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ICT and Economic Resilience during COVID-19: Cross-Country Analysis

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Abstract: The central objective of this paper is to empirically assess whether countries with better information and communication technology (ICT) infrastructure suffered less GDP growth deceleration during COVID-19. The scope of this paper is to apply linear estimation to a sample of 117 economies, including 86 emerging market and developing economies and 31 advanced economies, to analyze the relationship between ICT and GDP growth deceleration during the pandemic period. Controlling for other variables that can also influence economic performance, we find empirical support for a positive impact of ICT. For a given COVID-19 infection rate, we find that economies with better internet access showed greater resilience, defined as less in terms of economic growth. The obvious policy implication is that governments should invest more in ICT infrastructure to strengthen the resilience of their economies in the face of major shocks.

Keywords: information and communication technology; internet; GDP growth; economic resilience; COVID-19

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1. Introduction and Motivation

Information and communication are perhaps the most widely used factors of production. Information is used in the production of virtually all goods and services, and the same can be said about communication. For instance, exporters need information about exchange rates, bankers need information about interest rates, and farmers need information about the weather. Co-workers constantly communicate with each other, sellers and buyers constantly communicate with each other, and employers and employees constantly communicate with each other. Given the central role of information and communication in all economic activity, we can expect a good information and communication technology (ICT) infrastructure to have a positive impact on economy-wide productivity, rather than the productivity of a few firms or industries. In that sense, the economic impact of ICT infrastructure is like that of other infrastructure such as roads, water supply systems, and power plants.

ICT revolution, also known as the digital revolution, took off with the popularization of the internet in the 1990s even though its foundations were laid decades earlier. The main economic effect of ICT is a drastic reduction in the cost of information and communication. For example, we can communicate with anybody in the world at any time with emails or large number of other internet-based communication apps. Google and other search engines place virtually limitless information at the user's finger tips. It is difficult to overstate the dramatic effect of the sharp reduction of information and communication costs on productivity. To name just one example, in the pre-internet era, economists reviewing the literature on a particular topic went to libraries and manually searched catalogues for relevant academic works one by one. Now all economists need to do is to type in keywords in their keyboards and an online database will instantly retrieve all

relevant academic works. The time and effort used in internet search is a tiny fraction of the time and effort used in manual search.

In fact, a sizable empirical literature confirms a positive relationship between ICT and productivity. A well-known stylized fact is the acceleration of productivity growth in the US in the second half of the 1990s, which coincides with the peaking of the digital revolution. A substantial body of empirical evidence supports a causal effect of ICT on productivity. For instance, using a neoclassical analytical framework, Oliner and Sichel estimate that ICT contributed about two-thirds of the acceleration in the labor productivity of the US non-farm business sector between the first and second halves of the 1990s [1]. Similarly, Basu, Fernald, and Shapiro find that the increase in productivity growth in the late 1990s arose largely from technological progress associated with ICT [2]. They also find that ICT improved productivity in both manufacturing and non-manufacturing sectors. The balance of evidence supports a positive link between ICT and productivity growth in the US in the second half of 1990s although a few studies, most notably Gordon and Brynjolfsson, cast some doubt on the link [3,4]. Some recent studies also find a positive impact of ICT on both productivity growth, e.g., [5] and economic growth, e.g., [6].

Governments around the world have imposed lockdowns, stay-at-home orders, and other mobility-reducing restrictions to contain the spread of the coronavirus disease (COVID-19). According to Kumar et al., social distancing restrictions were more effective in containing the spread of COVID-19 than stringent lockdown measures [7]. The use of ICT has intensified in response to the various containment restrictions. ICT enables working from home, which has become much more pervasive. ICT is not a new technology and it has been around for decades. Likewise, thanks to ICT, it was possible for decades for certain groups of workers such as office workers to work from home. However, perhaps out of habit and inertia, very few workers took advantage of the opportunity to work from home. COVID-19 was a game-changer which opened the eyes of the world to the huge potential of ICT. Put differently, firms, workers and consumers had barely scratched the surface of ICT's potential before the pandemic, which forced them to shift their activities from offline to online. Offline requires the use of physical retail office, store, or space to work, sell products, or provide services that are limited to geographic locations. The online has a reduced need for such physical facilities, allowing wider geographic coverage for working and servicing the business. ICT enables office workers who cannot go their physical office to work from home instead. ICT enable shoppers who cannot go to stores and malls to shop online from home and students who cannot go to schools to take online classes. Movie aficionados are substituting Netflix for trips to the cinema, businesspeople are substituting Zoom for business trips and in-person meetings, and patients are substituting remote health care for visits to doctors.

Another clear sign of the digitalization of the economy during the pandemic is the rapid growth of digital products and services, which is reflected in the robust demand for semiconductors. Further proof comes from the strong performance of the stocks of companies like Amazon, an e-commerce giant, and Zoom, a video conferencing app. Countries are better off having economic resilience, which is the ability to limit the extent of production and consumption losses when negative events happen, and the capacity to adapt to the changing conditions to recover and thrive in the aftermath of such events. ICT mitigates the negative economic impact of mobility-reducing COVID-19 restrictions by moving economic activity from offline to online. The central role of ICT in economic activity during COVID-19 suggests that, in addition to drastically lower information and communication costs, another important economic benefit of ICT is economic resilience. However, emerging market and developing economies vary widely in their ICT infrastructure quality, proxied by per capita internet access, and they generally lag advanced economies (See Figure 1). Recent evidence also shows that while ICT capital investment has accelerated in developed countries, it has declined in developing countries, thereby worsening the digital divide [8].

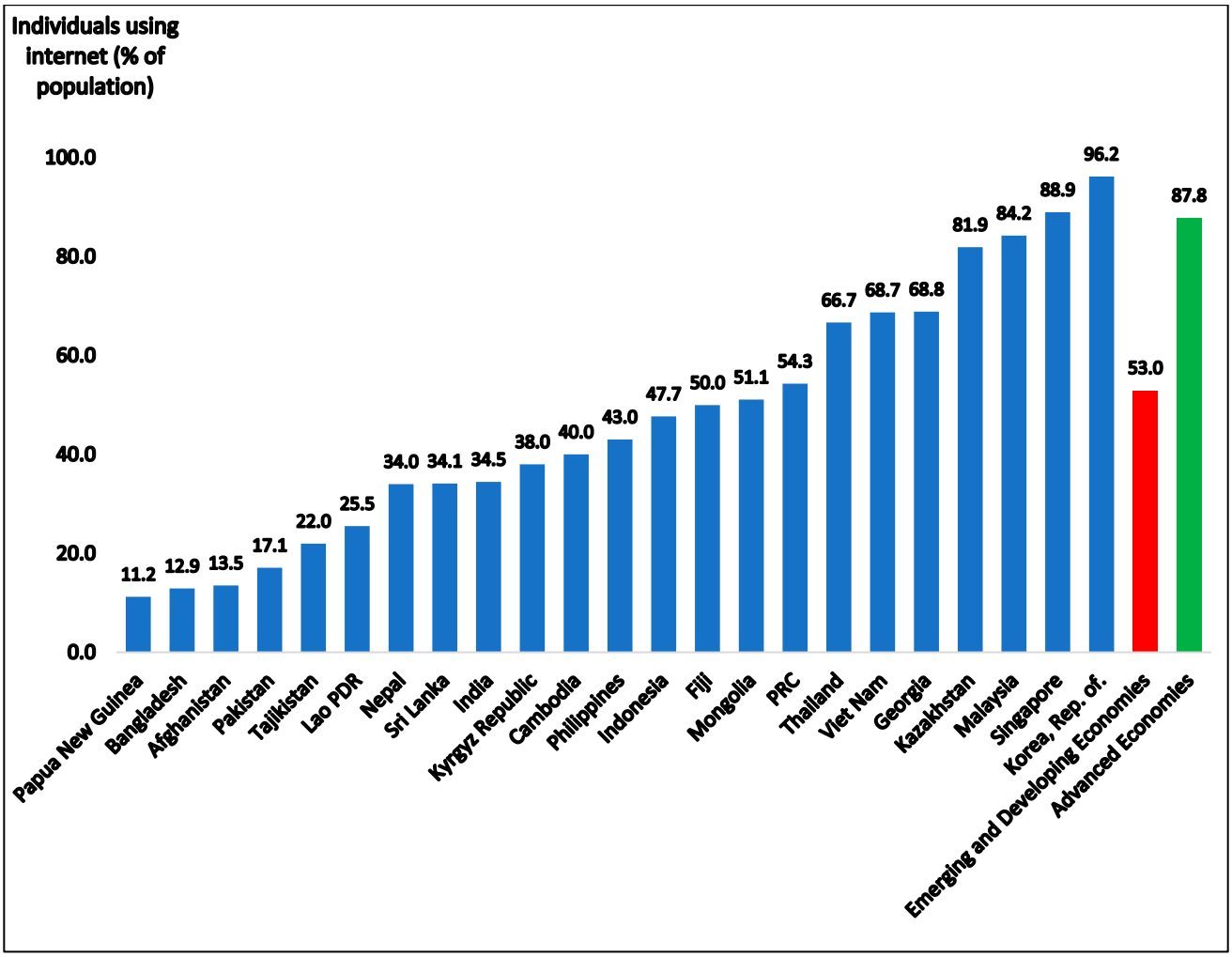

Figure 1. Share of population with internet access; Source: World Bank. https://data.worldbank.org/indicator/IT.NET.USER.ZS (accessed on 26 February 2021).

In light of the positive link between ICT and economic resilience, economies with better ICT infrastructure should have performed better during the pandemic. More generally, the quality of ICT infrastructure depends on ICT access, ICT use, and ICT skills in country [9]. In our paper, we test this intuitively plausible conjecture. Our analysis focuses on the change in growth and its forecast between the pre-pandemic period and that of the pandemic period, a measure of growth deceleration due to the pandemic crisis, as the dependent variable. The control variable of interest is ICT access, measured with the share of population using internet, as its availability and coverage allowing for the cross-country comparison. The empirical methodology is quasi-natural with the pandemic crisis as an exogenous shock. The ordinary least squares (OLS) estimation is done on a sample 117 economies. The testing hypothesis is whether ICT access is negatively associated with the growth deceleration in the cross-section of countries.

To sum up, the central objective of our paper is to empirically assess the relationship between ICT and economic resilience. The scope of our empirical analysis is to use cross-country data to see whether countries with better internet access performed better in terms of economic growth during the pandemic. Evidence of a positive effect will lend support to the notion that ICT can help economies withstand major shocks.

The rest of the paper is organized as follows. Section 2 discusses the various channels through which ICT can promote economic resilience. Section 3 selectively reviews the relevant literature. Section 4 discusses the data and empirical framework, and Section 5 reports and discusses the empirical results. Section 6 concludes the paper.

2. Channels through Which ICT Promotes Economic Resilience

There are various channels through which ICT promoted the resilience of economies during the COVID-19 pandemic periods. In this section, we discuss these channels.

2.1. Online Shopping or E-Commerce

COVID-19 has transformed online shopping from a shopping option to an indispensable tool of daily life for consumers. Without online shopping and online delivery, basic living would not have been possible for many people during lockdowns. Global e-commerce companies such as Amazon even introduced drone or robot delivery. The pandemic restricted many businesses but also created e-commerce opportunities such as online shopping and contactless delivery based on ICT. Online shopping minimized person-to-person contacted and thus the spread of COVID-19. Countries with well-developed ICT infrastructures were able to limit the negative impact of the disease on domestic consumption because a lot of consumption shifted from offline to online. Furthermore, the popularity of online shopping is likely to persist even after the pandemic recedes because many consumers discovered its convenience and safety. E-commerce has grown rapidly around the world during the pandemic [10]. The growth has varied across sectors and changed across the different stages of the pandemic. The growth of E-commerce has been especially rapid in countries that implemented stringent restrictions against mobility. China is a prime example. Global e-commerce giants such as Amazon and Alibaba can be expected to continue to invest heavily in e-commerce infrastructure.

2.2. Digital Payments

The rapid growth of online shopping or e-commerce has been accompanied by the rapid growth of digital payments. The normal functioning of an economy requires a well-functioning means of payment. In financially underdeveloped economies, cash tends to be the dominant means of payment. On the other hand, in financially more developed economies, credit cards and digital or online payments tend to play a greater role. During COVID-19, online sales replaced offline sales due to lockdowns and social distancing restrictions. In more developed economies where many consumers have credit cards and banking accounts, online purchases were paid for by digital or online payments. In this sense, contactless online payments promoted e-commerce and protected public health. Although the infrastructure for digital payment is less developed in developing countries, non-cash payments have risen in both advanced and developing countries. Estimates from McKinsey indicate that the number of non-cash transactions across the globe grew by 6% from 2019 to 2020. Moreover, McKinsey finds that the pandemic has accelerated the decline in cash usage, particularly in key markets like Indonesia and Thailand [11]. To some extent, this can be explained by the rapid growth of digital credit transfers, which are also available to consumers without banking accounts or credit cards, across the world during the pandemic. Finally, digital payment served as an important tool for transferring payments to households hit hard by the pandemic. Key examples include the distribution of consumption coupons via Alipay and WeChat Pay in the PRC, the PromptPay system in Thailand, the "JAM (Jan Dhan-Aadhaar-Mobile) Trinity" system in India, and "Bono COVID-19" in Chile [12]. Such fiscal stimulus, in turn, helped to keep economies afloat. Studies by Agur, Martinez Peria, and Rochon, as well as Una et al. have shown that the public sector use of digital payments tends to be more transparent, less costly, and better at identifying and targeting intended beneficiaries [13,14]. Thus, ICT enabled the effective delivery of public services.

2.3. Remote Work

Since the outbreak of COVID-19, a significant part of the global workforce worked from their homes rather than commuted to and from their offices. What made this drastic transformation of working arrangements possible was information and communication technology (ICT). The drastic reduction in the cost of information and communication due

to ICT enabled workers to continue to work as a team, constantly informing each other and communicating with each other via the internet. Remote work facilitates flexibility in the labor markets, in which firms can hire workers on a short-term, on-call basis by contracting out tasks at a relatively low cost (employer-driven) and, at the same, enables workers to have control over their workplace or schedule (employee-driven) [15]. Working from home or remote working was available for decades since ICT was available for decades but it was vastly under-utilized, perhaps due to the sheer force of inertia or doing things the same way for the sake of doing things the same way. However, the pandemic has been a game-changing catalyst because it forced many workers, especially office workers, to work remotely since lockdowns and social distancing restrictions prevented them from going to office. In other words, working from home replaced physical commuting as the default working arrangement out of necessity amid stringent restrictions against mobility and human contact. However, many workers, especially blue-collar workers, did not have the option of remote working home and remained more vulnerable. Virtual meeting apps such as Zoom and Teams facilitated online meetings and reduced the need for business travel.

2.4. Distance Learning

Schools around the world were shut down during the early phases of COVID-19. According to the IMF, as of mid-April of 2020, 191 countries announced or implemented school or university shutdown, affecting 1.57 billion students [16]. The pandemic thus disrupted the learning and education of a huge number of students, with damaging consequences for their well-being and future productivity. However, ICT enabled students to continue their education via the internet even though they were unable to go to school and interact with their teachers and classmates. While the lack of such interaction may adversely the quality of education, ICT and the availability of distance learning has meant the difference between education and no education at all. Technologies needed for distant learning are quite similar to those for remote work but also include virtual reality, augmented reality, artificial-intelligence-enabled robot teachers and 3D printing. There is plenty of scope for improving the quality of distance learning, including investment in the digital technology infrastructure to enhance the speed and reliability of the internet connection. There is also a need to expand internet access to students from poor households so that they are not disadvantaged. Nevertheless, ICT-enabled distance learning has allowed students to continue accumulating human capital even during an unprecedented global health crisis.

While technology enabled schools to continue operating during the pandemic, a key issue is that education systems around the world have diverse capacities to respond to the crisis through remote learning. UNICEF reviews the implications on remote learning from global school closures during the COVID-19 pandemic [17]. Its study combines a review of global literature on remote learning with analysis of data at the global, regional, and country levels. It finds that even short disruptions in children's schooling can have acute and long-lasting effects on their learning and well-being. In the same vein, the ADB estimates that school closures during the COVID-19 led to losses equivalent to over half a year's worth of learning [18]. Children from low-income households are the most disadvantaged as they have less access to quality remote education, are more exposed to economic hardship during the pandemic, and have a greater likelihood to drop out of schools.

2.5. Telehealth and Online Entertainment

Lockdowns and social distancing restrictions prevented many non-COVID patients from visiting hospitals during the height of the COVID-19 crisis. Given that containing the pandemic became the overriding priority of public health authorities, even patients suffering from serious diseases were not allowed to visit medical facilities. Once again, ICT came to the rescue. Telemedicine, or the remote diagnosis and treatment of patients by means of ICT, enabled the sick to receive at least basic medical care during the pandemic. Estimates by Bestsennyy et al. indicate that telehealth use in the United States has increased

38 times from the pre-COVID-19 baseline [19]. Telehealth refers to the entire spectrum of activities used to deliver care at a distance, and includes e-consult, remote patient monitoring, patient-initiated messaging, asynchronous patient portal messaging, and telephone or video visit [20]. Other categories of telehealth and digital care include sensor devices such as Global Positioning System (GPS) that notifies users to avoid potentially high level COVID-19 locations and virtual agents (Chatbots) that provide quick responses to health questions and connect quarantined patients to available physicians [21]. Telehealth contributed to economic resilience by safeguarding public health in the face of mobility restrictions, which prevented in-person consultations. Online entertainment is yet another significant channel through which ICT contributed to economic resilience. Leisure is a key component of a healthy work–life balance, which, in turn, contributes to a more productive workforce. The popularity of movie streaming services such as Netflix attests to a broader trend of consumers replacing offline entertainment with online entertainment. The tangible increase in online gaming is another example of the popularity of online entertainment during the pandemic. ICT has not only provided entertainment for consumers but it has also supported the resilience of the leisure industry, which accounts for a non-trivial share of the economy.

2.6. 5G Information Technology

All of the above channels through which ICT can promote the resilience of firms, households, and the economy as a whole depends on stable, reliable, and speedy internet connections which can be accessed from anywhere. In this connection, the recent emergence of 5G information technology is both promising and challenging. It is promising because it will bring about faster and better connectivity, but it is challenging, especially for developing countries, because it requires costly investment. 5G refers to the fifth-generation technology standards for broadband cellular networks. In 2019 telecom companies around the world began to deploy the technology, which will be the successor to the 4G networks that currently provide connectivity to most cellphones. The benefits of 5G will be felt across the spectrum of the healthcare value chain, from health-care providers to insurance companies, government institutions that pay for health services, and pharmaceutical companies, ultimately benefitting patients [22]. During the COVID-19 lockdowns, 5G has proven its efficiency in remote health monitoring and health care consultation. Expanded use of 5G will promote more inclusive access to the internet but the large cost of building 5G networks is a difficult challenge that policymakers must address.

COVID-19 demonstrated the importance of digital readiness, which allows business and life to continue as usual—as much as possible—during pandemics. Building the infrastructure which is required to support a digitized economy and capitalize on the latest technology will be essential for any business or country seeking to remain competitive in a post-COVID-19 world. In addition, an upgraded ICT infrastructure is a pre-condition for a human-oriented and inclusive approach to ICT governance. The pandemic had an outsized impact on global healthcare and, more generally, economies and societies. High-quality internet connectivity played a central role in ubiquitous and accessible digital medical services during the pandemic. Its role will become even more important in the post-pandemic era when societies must re-double their efforts to be prepared for pandemic outbreaks. To sum up, 5G networks and 5G-enabled e-health services will remain vital for a resilient public health system which, in turn, is vital for a resilient economy and society.

2.7. Supply Chain 4.0, 3D Printing, Robotics and Drones, and Other ICT-Enabled Technologies of the 4th Industrial Revolution

In addition to the various channels through with ICT directly contributes to economic resilience, there are a number of indirect channels through which ICT promotes resilience via its enabling role in the state-of-the-art technologies of the 4th Industrial Revolution. COVID-19 highlighted the risk of relying on distant global supply chains. Production disruptions in any single location can shut down the entire supply chain. However, greater

digitalization of the supply chain was put forth as a potential mechanism to improve the robustness of supply chains. In particular, ICT-enabled 4th Industrial Revolution technologies such as Big Data, cloud computing, Internet-of-Things, and blockchain can contribute to building more resilient supply chains by enhancing the accuracy of data and promoting data sharing. More generally, they improve cost competitiveness and logistics efficiency. 3D printing made significant contributions to health care during COVID-19 [23]. More specifically, the technology enabled quick production of medical devices like personal protection equipment (PPE), ventilators, specimen collectors, safety accessories, and isolation wards in the face of rapid escalation of demand during the pandemic's peak. Robots and drones were used to deliver services without human contact during COVID-19. Contactless delivery helped to reduce the spread of the disease. For instance, robots were used to sanitize buildings and deliver food to individuals under quarantine. Drones and walking machines, for their part, were used to deliver food and other items to homes.

To sum up, ICT promoted the resilience of firms, households, and the entire economy through a number of different channels. ICT helped to keep economies and societies stay afloat during COVID-19 by shifting economic, social, and other human activity from offline to online. Some channels, for instance online shipping, contributed directly to economic resilience. Other channels contributed indirectly. For instance, online healthcare played a key role in helping individuals keep healthy during the pandemic. Furthermore, it prevented the healthcare system from becoming overwhelmed and precipitating a health crisis, which would have had negative economic repercussions. Collectively, the various ICT channels were indispensable for mitigating the negative economic impact of COVID-19.

3. ICT and Economic Resilience: A Selective Literature Review

Various studies have shown that ICT drives economic growth by reducing the cost of information, accelerating communication, and harnessing innovation. Drawing on estimates from 59 econometric studies, Stanley, Doucouliagos, and Steel concluded that ICT has contributed positively to economic growth for both developed and developing countries [24]. While there is relatively large evidence on ICT's impact on economic performance, there is a dearth of research studies that explore ICT's contribution in mitigating the adverse impact of a pandemic on economic performance using econometric models. There are only a few studies that examine the hypothesis of whether economies with better connectivity experience less economic damage during a pandemic.

As discussed in the preceding section, there are various mechanisms by which ICT can promote economic resilience. Greater access to ICT is expected to moderate economic loss as it enables businesses to continue operating via e-commerce, facilitates financial transactions through digital payments, enables individuals to continue working even during lockdowns through remote work, and supports well-being through digital health services and social interactions. This section reviews some studies that have touched upon these mechanisms, including some nuances. More fundamentally, this section also draws on a limited set of literature that estimates the link between ICT and GDP resilience during the pandemic, which is akin to the approach taken in this paper.

While the pandemic restricted the operations of businesses, this has been mitigated by the shift to e-commerce. Revenues from business activities are expected to have declined less due to the acceleration of e-commerce. Surveys done by UNCTAD confirm that that there has been a rapid growth of e-commerce around the world, with China and Turkey having the highest rate of expansion in online shopping [10]. The surveys done by UNCTAD indicate that e-commerce is likely to continue to grow rapidly in the post-COVID era, supported by the structural shift of consumer preferences toward online shopping in many societies.

ICT is also expected to mitigate the adverse impact of the pandemic on international trade since e-commerce is not just limited to domestic transactions. It also takes place via cross-border transactions, through consumer purchases of imported goods as well as through online international business-to-business (B2B) transactions. Hayakawa,

Mukunoki, and Urata empirically investigate the moderating effect of e-commerce on the trade impacts of COVID-19 [25]. They estimate gravity equations for bilateral trade among 34 reporting countries and their 145 partner countries during 2019 and 2020. While they show that larger number of confirmed cases or deaths countries have significantly reduced international trade, they also find that e-commerce of importing countries have significantly mitigated the negative effects of COVID-19 on trade.

ICT has helped cushion the ill economic effects of the pandemic, by supporting employment through work from home arrangements. However, there are issues about the impact on productivity. Morikawa finds that mean work from home productivity is only 60–70% of the productivity at the usual workplace [26]. Productivity is also lower for employees and firms that have started the work from home setup only after the spread of the COVID-19 pandemic. Results from the study also show a large dispersion in work from productivity by individual and firm characteristics, with highly educated and high-wage workers having a small reduction in work from home productivity. In the same vein, Kitagawa et al. found declines in productivity under a work from home set up [27]. Despite the lower productivity, much more economic losses would have occurred if it were not for the online work opportunities.

ICT has contributed to economic resilience by making basic health services accessible to the workforce despite mobility restrictions. The study of Patel et al. highlights the potential benefits from telehealth services, such as more efficient care management, lower costs, the ability to examine patients within their homes while involving caretakers in medical decisions, maintaining social distancing, and greater patient satisfaction [28]. Further on how ICT is supporting health care, the study of Wang et al. study shows that COVID-19 has extensively increased research on the integration of digital technologies and health care [29]. In the case of China, an important factor in its success in fighting COVID-19 is the large-scale integration of digital technologies and public health.

Another avenue by which ICT has helped promote resilience during the pandemic is enhancing people's well-being by facilitating interaction through social media. Using structured interviews among a group of high school students in central Slovak Republic (formerly Czechoslovakia), the study of Tkáčová et al. confirms that the use of social media during the pandemic has contributed significantly to well-being [30]. This happens when social media are used as a tool to promote personal interests, motivation, communication and interpersonal connectivity, online education, and online games.

As earlier stated, there is limited empirical evidence that examines the link between ICT and GDP resilience during a pandemic. One empirical study is by Katz, Jung, and Callorda, which has been done in the context of SARs in 2003. It finds that among countries that were affected by the SARs outbreak, those with better broadband infrastructure were able to counteract part of the negative economic impact [31].

In a more recent study, Katz and Jung examine the impact of fixed and mobile broadband use in mitigating COVID-19 induced economic disruption using data for 139 countries [8]. Their study utilizes structural models, in which COVID prevalence and its interaction with broadband connectivity are introduced in the aggregate production function. Their study shows that countries having better broadband infrastructure were able to mitigate part of the negative economic impact. In countries where only less than 30% of households have fixed broadband, a 1% increase in COVID-19-related deaths per 100 population led to a contraction in GDP per capita of −0.024%. In countries where fixed broadband penetration is between 30% and 90%, the corresponding contraction in GDP is −0.021%, and consequently, 15% of the economic loss faced by less-connected economics is mitigated. Countries with more than 90% broadband penetration have the least economic impact, at –0.019%, and 21% of the economic damage is mitigated for countries with the least connectivity.

Another recent study by Papaioannou analyzed the role of ICT in a country's economic resilience during COVID-19 [32]. The study uses the cyclical component of GDP to measure resilience and finds that economic losses during the pandemic varied across Euro-

pean countries, depending on ICT intensity. Estimates from difference in differences and propensity score matching technique show that countries with higher internet connectivity experienced lower economic losses.

Empirical studies on how ICT has mitigated economic losses at the firm-level are also quite limited. One fairly new study is by Abidi, Herradi, and Sakha that used a sample of firms in the Middle East and Central Asia region and applied a difference-in-difference approach to examine the effect of an index of digitalization on firm revenues [33]. They find that digitally enabled firms experience a drop in sales that is about 4 percentage points lower compared to digitally constrained firms. Their findings underscore the importance of closing the digital divide to boost resilience of firms.

This paper contributes to the scant literature that quantifies the contribution of ICT in economic resilience, by using a different relevant measure of economic disruption, particularly, growth deceleration, applied over a wide set of countries. The topic is an under-researched area that deserves to be deeply explored to strengthen the case for stronger ICT investment and reforms, especially in developing countries.

4. Data and Empirical Framework

In this section, we discuss the data and empirical framework used for our empirical analysis. Basically, we run an OLS (ordinary least squares) regression on a cross-section of countries. The key dependent variable is the size of the economic damage that a country suffered during 2020, which is proxied by the deceleration of GDP growth. The deceleration is measured in two ways: (1) the gap between actual 2019 GDP growth and October 2019 forecast of 2020 GDP growth, and (2) the gap between October 2019 forecast of 2020 GDP growth and October 2020 forecast of 2020 GDP growth.

The key independent variables are a country's (1) ICT infrastructure, which is proxied by internet access per 100 people, (2) prevalence of COVID-19, which is proxied by the number of COVID-19 cases per 100 people, and (3) interaction between the two. Intuitively, better internet access should reduce GDP growth deceleration and higher COVID-19 prevalence should exacerbate GDP growth deceleration. For any given level of COVID-19 prevalence, better internet access should reduce the economic damage from the pandemic. This is captured by the interaction term. In addition, we include a number of control variables which may also influence the size of the economic damage. Therefore, our basic empirical specification is

$$GDP\_Dec_i = \alpha + \beta_1\, ICT_i + \beta_2\, COVID_i + \beta_3\, ICT_i * COVID_i + \beta_4\, X_i \quad (1)$$

where GDP_Dec_i is GDP deceleration of country i, ICT_i is internet access per 100 people in country i, $COVID_i$ is cumulative number of COVID-19 cases per population in country i, and X_i is a vector of control variables.

The control variables include two COVID-19-related variables. One is mobility reduction, which refers to the reduction in movement of people due restrictions imposed to contain the pandemic. The other is stringency index, which measures the stringency of a country's containment restrictions. Intuitively, higher values of both variables will exacerbate the economic damage from COVID-19. In addition, we include three control variables related to a country's economic profile, namely past GDP growth rate, trade openness, and share of services in GDP. Faster past growth reflects stronger growth momentum, which is likely to mitigate the negative economic impact of the pandemic. Trade openness will amplify the impact since the pandemic disrupted global trade. Services share too may amplify the impact since many services are directly affected by containment restrictions—e.g., restaurants. Table 1 below summarizes the variables, the predicted direction of their effect, and data sources.

Table 1. Dependent and independent variables.

Variable	Description	Predicted Sign	Data Source
Dependent variables			
GDP growth deceleration 1	Actual 2019 growth-2020 growth forecast		IMF WEO October 2020
GDP growth deceleration 2	2020 growth forecast (Oct 2019)—2020 growth forecast (Oct 2020)		IMF WEO October 2020 and WEO October 2019
Independent variables			
Key independent variables—COVID-19 prevalence and ICT			
COVID-19 prevalence	Total cumulative COVID-19 infections/population	(+)	WHO
ICT	Share of population using the internet	(−)	World Bank's WDI
Control variables			
Mobility reduction	Reduction in movement of people due to lockdowns, stay-at-home orders, and other social restrictions to contain COVID-19	(+)	Google
Stringency index	Stringency of containment measures	(+)	Oxford data in CSV from the GitHub
Trade openness	Trade as percent of GDP	(+)	World Bank's WDI
Services share	Share of services in GDP	(+)	World Bank's WDI
Past GDP per capita growth	Average GDP per capita growth (2000–2019)	(−)	World Bank's WDI

GDP = gross domestic product; ICT = information and communication technology; IMF = International Monetary Fund; WDI = World Development Indicators; WEO = World Economic Outlook; WHO = World Health Organization. Notes: A positive predicted sign means that the independent variable is likely to increase the economic damage from COVID-19. A negative predicted sign means that the independent variable is likely to reduce the economic damage from COVID-19. Source: Authors' compilation.

Countries in our sample are listed in Table 2 by quartile of internet access—i.e., share of population that uses the internet. The 117 economies cover all income groups and geographical regions. As expected, a larger share of the population has access to internet in richer countries.

Table 2. Countries grouped by ICT level quartile.

Quartile of Internet Access (% of Population)			
1st	**2nd**	**3rd**	**4th**
Afghanistan	Belize	Argentina	Australia
Angola	Bolivia	Belarus	Austria
Bangladesh	Botswana	Bosnia and Herzegovina	Bahrain
Benin	Brazil	Chile	Belgium
Burkina Faso	Bulgaria	Costa Rica	Canada
Cambodia	Cabo Verde	Croatia	Denmark
Cameroon	China	Czech Republic	Estonia
El Salvador	Colombia	Dominican Republic	Finland
Ghana	Ecuador	France	Germany
Haiti	Egypt, Arab Rep.	Georgia	Ireland
Honduras	Fiji	Greece	Israel
India	Gabon	Hungary	Japan

Table 2. *Cont.*

Quartile of Internet Access (% of Population)			
1st	**2nd**	**3rd**	**4th**
Kenya	Guatemala	Italy	Korea, Rep.
Kyrgyz Republic	Indonesia	Kazakhstan	Kuwait
Lao PDR	Iraq	Lebanon	Latvia
Mali	Jamaica	Lithuania	Luxembourg
Mozambique	Jordan	Malaysia	Netherlands
Nepal	Mauritius	Mexico	New Zealand
Nicaragua	Mongolia	Morocco	Norway
Niger	Namibia	Poland	Oman
Pakistan	Nigeria	Portugal	Qatar
Papua New Guinea	Panama	Romania	Saudi Arabia
Rwanda	Paraguay	Russian Federation	Singapore
Sri Lanka	Peru	Serbia	Spain
Tajikistan	Philippines	Slovak Republic	Sweden
Togo	Senegal	Slovenia	Switzerland
Uganda	South Africa	Trinidad and Tobago	United Arab Emirates
Yemen, Rep.	Thailand	Turkey	United Kingdom
Zambia	Vietnam	Uruguay	United States
Zimbabwe			

Note: 1st quartile is lowest ICT level and 4th quartile is highest ICT level. Source: Authors' compilation.

5. Empirical Results

This section reports and discusses the results of our empirical analysis. We perform cross-country empirical analysis of 117 economies (86 emerging market and developing economies and 31 advanced economies using a linear estimation to test our central hypothesis—i.e., that economies with better internet access fared better during COVID-19 since ICT mitigates the adverse effect of lockdowns and other restrictions on economic activity. To capture the adverse effect, we construct two measures of the deceleration of GDP growth in 2020, and these are our dependent variables. Our independent variables of interest are internet access per capita, which is our proxy for the quality of a country's ICT infrastructure and its interaction with COVID-19 prevalence, another key variable.

5.1. Descriptive Analysis

This sub-section provides the descriptive analysis of the data that was used for the empirical analysis. Tables 3–5 provide the summary statistics of the whole sample, the advanced economy sub-sample, and the developing economy sub-sample, respectively. For all three tables, 0.1 shows the summary statistics of all key variables. For each internet access quartile, 0.2 shows COVID-19 prevalence, 0.3 shows mobility reduction, and 0.4 shows Stringency Index.

Table 3. Summary statistics for whole sample (117 economies).

Variable	Mean	Std. Dev.	Min	Max
GDP growth deceleration 1	8.15	3.48	1.66	19.70
GDP growth deceleration 2	8.75	3.93	2.32	25.86
COVID-19 prevalence	0.02	0.02	0.00	0.07
Mobility reduction	17.02	20.14	−43.47	58.37
Stringency Index	50.51	11.38	9.68	72.69
Internet access	62.20	27.21	5.25	99.70
Trade openness	0.87	0.60	0.00	3.64
Past GDP per capita growth	2.39	1.79	−2.51	8.43
Services share	55.98	10.17	18.10	79.16

Table 3. *Cont.*

COVID-19 prevalence based on ICT level					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	30	0.0023	0.0035	0.000006	0.0124
2	29	0.01	0.01	0.000015	0.052673
3	29	0.03	0.02	0.003179	0.062313
4	29	0.03	0.02	0.000360	0.073353
Mobility reduction based on ICT level					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	30	19.07	14.92	−2.05	55.77
2	29	24.29	20.96	−43.47	58.37
3	29	16.41	19.54	−21.16	57.86
4	29	8.26	22.13	−28.84	51.91
Stringency Index based on ICT level					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	30	47.49	14.36	9.68	72.69
2	29	55.77	9.43	29.89	68.79
3	29	50.61	10.54	13.05	70.61
4	29	48.28	8.90	31.19	64.45

GDP = gross domestic product. ICT = information and communication technology. Source: Authors' estimates.

Table 4. Summary statistics for 31 advanced economies.

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
GDP growth deceleration 1	8.257	2.496	3.920	14.810
GDP growth deceleration 2	8.221	2.425	4.100	14.680
COVID-19 prevalence	0.030	0.020	0.000	0.073
Mobility reduction	2.357	18.044	−28.840	29.490
Stringency Index	46.482	7.372	31.186	56.155
Internet access	87.825	6.310	74.387	98.046
Trade openness	1.195	0.817	0.310	3.640
Past GDP per capita growth	1.870	1.369	0.116	5.425
Services share	65.522	5.765	56.606	79.158
COVID-19 prevalence based on ICT level for advanced economies				
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	8	0.039	0.015	0.013	0.062
2	8	0.024	0.020	0.001	0.056
3	8	0.022	0.019	0.0004	0.055
4	7	0.034	0.025	0.001	0.073
Mobility reduction based on ICT level for advanced economies					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	8	3.611	13.747	−21.160	26.030
2	8	9.218	13.369	−15.950	24.660
3	8	7.306	22.334	−27.210	29.490
4	7	−12.573	16.109	−28.840	10.500

Table 4. *Cont.*

Stringency Index based on ICT level for advanced economies					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	8	48.401	5.911	42.283	56.084
2	8	48.230	8.468	32.095	56.155
3	8	45.975	9.622	31.186	55.380
4	7	42.871	3.845	37.697	47.092

GDP = gross domestic product. Source: Authors' estimates. ICT = information and communication technology.

Table 5. Summary statistics for 86 emerging market and developing economies.

Variable	Mean	Std. Dev.	Min	Max
GDP growth deceleration 1	8.12	3.78	1.66	19.70
GDP growth deceleration 2	8.94	4.35	2.32	25.86
COVID-19 prevalence	0.01	0.02	0.00	0.06
Mobility reduction	22.31	18.22	−43.47	58.37
Stringency Index	51.96	12.23	9.68	72.69
Internet access	52.96	25.89	5.25	99.70
Trade openness	0.75	0.45	0.00	2.76
Past GDP per capita growth	2.58	1.89	−2.51	8.43
Services share	52.54	9.18	18.10	78.85
COVID-19 prevalence based on ICT level for emerging market and developing economies				
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	22	0.00	0.0025293	0.00001	0.012151
2	21	0.01	0.0067081	0.000022	0.026873
3	22	0.02	0.0165991	0.000015	0.058791
4	21	0.03	0.0158191	0.003179	0.055633
Mobility reduction based on ICT level for emerging market and developing economies					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	22	16.17	13.68	−2.05	50.84
2	21	21.27	21.64	−43.47	55.77
3	22	28.78	17.06	−2.71	58.37
4	21	23.01	18.73	−9.91	57.86
Stringency Index based on ICT level for emerging market and developing economies					
Internet access quartile	**Numbers of observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	22	45.51	14.86	9.68	72.69
2	21	55.10	10.19	35.38	68.79
3	22	55.27	9.35	29.89	70.61
4	21	52.13	11.81	13.05	64.45

GDP = gross domestic product. Source: Authors' estimates. ICT = information and communication technology.

5.2. Estimation Results

Table 6 reports the estimation results, focusing on the variables of interest, namely COVID-19 prevalence and the interaction of internet access and COVID-19 prevalence. The results indicate that COVID-19 prevalence decelerated growth while greater internet access mitigated the negative growth impact of the pandemic in countries where the pandemic was more prevalent.

Table 6. Internet access and GDP growth deceleration during COVID-19.

	Dependent Variables	
Independent Variables	**Actual 2019 Growth—2020 Growth Forecast (October 20)**	**2020 Growth Forecast (October 19)—2020 Growth Forecast (October 20)**
COVID-19 prevalence	314.3 *** (85.09)	328.0 *** (90.03)
Internet access * COVID-19 prevalence	−3.541 *** (0.955)	−3.898 *** (1.021)
Numbers of observations	117	
R^2	0.251	0.291

Notes: The figures in parentheses are robust standard errors. * $p < 0.05$ and *** $p < 0.001$. COVID-19 prevalence is the total cumulative COVID-19 infections/population. Source: Authors' estimates.

Please refer to Tables 7–9 for estimation results for full country sample, advanced economies, and emerging markets and developing economies, respectively. In addition to the variables of interest, we include all control variables to better identify the impact of internet access on economic growth deceleration during COVID-19. Our central result—that internet access mitigates the negative growth impact of the pandemic in countries where the pandemic is more prevalent—still stand for the full country samples and the subsample of emerging markets and developing countries. The results are discussed in greater detail below.

Table 7. Estimation results for the full country sample.

Model	**<1-1>**	**<1-2>**	**<1-3>**	**<2-1>**	**<2-2>**	**<2-3>**
Independent Variables	**Dependent Variables**					
	Actual 2019 Growth—2020 Growth Forecast			**2020 Growth Forecast (October 2019)—2020 Growth Forecast (October 2020)**		
COVID-19 prevalence	314.3 *** (85.09)	23.06 (20.80)	22.56 (21.17)	328.0 *** (90.03)	7.14 (23.97)	5.59 (24.77)
Mobility reduction	0.01 (0.0178)	−0.01 (0.0460)	0.03 (0.0176)	0.02 (0.0178)	−0.03 (0.0492)	0.03 (0.0182
Stringency Index	0.04 (0.0357)	0.06 (0.0363)	0.04 (0.0653)	0.06 (0.0324)	0.0750 * (0.0322)	0.03 (0.0607)
Internet access	0.00 (0.0141)	−0.02 (0.0170)	−0.03 (0.0429)	0.00 (0.0142)	−0.0365 * (0.0180)	−0.06 (0.0483)
Trade openness	0.62 (0.504)	0.42 (0.585)	0.46 (0.585)	0.77 (0.601)	0.54 (0.691)	0.62 (0.707)
Past GDP per capita growth	−0.13 (0.177)	0.07 (0.181)	0.06 (0.177)	−0.482 * (0.202)	−0.24 (0.193)	−0.26 (0.188)
Services share	0.07 (0.0421)	0.102 * (0.0483)	0.0974 * (0.0464)	0.102 * (0.0514)	0.138* (0.0582)	0.131 * (0.0574)
Internet access * COVID-19 prevalence	−3.541 *** (0.955)			−3.898 *** (1.021)		
Internet access * Mobility reduction		0.000491 (0.000550)			0.000862 (0.000601)	
Internet access * Stringency Index			0.000307 (0.000890)			0.000749 (0.000975)
Constant	0.80 (2.130)	−0.20 (2.347)	0.31 (2.865)	0.17 (2.254)	−0.89 (2.488)	0.39 (2.581)
Numbers of observations	117					
R^2	0.251	0.191	0.188	0.291	0.24	0.233

GDP = gross domestic product. Notes: Figures in parentheses are robust standard errors. * $p < 0.05$ *** $p < 0.001$. Source: Authors' estimates.

Table 8. Estimation results for advanced economies.

Model	**<1-1>**	**<1-2>**	**<1-3>**	**<2-1>**	**<2-2>**	**<2-3>**
Independent Variables	**Dependent Variables**					
	Actual 2019 Growth—2020 Growth Forecast			**2020 Growth Forecast (October 2019)—2020 Growth Forecast (October 2020)**		
COVID-19 prevalence	−498.80 (403.3)	28.57 (22.02)	30.59 (23.03)	−370.60 (456.0)	25.82 (20.11)	28.52 (22.40)
Mobility reduction	0.04 (0.0306)	−0.13 (0.392)	0.04 (0.0282)	0.04 (0.0319)	−0.30 (0.369)	0.04 (0.0293)
Stringency Index	0.07 (0.0712)	0.06 (0.0732)	0.25 (0.811)	0.05 (0.0728)	0.05 (0.0677)	0.08 (0.775)
Internet access	−0.280* (0.111)	−0.12 (0.0771)	−0.01 (0.465)	−0.23 (0.134)	−0.11 (0.0727)	−0.09 (0.440)
Trade openness	−0.65 (0.703)	−0.20 (0.692)	−0.29 (0.746)	−0.55 (0.706)	−0.16 (0.659)	−0.26 (0.713)
Past GDP per capita growth	0.11 (0.394)	−0.11 (0.494)	0.02 (0.532)	−0.18 (0.429)	−0.44 (0.499)	−0.27 (0.535)
Services share	−0.08 (0.120)	0.00 (0.101)	0.01 (0.0856)	−0.06 (0.140)	−0.03 (0.100)	0.00 (0.0909)
Internet access * COVID-19 prevalence	6.06 (4.577)			4.57 (5.160)		
Internet access * Mobility reduction		0.00182 (0.00441)			0.00372 (0.00412)	
Internet access * Stringency Index			−0.00232 (0.00952)			−0.000513 (0.00878)
Constant	34.36 * (15.51)	16.14 (7.899)	5.25 (41.84)	30.16 (18.24)	17.47 * (7.576)	13.57 (40.32)
Numbers of observations	31					
R^2	0.462	0.431	0.428	0.453	0.45	0.432

GDP = gross domestic product. Notes: Figures in parentheses are robust standard errors. * $p < 0.05$. Source: Authors' estimates.

Table 9. Estimation results for emerging markets and developing economies.

Model	**<1-1>**	**<1-2>**	**<1-3>**	**<2-1>**	**<2-2>**	**<2-3>**
Independent variables	**Dependent Variables**					
	Actual 2019 Growth—2020 Growth Forecast			**2020 Growth Forecast (October 2019)—2020 Growth Forecast (October 2020)**		
COVID-19 prevalence	325.1 ** (113.0)	21.76 (32.28)	21.09 (32.49)	285.4 * (122.1)	2.636 (34.51)	−0.297 (35.22)
Mobility reduction	0.00269 (0.0259)	0.00628 (0.0511)	0.0186 (0.0265)	−0.000589 (0.0270)	−0.0257 (0.0507)	0.0134 (0.0280)
Stringency Index	0.0389 (0.0413)	0.0518 (0.0427)	0.0407 (0.0703)	0.0565 (0.0352)	0.0705 * (0.0342)	0.0245 (0.0600)
Internet access	0.0136 (0.0199)	−0.0215 (0.0222)	−0.0280 (0.0545)	0.00861 (0.0191)	−0.0350 (0.0202)	−0.0674 (0.0520)
Trade openness	1.112 (0.859)	1.550 (0.910)	1.547 (0.945)	1.487 (0.921)	1.969 * (0.956)	1.990 (1.028)
Past GDP per capita growth	−0.161 (0.213)	−0.00380 (0.234)	−0.00989 (0.224)	−0.598 * (0.253)	−0.422 (0.267)	−0.435 (0.252)
Services share	0.0793 (0.0684)	0.123 (0.0670)	0.123 (0.0661)	0.157 (0.0816)	0.202 * (0.0792)	0.205 * (0.0795)
Internet access * COVID-19 prevalence	−3.960 ** (1.283)			−3.688 * (1.406)		

Table 9. *Cont.*

Model	<1-1>	<1-2>	<1-3>	<2-1>	<2-2>	<2-3>
Independent variables	**Dependent Variables**					
	Actual 2019 Growth—2020 Growth Forecast			**2020 Growth Forecast (October 2019)—2020 Growth Forecast (October 2020)**		
Internet access * Mobility reduction		0.000222 (0.000747)			0.000708 (0.000769)	
Internet access * Stringency Index			0.000224 (0.00106)			0.000942 (0.00102)
Constant	0.215 (2.957)	−1.770 (3.122)	−1.447 (3.566)	−2.500 (3.391)	−4.245 (3.443)	−2.840 (3.362)
Numbers of observations	86					
R^2	0.259	0.204	0.204	0.328	0.295	0.295

GDP = gross domestic product. Notes: Figures in parentheses are robust standard errors. * $p < 0.05$; ** $p < 0.01$. Source: Authors' estimates.

5.3. Discussion

This sub-section discusses the empirical results. Predictably, COVID-19 prevalence had a significant exacerbating effect on the GDP growth deceleration. Countries that had bigger pandemic outbreaks suffered bigger economic downturns (see Tables 7 and 9). As presented Tables 7–9, except one case of estimation result of advanced economy at Table 8, Internet access, our key variable of interest, is not statistically associated with GDP growth deceleration during COVID-19.

However, the interaction term between internet access and COVID-19 prevalence reduces GDP growth deceleration, and the effect is statistically significant for the full country sample at Table 7 and the sample of emerging markets and developing economies at Table 9. For any given level of COVID-19 prevalence, greater internet access will reduce the economic damage from COVID-19. The deceleration in GDP growth between 2019 and 2020, evaluated at the average COVID-19 prevalence (0.02), due to having a one standard-deviation increase (27.2) in the share in the population with internet access, is lower by $3.5 \times 27.2 \times 0.02 = 1.90$ percentage points for the full country sample (column 1, Table 7), and $3.9 \times 25.9 \times 0.01 = 1.01$ percentage points in the developing country sample (column 1, Table 9). This finding supports our conjecture that ICT reduces the pandemic's negative economic impact by shifting economic activity from offline to online. In other words, the reduction of factors of production such as decrease of working hours due to lockdowns during COVID-19 had not proportionally led to the reduction in production where the replacement of online work and automated production systems were available. Looking back on the situation at the time, while COVID-19 prevalence was very serious in countries such as the United States, Europe, and South Korea, many of them including South Korea made use of ICT in minimizing the disruptions to production and trade.

The results also indicate that mobility reduction and stringency index, and their interactions with internet access, are statistically insignificant regardless of samples, and past GDP growth (see Tables 7–9). Trade openness at the sample of emerging markets and developing economies at Table 9 showed a negative impact to the economic growth. The production decline in the global value chain from the closure of global production bases, for example China's zero-corona policy during the COVID-19 outbreak as well as the border blockade between countries clearly impaired the international trade thus the economic growth of countries with high level of trade openness would be declined.

Overall, the results are broadly in line with our expectations and, most significantly, lend some empirical support to the notion that countries with better ICT infrastructure were able to better cushion the economic shock due to COVID-19. The results are consistent with those of other empirical studies that focused on the recent pandemic, in particular, the study of Katz and Jung and that of Papaioannou, although their measures of resilience, which refer to effects on GDP per capita growth and cyclical output, differ from this study [8,32].

The estimated results are mostly in accordance with our expectations. Both number of COVID-19 cases per population and the share of services of the full sample at Table 7 and the sample of emerging markets and developing economies at Table 9 exacerbate the economic downturn, at 1% and 10% levels of statistical significance, respectively. Mobility reduction is statistically insignificant which can be found from the results reported at Tables 7–9). The share of population using the internet is also insignificant in most cases (please refer to Tables 7–9) but its interaction with COVID-19 mitigates the economic slowdown, at 1% level of significance as shown at Tables 7 and 9. This implies that even countries with larger COVID 19 outbreaks can conceivably suffer smaller economic declines if a larger share of their population uses the internet which implies that some parts of economic activities were able to be replaced by the remote work. Countries with higher share of services in GDP suffer a steeper economic decline at 10% level of significance. This is probably due to the pronounced impact of lockdowns on hospitality and other service industries, which often require person-to-person contact.

In emerging market and developing economies, as presented at Table 9, the number of COVID-19 cases per population and the stringency index both exacerbate economic decline at 5% to 10% significance levels, respectively. On the other hand, mobility reduction is insignificant. The share of population using the internet is also insignificant but its interaction with COVID-19 deepens economic decline at 5% significance level. Table 9 also indicates that Interaction between internet use and both mobility reduction and stringency index have insignificant results.

Furthermore, according to our results, the impact of ICT on economic resilience during COVID-19 is not only statistically significant but also economically significant. That is, differences in ICT seem to be associated with a tangible, non-negligible difference in economic performance. For example, the coefficient estimates in Table 6 and the sample average COVID-19 infection rate imply that an improvement of internet access per population from the emerging market and developing economy average (52.96%) to the advanced-economy average (87.83%) helps cut the former's growth deceleration by half. (The average of estimates of COVID-19 in Table 1 is 321.15 [314.3, 328.0]. The mean COVID-19 inflection is 0.02% for the whole sample. The product is 321.15 × 0.02 = 6.423%; this is the estimated growth reduction due to COVID-19. The average of estimates of Internet access * COVID-19 is −3.7195 [−3.541, −3.898]. The difference in Internet access between advanced economies (87.83) and developing countries (52.96) is 34.87. The product evaluated at the mean COVID-19 infection is −3.824 × 38.14 × 0.02 = −2.59. Therefore, in developing countries, improved internet access should cut by half (|−2.59|/6.46) the growth reduction due to COVID-19.) An emerging market and developing economy which saw its GDP growth rate fall by 6.5% in 2020 may have suffered only a 2.6% decline if it had better ICT.

6. Conclusions and Recommendations

Our empirical analysis of a cross-section of 117 economies provides some empirical support for a beneficial impact of ICT. More specifically, we find that for any given level of COVID-19 prevalence, better internet access reduces the economic slowdown due to the pandemic. This is our key finding. The deceleration in GDP growth between 2019 and 2020, evaluated at the average COVID-19 prevalence, due to having a one standard-deviation increase in the share in the population with internet access, is lower by 1.90 percentage points for the full country sample, and 1.01 percentage points in the developing country sample. Interestingly and significantly, the positive effect of ICT on economic resilience during COVID-19 is economically significant. For instance, the coefficient estimates in Table 6 and the sample average COVID-19 infection rate imply that an improvement of internet access per population from the emerging market and developing economy average of 52.96% to the advanced-economy average of 87.83% helps cut the former's growth deceleration by half.

The contribution of our paper is that unlike previous research we define economic resilience in terms of impact on GDP growth deceleration. So a direct and precise compar-

ison with previous research is difficult. In other studies, economic resilience refers to (i) how much broadband infrastructure tends to diminish the impact of an increase in COVID prevalence on GDP per capita growth and (ii) how do economic losses, in terms of cyclical output, due to the pandemic vary across countries depending on internet connectivity. Although the measures of resilience in other studies differ with that used in our study, we share similar broad findings. That is, better connectivity contributes to economic resilience or the capacity of economies to withstand major shocks.

Since the main objective of our study is to examine the factors that affect economic resilience during COVID-19, the sample period is the pandemic.

In terms of the way forward, the natural policy implication of our empirical evidence is that investments in ICT infrastructure foster economic resilience in the face of pandemics. The huge economic cost of COVID-19 highlights the huge potential benefits of such investments. Our evidence thus further strengthens the case for investments in ICT, which boost economy-wide productivity by sharply reducing the cost of information and communication. While our evidence provides some evidence of a positive impact of ICT on economic resilience, it is far from definitive and marks only a preliminary initial effort. We hope that our study will kick off a vibrant new research stream that delves into the relationship between ICT and economic resilience. For instance, industry- and firm-level studies on the impact of ICT on industry and firm resilience during COVID-19 can shed light on exactly how ICT helps economic agents cope with a severe shock such as COVID-19. Such analysis, in turn, can help policy makers design and implement more effective policies.

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