita growth tend to find it more challenging to improve their economic performance than districts with a lower initial GDP per capita growth.

Moreover, the coefficients of the other variables, as shown in Table 12, validate the main model's results. At a significant level of 1%, internet penetration negatively influences the GDP per capita growth. In addition, at a significance level of 5%, COVID-19 cases had a negative impact on the dependent variable. However, when we examine the coefficient for the interaction term between internet penetration and COVID-19 cases, we observe a positive sign and statistical significance at 1%. It might be argued that internet penetration mitigates the negative effect of COVID-19 on economic performance, or that it makes districts more resilient during the COVID-19 pandemic. Moreover, the COVID-19 policy negatively affects GDP per capita growth at a 5% significance level. Furthermore, the convergence is also demonstrated when the dependent variable is changed to HDI growth, as shown in Appendix 8. When we utilized HDI growth as the dependent variable, added the lagged value of the natural logarithm HDI as a regressor, and left all other specifications the same, the coefficient of the lagged value is negative and statistically significant at 0.1%. However, other coefficients become statistically insignificant even though the direction still supports the main model results.

Table 12. Impact of Internet Penetration on GDP per Capita Growth Considering Lagged Dependent Variable

	GDP per Capita Growth
L.GDP per Capita	-0.198
	(0.391)
Internet Penetration	-0.226**
	(0.070)
COVID-19 Cases	-0.492*
	(0.196)
Internet Penetration * COVID-19 Cases	0.759**
	(0.293)
Education Level	0.113
	(0.187)
Poverty Rate	-1.213
	(0.662)
Audit Result	-0.003
	(0.004)
COVID-19 Policy	-0.008*
	(0.004)
2021.Year	0.079***
	(0.018)
_cons	3.605
	(6.709)
N	962
p	0.000
r2	0.597

Notes: “*” indicates the estimation is significant at the 5%, “**” at the 1% level, and “***” at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

5.2.8 Impact of Internet Penetration on GDP per Capita Growth During COVID-19 Pandemic by Excluding Regional Expansion Districts

As indicated in the methodology section, Indonesia had regional expansions over the study period. Then, as the robustness test, besides eliminating new districts from regional expansion, we also exclude the regions from which the new areas originated. Table 13 below displays the outcomes. The regression results further confirm the reliability of our primary model's findings that internet penetration negatively influences the GDP per capita growth at the 0.1% significant level. Moreover, at a significance level of 1%, COVID-19 cases negatively impact GDP per capita growth. However, when we evaluated the coefficient for the interaction term between internet penetration and COVID-19 instances, it showed a positive sign and a statistically significant value of 1%. In other words, internet penetration makes districts more resilient during the COVID-19 pandemic. Moreover, COVID-19 policy negatively impacts GDP per capita growth at a 5% significance level.

Table 13. Impact of Internet Penetration on GDP per Capita Growth Excluding Regional Expansion Districts

	GDP per Capita Growth
Internet Penetration	-0.235***
	(0.048)
COVID-19 Cases	-0.580**
	(0.214)
Internet Penetration * COVID-19 Cases	0.886**
	(0.307)
Education Level	0.143
	(0.176)
Poverty Rate	-0.640
	(0.754)
Audit Result	-0.005
	(0.004)
COVID-19 Policy	-0.009*
	(0.004)
2021.Year	0.083***
	(0.008)
_cons	0.140
	(0.089)
N	932
p	0.000
r2	0.603

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Chapter 6
Conclusion

The first equation reveals that during the COVID-19 period (2020-2021), internet penetration had a statistically significant negative influence on GDP per capita growth, but its effect was insignificant prior to the COVID-19 period. Using GDP growth yields similar outcomes. However, when HDI growth is used as the dependent variable, the influence of internet penetration becomes positive and statistically significant before and during COVID-19. This could be because the HDI covers not only monetary variables such as per capita income, but also education and health. Due to the disruption it causes, the internet can harm the economy, but in the health sector and education sector, for instance, the use of e-health increased during the pandemic, which helps people obtain health services despite the limitations of health care used by COVID-19 patients, and the use of e-learning increases due to restriction policies that prevent students from studying offline. Therefore, internet access may have a positive influence on HDI growth.

Furthermore, the negative effect of the internet penetration on GDP per capita growth and GDP growth may be a result of the internet's disruptive impacts on the economy. There are several reasons for this, including the COVID-19 shock that forced people to switch to digital activities despite their lack of preparedness and the costs that individuals and businesses must incur to adapt to online activities, making the internet a short-term economic disruption. In addition, the usage of the internet, which is still dominated by unproductive activities such as social media, may also contribute to the internet's negative economic impact. The existence of the internet, which promotes digitalization, can pose a threat to conventional industries too.

The results become interesting when examining ICT's contribution to economic resilience in greater detail using a second equation that includes an interaction term between ICT and the COVID-19 variable. The results show that the impact of internet usage on GDP per capita growth is still negative, the effect of COVID-19 on the economy is also significant and negative, but when ICT and COVID-19 variables interact, the effect becomes positive and statistically significant. It can be interpreted that internet penetration can help districts be more economically resilient during COVID-19. In addition, the regression results indicate that restriction policies or lockdown can harm the economy. The economic performance of districts with strong restriction policies is inferior to those with less restrictive or no policies. Moreover, the results are valid when the ICT penetration proxy changes from internet penetration to mobile penetration and internet speed. They are also reliable with other COVID-19 proxies (COVID-19 cases and COVID-19 deaths). The results are also robust with a random effect model. Besides that, the results are still valid when we use the lagged dependent variable as the explanatory variable and exclude data related to regional expansion.

According to the regression results, 63.8% is the minimal internet penetration required for districts to tackle the harmful effects of COVID-19 cases. Then, 57.5% internet penetration is necessary for districts to address the detrimental effects of COVID-19 fatalities. Based on that, the internet penetration threshold required to neutralize the COVID-19 fatalities effect is lower than COVID-19 cases. It implies that the deaths from COVID-19 are less disruptive than the cases of COVID-19. Moreover, the minimal mobile phone penetration required for districts to combat the detrimental effects of the COVID-19 pandemic is 78.6%. Compared to the results obtained by using internet penetration as a proxy for ICT penetration, the mobile phone penetration threshold required to neutralize the COVID-19 instances impact is greater. Therefore, the districts need a higher mobile phone penetration rate to counteract the adverse effects of COVID-19. In addition, regarding internet speed, the districts must have a minimum average internet speed of 37.5 Mbps to tackle the detrimental effects of the COVID-19 pandemic. Then, based on the regression using sectoral data, the outcomes demonstrate that Transportation is the sector most negatively impacted by COVID-19. In addition, based on the main model in the second equation, the GDP per capita growth of districts with stringent restriction policies is 0.8% lower than those with less restrictive or no policies.

Moreover, this study's findings can contribute to existing knowledge by enriching knowledge and empirical evidence regarding the relationship between ICT and economic performance, especially its role in helping districts to be more resilient during the COVID-19 pandemic. By using district data in Indonesia, where many previous studies used country-level data, this research can enrich previous research. The variation of ICT penetration used in this research (internet penetration, mobile phone penetration, and internet speed) can also be a strength. However, if the available period during COVID-19 and after COVID-19 is longer, this research could be more interesting. This is because the results' findings are intriguing and raise the question of whether the internet disruption to the economy will continue after the COVID-19 period or whether, since the internet has proven to make districts more resilient to economic shocks during the COVID-19 and COVID-19 making people and industries have adapted to the internet, perhaps it makes ICT no longer a disruption to the economy but instead helps the economy to develop more. So, further research can analyze it if more extended data is available after COVID-19.

In addition, the outcomes of this study can be useful for policymakers. They can consider policies or other ways to mitigate the economic disruption caused by ICT and to encourage ICT to contribute more positively to the economy, such as by expanding the internet's participation in more productive activities and encouraging traditional sectors to utilize ICT. In addition, by determining the threshold of internet penetration, mobile phone penetration, or internet speed required to mitigate the harmful effects of COVID-19, the Government can concentrate on enhancing the districts that remain below the threshold. This is important to make more targeted policies. In addition, the Government can also consider this in determining which areas are development priorities amidst limited Government budgets and high fiscal burdens for post-COVID-19 economic recovery.

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Appendices

Appendix 1. Impact of Internet Penetration on GDP Growth per Sector

	GDP Growth Information and Communication	GDP Growth Business	GDP Growth Health and Social
Internet Penetration	0.006	0.399	0.200*
	(0.519)	(0.283)	(0.088)
Education Level	-0.647	-0.577	0.190
	(0.970)	(0.643)	(0.233)
Poverty Rate	7.043	1.668	-2.185***
	(3.652)	(2.305)	(0.613)
Audit Result	0.019	-0.035	0.013
	(0.049)	(0.025)	(0.009)
2020.Year	0.051	-0.116***	0.026***
	(0.035)	(0.022)	(0.008)
2021.Year	-0.015	-0.106*	-0.023
	(0.066)	(0.050)	(0.015)
_cons	-0.690	0.016	0.113
	(0.555)	(0.324)	(0.104)
N	1433	1444	1447
p	0.001	0.000	0.000
r2	0.006	0.018	0.026

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Appendix 2. Impact of Internet Penetration on GDP Growth per Sector

	GDP Growth Agriculture, Forestry, and Fishing	GDP Growth Manufacturing	GDP Growth Transportation	GDP Growth Accommodation and Food Service
Internet Penetration	-0.010	-0.065	-1.577*	-0.007
	(0.058)	(0.095)	(0.800)	(0.070)
Education Level	0.242	0.155	0.920	-0.237
	(0.231)	(0.439)	(1.150)	(0.138)
Poverty Rate	0.662**	-1.417***	42.84***	-0.620
	(0.246)	(0.356)	(7.581)	(0.406)
Audit Result	0.000	-0.004	0.001	-0.006
	(0.004)	(0.008)	(0.101)	(0.009)
2020.Year	-0.028**	-0.059***	1.005***	-0.154***
	(0.009)	(0.015)	(0.058)	(0.007)
2021.Year	-0.016	-0.001	1.002***	-0.036***

	(0.012)	(0.017)	(0.114)	(0.011)
_cons	-0.104*	0.217*	-5.461***	0.234**
	(0.046)	(0.098)	(1.079)	(0.087)
N	1447	1447	1445	1447
p	0.000	0.000	0.000	0.000
r2	0.006	0.017	0.435	0.278

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Appendix 3. Impact of Internet Penetration on GDP Growth

	2020-2021 GDP Growth	**<=2019 GDP Growth**
Internet Penetration	-0.052*	-0.030
	(0.024)	(0.016)
Education Level	-0.063	0.008
	(0.095)	(0.025)
Poverty Rate	-0.865*	-0.088
	(0.366)	(0.047)
Audit Result	-0.000	-0.000
	(0.002)	(0.001)
2012.Year		-0.002
		(0.002)
2013.Year		-0.006*
		(0.003)
2014.Year		-0.007**
		(0.002)
2015.Year		-0.003
		(0.003)
2016.Year		-0.004
		(0.003)
2017.Year		-0.003
		(0.003)
2018.Year		-0.001
		(0.005)
2019.Year		-0.002
		(0.006)
2020.Year	-0.060***	
	(0.003)	
2021.Year	-0.004	
	(0.007)	
_cons	0.187**	0.072***
	(0.062)	(0.009)
N	1445	4103
p	0.000	0.000
r2	0.470	0.007

Appendix 4. Impact of Internet Penetration on HDI Growth

	2020-2021	**<=2019**	**2020-2021**	**<=2019**
	HDI Growth	**HDI Growth**	**HDI Growth**	**HDI Growth**
Internet Penetration	0.008*	0.007**	0.007*	0.007**
	(0.003)	(0.002)	(0.003)	(0.003)
Education Level			0.018***	0.008
			(0.005)	(0.005)
Poverty Rate	0.052*	0.005	0.036	0.006
	(0.023)	(0.008)	(0.023)	(0.008)
Audit Result	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
2012.Year		-0.000		-0.000
		(0.001)		(0.001)
2013.Year		-0.000		-0.000
		(0.000)		(0.000)
2014.Year		-0.003***		-0.003***
		(0.001)		(0.001)
2015.Year		-0.001		-0.001
		(0.001)		(0.001)
2016.Year		-0.002***		-0.002***
		(0.001)		(0.001)
2017.Year		-0.003***		-0.003***
		(0.001)		(0.001)
2018.Year		-0.002**		-0.003***
		(0.001)		(0.001)
2019.Year		-0.002*		-0.003**
		(0.001)		(0.001)
2020.Year	-0.008***			
	(0.000)		-0.008***	
2021.Year	-0.006***		(0.000)	
	(0.000)		-0.006***	
_cons	0.001	0.010***	-0.002	0.008***
	(0.003)	(0.001)	(0.003)	(0.002)
N	1445	4099	1445	4099
p	0.000	0.000	0.000	0.000
r2	0.666	0.028	0.671	0.028

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Appendix 5. Impact of Internet Penetration on GDP per Capita Growth (Period Change)

	2020-2021 GDP per Capita Growth	**2010-2021 GDP per Capita Growth**
Internet Penetration	-0.106***	-0.063**
	(0.029)	(0.022)
Education Level	-0.136	0.022
	(0.101)	(0.034)
Poverty Rate	-0.953*	-0.130
	(0.396)	(0.082)
Audit Result	-0.002	0.000
	(0.002)	(0.001)
2012.Year		-0.005*
		(0.002)
2013.Year		-0.006
		(0.003)
2014.Year		-0.006
		(0.003)
2015.Year		0.011*
		(0.005)
2016.Year		0.002
		(0.003)
2017.Year		0.005
		(0.004)
2018.Year		0.007
		(0.006)
2019.Year		0.009
		(0.007)
2020.Year	-0.057***	-0.052***
	(0.003)	(0.008)
2021.Year	0.013	0.011
	(0.007)	(0.010)
_cons	0.232***	0.063***
	(0.066)	(0.011)
N	1445	5065
p	0.000	0.000
r2	0.447	0.141

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Appendix 6. Impact of Mobile Phone Penetration on GDP per Capita Growth

	2020-2021 GDP per Capita Growth	**<=2019 GDP per Capita Growth**
Mobile Phone Penetration	-0.066	0.059
	(0.049)	(0.042)
Education Level	-0.137	-0.079
	(0.097)	(0.117)
Poverty Rate	-0.954*	-0.192
	(0.405)	(0.289)
Audit Result	-0.002	0.004
	(0.002)	(0.002)
2018.Year		-0.004
		(0.004)
2019.Year		-0.009
		(0.006)
2020.Year	-0.061***	
	(0.002)	
2021.Year	0.002	
	(0.006)	
_cons	0.240**	0.027
	(0.089)	(0.033)
N	1445	1438
p	0.000	0.398
r2	0.445	0.010

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation

Appendix 7. Impact of Internet Penetration on GDP Growth per Sector During COVID-19 Pandemic

	GDP Growth Agriculture, Forestry, and Fishing	**GDP Growth Mining and Quarrying**	**GDP Growth Manufacturing**
Internet Penetration	-0.007	-0.105	-0.109
	(0.096)	(0.235)	(0.179)
COVID-19 Cases	-0.049	4.073	-0.290
	(0.656)	(2.890)	(0.831)
Internet Penetration * COVID-19 Cases	-0.417	-6.877	0.117
	(0.970)	(5.016)	(1.308)
Education Level	0.515	-1.070	0.929
	(0.638)	(1.023)	(0.997)
Poverty Rate	-0.414	-3.721	2.536

	(1.187)	(4.816)	(2.246)
Audit Result	0.004	-0.010	0.000
	(0.004)	(0.010)	(0.007)
COVID-19 Policy	0.040	0.112	0.069
	(0.028)	(0.062)	(0.038)
2021.Year	-0.003	0.017	0.014
	(0.022)	(0.028)	(0.028)
_cons	-0.095	0.767	-0.503
	(0.248)	(0.791)	(0.409)
N	962	920	962
p	0.146	0.001	0.000
r2	0.007	0.040	0.018

	GDP Growth Electricity and Gas	**GDP Growth Water Supply and Waste**	**GDP Growth Construction**
Internet Penetration	-0.122	0.151	-0.026
	(0.190)	(0.131)	(0.182)
COVID-19 Cases	-2.112**	-0.949	-0.833
	(0.775)	(0.707)	(1.000)
Internet Penetration * COVID-19 Cases	3.319**	1.538	1.628
	(1.205)	(1.093)	(1.347)
Education Level	-0.382	-0.701	1.301
	(0.737)	(0.704)	(1.271)
Poverty Rate	-1.086	-1.388	7.629
	(1.970)	(1.312)	(6.546)
Audit Result	-0.001	0.002	0.016
	(0.007)	(0.005)	(0.011)
COVID-19 Policy	0.011	-0.006	-0.013
	(0.031)	(0.031)	(0.034)
2021.Year	-0.037	-0.024	0.028
	(0.027)	(0.024)	(0.026)
_cons	0.353	0.312	-1.301
	(0.327)	(0.271)	(1.033)
N	942	945	962
p	0.107	0.750	0.000
r2	0.013	0.004	0.028

	GDP Growth Wholesale and Retail	**GDP Growth Transportation**	**GDP Growth Accommodation and Food Service**
Internet Penetration	0.102	-0.251	-0.098
	(0.079)	(0.158)	(0.142)
COVID-19 Cases	1.524	-2.176*	-1.240
	(1.512)	(0.961)	(0.833)
Internet Penetration * COVID-19 Cases	-1.733	2.827*	1.586

	(1.793)	(1.240)	(1.121)
Education Level	0.103	1.246	-0.543
	(0.157)	(1.179)	(0.404)
Poverty Rate	0.395	6.995	-7.071**
	(0.519)	(6.029)	(2.141)
Audit Result	0.003	0.003	0.013
	(0.003)	(0.009)	(0.013)
COVID-19 Policy	0.006	0.011	0.026
	(0.006)	(0.032)	(0.021)
2021.Year	-0.017	-0.021	0.132***
	(0.013)	(0.024)	(0.026)
_cons	-0.084	-1.009	0.853**
	(0.141)	(0.953)	(0.328)
N	962	961	962
p	0.914	0.000	0.000
r2	0.033	0.014	0.185

	GDP Growth Information and Communi-cation	**GDP Growth Financial and Insur-ance**	**GDP Growth Real Estate**
Internet Penetration	0.035	0.005	-0.131
	(0.112)	(0.150)	(0.152)
COVID-19 Cases	-0.777	-0.562	-2.076
	(1.064)	(0.831)	(1.259)
Internet Penetration * COVID-19 Cases	-0.003	1.243	2.866
	(1.307)	(1.098)	(1.526)
Education Level	-0.638	0.981	-0.005
	(0.568)	(0.957)	(0.959)
Poverty Rate	-0.145	6.037	4.457
	(0.869)	(4.921)	(3.448)
Audit Result	-0.006	0.015	0.001
	(0.006)	(0.009)	(0.007)
COVID-19 Policy	0.031	-0.008	0.016
	(0.022)	(0.029)	(0.028)
2021.Year	-0.056*	0.034	-0.008
	(0.022)	(0.024)	(0.023)
_cons	0.310	-1.047	-0.429
	(0.199)	(0.772)	(0.573)
N	954	957	962
p	0.000	0.000	0.000
r2	0.040	0.039	0.006

	GDP Growth Business	GDP Growth Education	GDP Growth Health and Social
Internet Penetration	0.923	0.145	0.242
	(0.537)	(0.185)	(0.141)
COVID-19 Cases	-2.929	0.492	0.336
	(1.885)	(1.164)	(1.072)
Internet Penetration * COVID-19 Cases	5.042	-1.031	0.081
	(2.594)	(1.477)	(1.352)
Education Level	-1.513	-0.978	1.060
	(1.725)	(0.803)	(0.639)
Poverty Rate	7.361	-5.229	1.706
	(12.087)	(3.537)	(2.028)
Audit Result	0.009	-0.007	0.012
	(0.014)	(0.006)	(0.008)
COVID-19 Policy	-0.045	0.036	0.001
	(0.074)	(0.025)	(0.023)
2021.Year	-0.045	0.001	-0.071**
	(0.071)	(0.022)	(0.024)
_cons	-0.928	0.836	-0.565
	(1.459)	(0.548)	(0.335)
N	960	962	962
p	0.000	0.586	0.001
r2	0.009	0.014	0.029

Notes: “*” indicates the estimation is significant at the 5%, “**” at the 1% level, and “***” at the 0.1% level. Robust standard errors, correcting for clustering at the districts level, are provided in parentheses.

Source: Author's calculation

Appendix 8. Impact of Internet Penetration on HDI Growth During COVID-19 by Considering Lagged Value of Dependent Variable

	HDI Growth
L.HDI	-1.043***
	(0.047)
Internet Penetration	0.002
	(0.004)
COVID-19 Cases	-0.011
	(0.014)
Internet Penetration * COVID-19 Cases	0.018
	(0.018)
Poverty Rate	-0.008
	(0.042)
Audit Result	0.000
	(0.000)
COVID-19 Policy	-0.000

	(0.000)
2021.Year	0.004***
	(0.000)
_cons	4.429***
	(0.197)
N	962
p	0.000
r2	0.740

Notes: "*" indicates the estimation is significant at the 5%, "**" at the 1% level, and "***" at the 0.1% level. Robust standard errors, correcting for clustering at the district level, are provided in parentheses.

Source: Author's calculation