The Impact of Digitalization: What Can Technology Adoption Tell Us about the International Economic Response to the COVID-19 Pandemic?

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May 6, 2022

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Mathematical Methods in the Social Sciences
Acknowledgements

I’d firstly like to thank my advisor, Professor Chris Udry, for all of his guidance and feedback while I was completing my senior thesis. His advice and thoughts were extremely helpful as I was crafting the paper. Next, I want to thank all of the professors I have had the privilege of taking classes and working with over my four years here at Northwestern. I’d also like to thank the MMSS program for providing me with the opportunity to challenge myself and grow alongside my fellow cohort of students. Finally, I want to express my gratitude to my parents, as I would not be here or the person I am today without their constant support and sacrifice. I’d also like to thank my twin for being a great sister.
Introduction

When COVID-19 hit the world in early 2020, it impacted every single nation and economy on the planet. The economic impacts of COVID-19 have been broad and drastic while taking place in an extremely short time period. In fact, the resulting global recession was the most severe since the end of World War II, with the global economy shrinking by 3.5 percentage points in 2020 (Yeyati & Filippini, 2021). As a result, the global economic response to the pandemic has been of intense interest to economists and businesses alike. The common shock and resulting differential economic responses by each nation provide a valuable opportunity for studying why certain countries reacted the way they did. That is, the COVID-19 shock can be thought of as a natural experiment of sorts in which every person, business, and economy was a participant. The question now becomes, which factors actually mattered in shaping or contributing to each nation’s economic response.

Of course, one of the major impacts of the pandemic was a forced transition of social and business activity to a more online setting. As governments implemented quarantines and social distancing measures, society was kept functioning through online communication. Those with jobs easier to transition online saw lower rates of unemployment compared to those who had more manual labor-dependent jobs which were not as easily transitioned (Joblist, 2021).

Putting together these two conclusions, that COVID-19 pushed societies to a more online setting and that each nation had a differing economic response, leads to a logical question regarding whether nations that were more equipped to transition online had better economic outcomes. However, given that many factors were at play in determining the economic response
of each country beyond their capacity to transition online, it remains to be seen which technology factors matter and if so, why and by how much.

This paper considers a handful of key indicators which measure a nation’s technological development and compares them to its resulting immediate economic response as a result of COVID-19. The indicators considered are the Share of Population Using the Internet, ICT Exports as a Percentage of Total Exports, Mobile Phone Subscriptions (per 100), and ATM Density (per 100,000). The main economic response variable studied will be the Percentage Change in GDP Growth from Q1 to Q2 2020. The countries’ economic responses will be examined from a variety of angles including high income compared to low income and by varying levels of technological development as measured by the aforementioned indicators.

**Literature Review**

Given the magnitude of the impacts of COVID-19, there has unsurprisingly been much academic interest in studying the economic results of the shock. Furthermore, the major role that technology played in the early transition stage of the pandemic has been recognized as an important factor to investigate as well. Given the varying levels of technology adoption at both an international level and within nations themselves, there exists a great opportunity for studying the resulting varying economic impacts to see if any type of relationship exists.

An example of such a paper is *Digitalization and Resilience: Firm-level Evidence During the COVID-19 Pandemic* (Abidi et al., 2022). The authors’ main objective was to use firm-level data to study whether firms that were more digitally enabled were better able to mitigate
pandemic-related losses compared to those firms which were less technologically sophisticated. They compare non-financial corporations before and after 2020 in the Middle East and Central Asia region. The data used was the EBRD-EIB-World Bank Business Environment and Enterprise Performance Survey (BEEPS), which collects responses on the firm level regarding characteristics such as sales, size, infrastructure, innovation, and other similar factors. The sample included 13 economies from 2013-2020 in the non-agricultural and non-financial sectors. Among the variables measured by this survey is digitalization. Further, the chosen response variable was the degree to which a firm’s sales changed before and after 2020. This data was provided by the ES COVID-19 Follow-up Enterprise Survey (ES COVID Survey) and the World Bank’s Business Pulse Survey (BPS). Using this data, the researchers were able to compute the percentage change in sales for each firm.

Their initial results revealed that there was a significant relationship between firm digitalization and sales. Specifically, before and after the pandemic hit, digitally-enabled firms had a statistically significant higher average level of sales in comparison to the less digitally sophisticated firms (Abidi et al., 2022). Further analysis included a difference-in-difference regression in order to further explore the resilience of digitally-enabled firms compared to digitally-constrained firms. The approach taken was to create a digital connectivity index incorporating many measures of digitalization. In addition, firm-level control variables were incorporated such as age and firm size. The main response variable was the logarithm of total sales. Results showed that across all regression designs, the pandemic negatively impacted firms’ sales performance and that digitalization is positively correlated with sales. Finally, perhaps the most significant finding was that when comparing two firms of the same size, age,
country, and industry (and other characteristics), the more digitally-enabled firms saw a 4.4 percentage point lower decrease in their sales due to the pandemic compared to the digitally-constrained firms (Abidi et al., 2022).

Issues with this approach include the presence of many potentially unobserved variables impacting the decision of a firm to digitalize. The researchers addressed this by incorporating additional firm-level control variables for factors such as innovation and research and development (R&D) spending during the last fiscal year. Furthermore, the researchers are careful to note that this initial result does not prove any sort of casual relationship between digitalization and firm performance, only that there is some evidence of the positive impacts of technology. In any sort of analysis that we perform, we must be similarly careful to incorporate relevant control variables and not overstate any preliminary findings.

Another paper that studied the economic impacts of COVID-19 in relation to technology adoption is *IT Shields: Technology Adoption and Economic Resilience during the COVID-19 Pandemic* by Pierri & Timmer (2020). Similar to the aforementioned work from Abidi, this paper’s goal was to study firm-level economic responses as a result of COVID-19 and compare firms that were more technologically enabled to those that were not (Pierri & Timer, 2020). However, the main economic response variable studied here was unemployment rather than the change in sales. Furthermore, rather than using a multinational sample, the United States and its firms were the main focus of the study. The data was sourced from the Current Population Survey (CPS) to capture the effect of pandemic-related lockdowns on the labor market on a monthly level. The researchers were then able to calculate the monthly unemployment rate at different levels such as at the MSA, state, and national levels. Furthermore, mobility data was
collected from Google Community Mobility Reports to measure the location history of consumers and see how their retail activity changed before and after the COVID-19 lockdowns. They also incorporated data on lockdowns in terms of 11 intervention dummy variables which would have a value of 1 if the specified type of lockdown was in place in a certain area. IT data was sourced from a survey from CiTBDs Aberdeen in 2016 that provides the IT budget per employee for nearly 3 million firms in the United States.

The analysis involved a cross-sectional regression where the change in consumer spending was the response variable and the change in mobility was the independent variable (also incorporating state-level control variables such as GDP Per Capita and population density). This revealed a significant and positive association between the decrease in mobility and the decrease in spending (Pierri & Timmer, 2020). Further analysis included another cross-sectional regression with the change in the unemployment rate as the response variable. The independent variables were an IT dummy variable that indicated whether a state was above the median of IT adoption and zero if it was below, the average change in mobility for a state, the interaction between those two variables, and a variety of state-level control variables. This regression revealed a higher level of IT adoption was correlated with a lower increase in the unemployment rate. Specifically, states that had a higher than average IT adoption had a 1.8 percentage point lower increase in unemployment compared to states that had lower IT adoption.

Finally, the researchers estimated the potential impact of the pandemic had it hit 5 years earlier in 2015 using a counterfactual approach. They assumed that IT adoption grew at 2 percent annually and would thus be 10% smaller in 2015 than in 2020. From here they were able to estimate that under the 2015 level of IT adoption the unemployment rate would have been 16%
compared to the observed number of 14%. This further highlights the positive impacts that technology adoption can have on firms, workers, consumers, and the broader economy.

Another paper that explores the potential positive impacts of technology on firms, and not just necessarily in the context of the pandemic, is *Financial Technology Adoption* by Higgins (2020). This paper examines the impacts of an early 2010’s Mexican government program to distribute one million debit cards to a certain low-income segment of the population as part of a broad transfer initiative. It finds that there were spillover welfare gains to both richer consumers as well as on the supply side to small retail firms that adopted new point-of-sale terminals to accept card payments. Clearly, it is not just IT adoption and internet accessibility that impacts firm and broader economic outcomes. Payment facilitation technologies, and other similar forms of innovation, also offer value.

It is no question that the pandemic further highlighted ways in which these types of innovations and technology adoptions can benefit firms. One paper that explores how Micro and Small Enterprises (MSEs) can leverage digital technologies for sustainable growth by exploring the impacts of the pandemic is *COVID-19 pandemic digitization lessons for sustainable development of micro and small- enterprises* (Bai et al., 2021). This study highlights that the COVID-19 lockdown restrictions are more severe for small firms compared to larger, global firms and that MSEs are of major importance for the growth of developing regions with more than 90% of businesses in Africa being classified as such. Furthermore, it details the potential value to MSEs of innovations such as mobile money and social protection programs. Particularly in developing regions with underdeveloped banking infrastructure, these types of innovations can support communities and businesses during hard economic times such as the pandemic. The
paper further illustrates that digitally-enabled MSEs can improve employment prospects, reduce poverty and increase sustainability (Bai et al., 2021).

In summary, there has been much research into the role of technology in the economic response of firms to the COVID-19 pandemic. Clearly, results show that both in theory and practice certain adoptions of technology offer value in terms of economic resilience and adaptation. However, much of this work has been conducted on the firm level rather than using a global dataset of nations. This paper will build upon the foundation laid by the work already done exploring the impacts of technology on firms’ economic responses by performing an analysis on the national level. Specifically, we will compare higher-income nations to lower-income nations and more technologically sophisticated countries’ economic responses to less technologically advanced nations’ outcomes.

Data and Variables

As mentioned above, the purpose of this paper is to analyze how well certain measures of technology adoption help explain the varying economic outcomes of nations to the COVID-19 pandemic. As such, we will incorporate a set of independent variables, which capture technology level, and an economic response variable which measures each nation’s immediate reaction to the COVID-19 shock. The measures of technology adoption were chosen to provide a measure of how well technology is disseminated within a country as a whole. That is, each indicator was intentionally chosen to model adoption at a national level, rather than on a regional or local level. The four technology indicators that were selected were Share of Population Using the Internet, ICT Exports as a Percentage of Total Exports, Mobile Phone Subscriptions (per 100), and ATM
Density (per 100,000). The key economic response variable selected is the Percentage Change in GDP Growth from Q1 to Q2 2020. Supplemental economic response variables also analyzed include the Change in GDP Growth from Q1 to Q3 2020.

**Share of Population Using the Internet**

This indicator was chosen as one which would be potentially illuminating when trying to decipher or decode what technology factors might have impacted each nation’s economic response. Specifically, in terms of the labor market, given that one of the major shifts that occurred was that to an online working environment, one might believe that nations that had more of their population already utilizing the web might have had a smoother transition to a more online routine (Pew Research Center, 2021). Further, on the supply side, many firms quickly had to adapt to online ordering and other non-direct contact business measures in the immediate aftermath of the COVID-19 shock. Thus, if a nation had a more developed internet infrastructure and accessibility, it may be reasonable to assume that the firms of this country would be relatively better equipped to quickly transition more of their activity online.

In terms of data collection, the data was accessed through The World Bank database and more specifically from the International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database (The World Bank, 2020). The initial sample includes 266 nations and provides historical trend data from the year 1960 to 2020. Our focus is to capture the most recent measure of internet accessibility and thus we will be focusing on this most recent data point for each nation. The data as a whole sees a constant increase over time at
the global level for all nations aggregated from the year 2000 onwards. The growth from 2000 to 2020 is about 7.42-fold (The World Bank, 2020).

**ICT Exports as a Percentage of Total Exports**

The rationale behind selecting this indicator comes from the fact that given that the world as a whole was suddenly pushed to a more online experience, it would be reasonable to assume that there would be a corresponding increase in global demand for technology. Thus, if a nation had a larger portion of its total exports coming in the form of technology products and services, there may be a chance that this would impact how well it would be able to immediately cope with the COVID-19 shock.

A counteracting narrative here could be one of supply chain shortages. Specifically, as the world was hastily implementing quarantine measures, many industries and supply chains were hit, resulting in shortages. The ICT sector may not have been an exception (Palladino & Moline, 2022). Thus, it remains to be seen whether this indicator is relevant to how nations economically responded to the initial shock. The data comes once from The World Bank’s data library and more specifically from the United Nations Conference on Trade and Development's UNCTADstat database (The World Bank, 2020). It spans from 2000 to 2020. Once more, we are most interested in how much of a nation’s exports were ICT goods in the year most proximal to 2020, the year the pandemic took hold over much of the globe. Thus, the data points will be for each nation’s most recent entry up to 2019.
**Mobile Phone Subscriptions**

Mobile phones have been rapidly adopted over the recent few decades, with developing regions such as Asia and Africa seeing dramatic growth. As such, this indicator was selected to provide a measure of the access level each country’s population has to one of the 21st century’s most prominent and key technological advancements. Among the mobile phones' most important functions beyond voice and text messaging for social contact, is aiding business transactions and communications.

For instance, mobile phones have become means of payment and in many developing countries they provide access to banking and credit. An example is Kenya’s mobile money system, M-Pesa (Piper, 2020). Furthermore, in more recent years the introduction of the smart mobile phone has brought with it the ability for noncontact payments and user-to-user payment services. The growth of mobile phones also accompanies cellphone tower and communications infrastructure development, which may have positive externalities on business activity and potentially economic resilience. Thus, these associated attributes and capabilities that come with the mobile phone may help us determine whether certain countries saw less of an initial shock or responded differently in COVID-19’s immediate aftermath.

The data comes once more from the World Bank and more specifically from the International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database (The World Bank, 2020). It shows a sharp rise for the world from the year 2000 to 2020 (12.04 to 107.52).
ATM Density (per 100,000 adults)

This indicator was selected in order to capture the permeation of technology more focused on banking and financial services. Further, it was chosen to be distinct from the other aforementioned indicators. Specifically, all 3 of the previous indicators exist in the realm of communications and connection technology. However, ATMs do not necessarily connect individuals directly with others, but rather connect individuals to the broader financial system. They also allow for easy access to cash and funds which may be potentially beneficial for economic resilience.

Further, a higher prevalence of ATMs may have possibly aided the ability of people to continue their purchases in the face of a shock such as the one brought on by COVID-19. The data comes from the World Bank and more specifically the International Monetary Fund’s Financial Access Survey (The World Bank, 2020). It shows substantial growth at a global level from 2004 to 2020 (17.95 to 51.66).

Change in GDP Growth From Q1-Q2 2020

The primary economic response variable selected measures the percentage change in GDP growth for each nation from Q1 to Q2 2020. Once more, we are specifically interested in the immediate economic response of each nation to COVID-19. March 2020 is when the pandemic took hold over much of the world. Thus, the shift in the Q1 to Q2 GDP growth rate should capture the macroeconomic response of each country. GDP captures the gross value of goods and services in a nation and is the exact type of economic indicator that would pair well with the national level technology indicators that we have chosen to study. Furthermore, we will
utilize higher precision quarterly data which will let us examine the immediate aftermath of the COVID-19 shock. This is in comparison to other measures such as the annual change in GDP which would be more convoluted and give more time for nations to adjust to the pandemic status quo. The quarterly data comes from the OECD database for the OECD countries (OECD, 2022). For the remaining nations, the data comes from various national government agencies and reports (The Global Economy, 2022). The initial sample includes 119 countries, which was all the nations for which quarterly data was easily accessible.

Other Control and Response Variables: Healthcare Spending as Percentage of GDP, GDP Per Capita

In addition to the aforementioned technology indicators and the economic response variable, when studying the relationship between the two, there will certainly be other confounding factors that we must take into account. The economic response between nations may vary for many reasons that do not necessarily have to do with their technological capabilities. As such, in the experimental design, we have included a handful of control variables that were felt to be most relevant.

One of these control variables is GDP Per Capita. This measures the rough income level of each nation adjusted for population size. This variable was included as a control due to the reasonable expectation that richer and poorer nations might have different types of economic responses to the COVID-19 shock due to their wealth level. The data comes from the World Bank and is measured in US dollars (The World Bank, 2020).
Another control variable included captures the level of healthcare spending as a percentage of GDP for each country. This variable was included with the reasoning that nations with relatively more developed healthcare infrastructure might be better equipped to handle the pandemic, and thus might have had a better economic response in the short run. The data comes once more from the World Bank and more specifically from the World Health Organization Global Health Expenditure database (The World Bank, 2020).

Limitations of the Data

The primary limitation of the data is that of availability. That is, the technical indicators and quarterly GDP data are not available for every nation. Although there is solid representation of low-income nations, some of the lowest-income countries did not have data available. As such although our initial sample of countries is well over 100, it does not include every possible nation.

Another limitation already mentioned above is the presence of confounding factors. When trying to determine what type of impact technology had on post-COVID-19 economic responses, there understandably may be a number of other factors that influence the response of each country. This issue was addressed through the inclusion of relevant control variables as discussed above. Furthermore, our method of analysis (as will be discussed shortly) will be careful not to overstate any results.
Methods

The following section will detail what approach was taken as far as the data analysis and what the overall goal was in terms of the analysis. Given our aforementioned selected technology indicators, economic response variable, and control variables we will need to employ a few different methods in order to understand what trends are present between them all. This takes the form of splitting the samples into multiple groups of two by each indicator and examining boxplots and percentiles, running various two-sided $t$ tests, and conducting multivariate regressions incorporating our control variables to account for omitted variable bias.

Boxplots and Percentiles

The first analytical tool that we will be utilizing is the box and whiskers plot. As stated beforehand, one of our primary initial goals is to generally understand the trends across different subsamples of the countries based on our chosen indicators. Thus, by splitting each indicator into a higher median group and a lower median group (for instance upper median GDP Per Capita and lower median GDP Per Capita) and running a box and whiskers plot using the GDP drop from Q1-Q2 2020 as our response variable, we can compare how these different groups faired at a high level. The value of this analysis method is that it can be extended to each technology indicator and we can thus compare the response for countries with higher levels of a certain technology versus the lower median group.

Of course, this does not necessarily indicate a causal relationship between higher levels of technology and the economic response to COVID. We will employ other additional tools to
attempt to study this. Furthermore, in order to supplement the box and whiskers plot analysis, we will be generating percentiles for each group’s response. This provides a higher level of detail when comparing the responses of the different groups to see whether there are any outliers in the data.

\(t\) tests

Given our interest in examining any potential differences in the economic responses of more technologically sophisticated countries compared to those that are not as technologically advanced, the two-sided \(t\) test will be utilized to see if there is any statistically significant difference. Specifically, we will conduct 4 tests, one for each of the technology indicator subgroup pairs. In each test, one group will be the higher median split of technology adoption (e.g., the higher median half of Share of Population Using the Internet) and the other will be the lower median split (e.g., the lower median half of Share of Population Using the Internet). The null hypothesis will be that the mean Change in GDP Growth from Q1 to Q2 2020 is the same for both groups, and the alternative hypothesis will be that they are not the same. A result where we can reject the null hypothesis would lend support to the notion that the observed technological indicator did indeed play a role in a nation’s immediate economic response to the pandemic.

Multivariate Regressions

We will also be utilizing a multivariate regression in order to piece together any potentially significant association between the indicators and nations’ immediate COVID-19
economic response. Since we have four technology indicators and additional control variables, the best way to isolate a single indicator’s relationship with the change in GDP growth is a multivariate regression. This design was similarly utilized by the examined literature, but we will be substituting in our specific variables of interest. The primary dependent variable will be the Percentage Change in GDP Growth from Q1 to Q2 2020. The regressors will be Share of Population Using the Internet, ICT Exports as a Percentage of Total Exports, Mobile Phone Subscriptions (per 100), ATM Density (per 100,000), Healthcare Spending as a Percentage of GDP, and GDP Per Capita.

We will run two regressions, identical in terms of regressors and economic response variable, but one will be for the high-income subset of countries and the other will be for the low-income subset of countries (as measured by GDP Per Capita). This will allow us to compare the potential impacts that the technologization factors have on low-income countries versus high-income countries. Specifically, the following equation will be estimated once for the high-income sample and once for the lower-income sample:

\[
\%\Delta GDP_i = \beta_1 ShareInt_i + \beta_2 ICTExports_i + \beta_3 PhoneSubs_i + \beta_4 ATMs_i + \beta_5 GDPPerCapita_i + \beta_6 HCSpending_i + \beta_0
\]

A positive coefficient for any of these variables would indicate that as the level of technology adoption or healthcare spending or per capita wealth increases, the resulting immediate COVID-19 GDP drop is lower in magnitude (less negative). This is because the percentage change will be more negative the higher the drop in GDP growth was going from Q1 to Q2 2020 (and would be positive if the Q2 GDP growth rate was higher than in Q1).
Results and Analysis

High Income vs. Low Income GDP Drop

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<td>-104.728</td>
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Low Income Countries Q1-Q2 2020 Percentage GDP Drop

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The medians for the high and low income (split at median GDP Per Capita for the initial sample of countries) groups were -5.110 and -4.327 respectively. Interestingly, this shows a lower magnitude percentage drop for low-income countries. Only the 10th percentile for high-income countries shows a lower magnitude percentage drop than the low-income countries (due to the minimum value being lower for low-income countries than for high-income countries, and similarly the maximum for high-income countries is greater than the low-income countries). Perhaps higher-income countries were more connected to the global economy and thus experienced more severe shocks in the immediate term, however, across the percentiles the difference between the drops was consistently within 1 to 2 points besides the minimums.
Furthermore, this result of the impacts being largely the same across the two samples is upheld when conducting a two-sided $t$ test with one group being the high-income nations and the other being the low-income nations. The null hypothesis is that the mean Change in GDP Growth from Q1 to Q2 2020 is the same for both groups. The results show that the null hypothesis cannot be rejected ($p$ value = 0.173). This is highly surprising given that we would expect that there should be some type of significant difference in terms of the immediate economic response of higher-income countries in comparison to lower-income nations. Whether that be in terms of the higher-income nations being more able to adapt quickly or the lower-income countries not having the medical infrastructure to manage the initial surge of the pandemic.

**High Internet vs. Low Internet GDP Drop**

![High Internet vs. Low Internet GDP Drop](chart.png)

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<td></td>
<td>63.628</td>
<td>78.218</td>
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The percentage of the population using the internet is 89.244 for high-income countries compared to the lower-income half having a median of only 54.601. This is as expected, given that the higher-income countries would have more developed communication infrastructure and technology accessibility in general. Interestingly, however, the higher-income sample has a median magnitude GDP drop from the initial COVID shock moving from Q1 to Q2 2020 that is marginally higher than the lower-income group. This may suggest that when comparing the economic responses of high-income countries against low-income ones, internet users may not be the most relevant metric.

The seeming similarity in terms of economic response between the two samples is upheld when we run a two-sided $t$ test with the null hypothesis being that the mean Change in GDP
Growth from Q1 to Q2 2020 is the same for both groups. The results show that the null hypothesis cannot be rejected ($p$ value = 0.229). However, this does not mean that this indicator has absolutely no value in terms of explaining the varying economic responses of countries as a result of the pandemic. In fact, as we will see later on, this variable provides insight in terms of interpreting the economic responses of high-income countries against one another.

High ICT Export vs. Low ICT Export GDP Drop

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<td></td>
<td>-143.000</td>
<td>-31.665</td>
<td>-18.345</td>
<td>-8.962</td>
<td>-6.692</td>
<td>-4.606</td>
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Interestingly, the median magnitude drop for the high ICT exporting countries (again split at the median) was much higher than for the low ICT exporting half. That is, the median for the former was -6.692 compared to -4.501 for the latter. Furthermore, the minimum and every other calculated percentile were higher for the high ICT exporting countries compared to the low ICT exporting countries. This holds true even at the extremes, with the minimums and maximums being fairly similar in size (-143.000 and -128.700 as minimums and .0110 and .553 as maximums for the high ICT and low ICT samples respectively). This result is a bit intriguing as one might expect that there would have been an increase in global demand for ICT components, potentially leading those nations that derive more economic value from these goods to better handle the initial shock. However, the initial results do not seem to support this hypothesis.
One potential interpretation or explanation here may be that given the economic response variable is examining the immediate quarter to quarter shock from Q1-Q2, the countries that relied more heavily on ICT exports may have experienced supply chain bottlenecks facing rising domestic and foreign demand for such products. It may have taken them some time to adjust to the new situation. As such, it might be worth looking at the results for this same sample of countries but instead comparing the Change in GDP Growth from Q1 to Q3 2020.

However, when running a $t$ test comparing the high ICT export countries to the low ICT export countries using the Percentage Change in GDP Growth from Q1 to Q3 2020 as the response variable, we are unable to reject the null hypothesis ($p$ value = .414). Thus, this indicator may not provide the greatest insight into how well a nation fared in response to the pandemic. This may be due to the fact that it is measuring exports and manufacturing specialization, and does not directly capture the ability of firms and individuals to better transition to an online environment.
High Mobile Phone Subscriptions vs. Low Mobile Phone Subscriptions GDP Drop

GDP Drop for High Mobile Phone User (per 100 people) Countries

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GDP Drop for Low Mobile Phone User (per 100 people) Countries
The mobile phone results show that the countries with higher levels of mobile phone subscriptions actually had a higher median drop in GDP compared to the lower half of countries in terms of mobile phone subscriptions (-6.556 vs. -3.694). As expected, the median GDP Per Capita for the high mobile phone sample was higher than for the low mobile phone countries. However, once we conduct the two-sided t test, we are once more unable to reject the null hypothesis that the mean responses for the two groups are significantly different (p value = .562). One potential interpretation here is that given that mobile phones have been around for decades at this point, they do not necessarily signal anything particularly relevant regarding how well-suited an economy would be to a transition to a more online status quo.

Further, the presence of a mobile phone does not necessarily indicate internet or computer accessibility. Thus, not all technology indicators are created equal as far as giving us interesting interpretations of the corresponding economic responses of different nations. Further, context matters with regards to nations’ income levels impacting how potentially relevant a technology indicator might be.
High Mobile ATM Density vs. Low ATM Density GDP Drop

GDP Drop for High ATM Density Countries (per 100,000 adults)

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</table>

GDP Drop for Low ATM Density Countries (per 100,000 adults)
The results comparing the higher ATM density countries to the lower ATM density sample shows that immediately, the median GDP drop from Q1 to Q2 2020 was not drastically different (-4.591 compared to -5.521). Although the lower ATM density sample did indeed have a greater median drop in GDP, it was within 1 percentage point of and not radically different from the higher density sample. This may initially indicate that the observed countries that had more ATMs per capita experienced a better transition to Q2 in the face of the pandemic. However, when we run a $t$ test comparing the mean GDP drop for the two samples, we are unable to reject the null hypothesis that the mean GDP Drop is the same for the two samples ($p$ value = .518). Once more, it appears that this indicator does not statistically significantly differentiate the economic responses of nations based on this 2 group design.

**GDP Drop vs. Technology Indicators High Income Regression**

<table>
<thead>
<tr>
<th>Estimate</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-7.608e+01</td>
</tr>
<tr>
<td>Share Using Internet</td>
<td>6.591e-01</td>
</tr>
<tr>
<td>Share of ICT Exports</td>
<td>7.440e-02</td>
</tr>
<tr>
<td>Mobile Phone Subscriptions</td>
<td>-3.195e-02</td>
</tr>
<tr>
<td>ATM Density</td>
<td>3.128e-02</td>
</tr>
<tr>
<td>Healthcare Spending</td>
<td>2.997e-01</td>
</tr>
<tr>
<td>GDP Per Capita</td>
<td>6.303e-05</td>
</tr>
</tbody>
</table>
Running a regression of Percentage Change in GDP Growth from Q1 to Q2 2020 on our chosen technology indicators, controlling for GDP Per Capita and Healthcare Spending as a Percentage of GDP, for the high-income countries reveals a positive coefficient for Share of Population Using the Internet, ICT Exports as a Percentage of Total Exports, Mobile Phone Subscriptions, ATM Density, Health Expenditure, and GDP Per Capita. Interestingly, the coefficient on Mobile Phone Subscriptions is negative, which supports the earlier finding that this indicator may not be the most informative in terms of identifying differential economic responses.

Furthermore, only the intercept and the coefficient on Share of Population Using the Internet are statistically significant. The coefficient of 6.951e-01 is significant at a .10 significance level (p value = .0699). The positive sign would indicate that as the share of the population using the internet increases, the resulting decrease in GDP would be less negative. This preliminary result does not definitively suggest any causal relationship, but potentially hints that the characteristics of high-income countries with greater internet user density may have helped them better adjust to the initial shock compared to other high-income countries. This lines up well with the findings of the literature showing that more digitally enabled firms experienced a lower percentage drop in sales before and after the pandemic (Abidi et al., 2022). Our result reflects that finding on a national level. Perhaps once a nation reaches a higher income threshold, then that is when a technology indicator like internet usage might begin to matter as a relevant factor. This analysis can be expanded by exploring additional technology factors.

The other coefficients are not significant and do not seem to indicate any strong association between an increase in technology level (as measured by these other factors) and the
economic response of high-income countries to the initial COVID-19 shock. Interestingly, Healthcare Spending as a Percentage of GDP as a control variable is also not significant, which is somewhat surprising as one would expect that those nations that spend a greater percentage of GDP on healthcare might have had more developed health infrastructure to handle the pandemic. The other control variable, GDP Per Capita, not being significant aligns with our earlier result showing that there was not a statistically significant difference between the economic responses of the high and low GDP Per Capita samples. Now, we will turn to examine the results for low-income countries.

GDP Drop vs. Technology Indicators Low Income Regression

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-7.579e-03</td>
<td>.897</td>
</tr>
<tr>
<td>Share Using Internet</td>
<td>-2.147e-05</td>
<td>.983</td>
</tr>
<tr>
<td>Share of ICT Exports</td>
<td>1.897e-04</td>
<td>.904</td>
</tr>
<tr>
<td>Mobile Phone Subscriptions</td>
<td>5.024e-04</td>
<td>.294</td>
</tr>
<tr>
<td>ATM Density</td>
<td>-1.071e-03</td>
<td>.113</td>
</tr>
<tr>
<td>Healthcare Spending</td>
<td>-6.330e-03</td>
<td>.323</td>
</tr>
<tr>
<td>GDP Per Capita</td>
<td>-5.961e-06</td>
<td>.518</td>
</tr>
</tbody>
</table>

Results are inconclusive for the low-income countries (coefficients not significant) when running the same regression. It may be the case that there is too much heterogeneity across the low-income country economic responses as far as each economy not being as impacted by technology factors like internet connectivity. That is, there may be more relevant and important
circumstances impacting their economic response compared to the high-income countries. Thus, it may be the case that the level of technology (or at least the handful of indicators studied in this analysis) is not entirely relevant for comparing overall economic resilience in this scenario. This analysis can be extended by testing more technology factors and seeing if this result holds and additionally refining the experimental design by varying the economic response and control variables.

Conclusion

We began our study by acknowledging that the COVID-19 shock impacted every nation on Earth. Further, every country had a different resulting economic response, and our initial theory was that the level of technological sophistication or permeation in society would impact the ability of each country to adapt to a suddenly more online way of life. Given our interest in the aggregate adaptability or adjustment of each nation in the immediate aftermath of the shock in the short term, our chosen economic response variable was the percentage change in GDP growth rate from Q1 to Q2 2020.

Our analysis indicates that of our four chosen technology indicators, the only one that showed significant results was the Share of Population Using the Internet. Interestingly, the major difference between this indicator and the other 3 (ICT Exports as a Percentage of Total Exports, Mobile Phone Subscriptions, and ATM Density), is that the other three do not directly measure the capability of individuals to work remotely or for firms to transition their activities online. ICT exports are more concerned with manufacturing specialty and trade balance, whereas
Mobile Phone Subscriptions and Density of ATMs measure technologies that do directly capture access to the Internet. Furthermore, it appears that even in the case of Share of Population Using the Internet, this factor only seems to matter once the nation has reached a certain level of wealth, as the lower-income countries had comparatively much more variability in their economic responses to the pandemic.

In some ways, although these results do not necessarily indicate a causal relationship, they seem to reflect that our initial hypothesis may have been partially correct. That is, although one chosen technology indicator does seem to matter for the associated economic response, not all of them do. This suggests that not all technology indicators are created equal, and that there exists much more potential for extending this analysis. For instance, more relevant internet technology measures could be studied (e.g. computer user density). In addition, the economic response variable can be varied to include other relevant measures such as unemployment and household income. Finally, although the world has developed greatly in terms of technology usage in the last 10 years, other historical economic shocks could be studied in a similar manner such as potentially the Great Recession. Further exploring which technologies and innovations seem to matter for a nation’s economic resilience in the face of unexpected shocks would provide great value in terms of guiding meaningful technology investment and development for nations around the world.
References


[https://doi.org/10.5089/9798400201073.001](https://doi.org/10.5089/9798400201073.001)


https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

https://seankhiggins.com/assets/pdf/higgins_FinancialTechnologyAdoption.pdf

Home. OARC Stats. (n.d.). Retrieved May 6, 2022, from
https://stats.oarc.ucla.edu/stata/dae/multivariate-regression-analysis/

https://data.worldbank.org/indicator/TX.VAL.ICTG.ZS.UN

Individuals using the internet (% of population). Data. (2020). Retrieved May 6, 2022, from
https://data.worldbank.org/indicator/IT.NET.USER.ZS


Mobile cellular subscriptions (per 100 people). Data. (2020). Retrieved May 6, 2022, from
https://data.worldbank.org/indicator/IT.CEL.SETS.P2

https://doi.org/10.2139/ssrn.3744676

