Digitalisation and Economic Growth in G-20 Countries: A Panel ARDL Analysis

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Abstract

The 4th industrial revolution, or Industry 4.0 for short, has been ushered in by technological improvements over the past 30 years. As a result, the growing trend of digitalization has had a distinctly beneficial effect on economic growth, particularly in the banking and financial sector where it has increased productivity and efficiency due to reduced information asymmetry and by making financial services more widely available and reasonably priced for a wider range of people. Keeping in mind the notable benefits brought about by rising digital advancements and its impact on financial sector, this study aims to show the dynamic relationship between digitalization, financial inclusion and economic growth for G20 nations. We used the annual data for the time span of 2010 to 2020 for G20 countries and has used panel ARDL approach for the analysis. The panel ARDL technique reveals a positive correlation between digitalization and long-term economic growth. Conversely, the research findings indicate a negative relationship between them in the short run. Similarly, we spot an detrimental long-term association between financial inclusion, measured as the number of commercial bank branches, and economic growth. The study also comes to the conclusion that, in the short and long terms, respectively, population and gross-fixed capital formation have an impact on economic growth. Further, we have checked the robustness of our results by using internet usage as proxy for digitalization. The finding in this case proves the robustness of our study. Based on our study, we suggest that widespread digitalization and financial inclusion along with the introduction of FinTech might contribute to sustainable economic growth from a policy perspective.

Keywords: Digitalization, Financial Inclusion, G20 countries, Panel ARDL model, Technological Innovation and Economic Growth

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1. Introduction

The growing adoption of cutting-edge digital technologies in the digital realm, such as blockchain, big data, and the Internet of Things (IoT), not only boosts productivity and lowers transaction costs, but also benefits consumers and helps get past infrastructure-related obstacles to financial inclusion. These barriers include both physical infrastructure impediments in the form of the supply of bank branches (Célerier & Matray, 2019) and also social and cultural impediments (Miller, Reichelstein, Salas, & Zia, 2015), which obstruct the benefits of these services to reach to communities that varies in education (Carpena et al., 2019; Lusardi & Mitchell, 2014), ethnicity as well as sex (Sharier, 2016; 2018; Sharier et al., 2020). The term "digital economy" refers to the use of digitally enabled technologies, such as cloud computing, big data, fintech, the Internet of Things, and others, to digitally gather, store, analyse, and share information, giving modern economic activities greater flexibility and agility. To add further, digitalization refers to the adoption of technological innovations into all areas of the economy and society that has altered the way enterprises operate and offer value. Use of technologies, platforms, and processes that improve effectiveness, innovation, and performance is an aspect of this evolution.

Pushing economic progress, increasing the productivity of current companies and trade, fostering new markets and sectors, and advancing inclusive and sustainable growth are all made possible by digitalization. In addition to that, the rising trend of digitalization may exert a positive influence on GDP growth and enhanced economic performance in the form of increased productivity, efficiency, and consumption, as well as increased financial inclusion through better access to resources, knowledge, markets, increased communication capacity, and improved infrastructure. Subtle changes have been observed in the operation and strategies of different sectors worldwide because of rapidly increasing digital technologies. Digital technology has transformed the firms' operations, from e-commerce and online sales to outsourcing business processes (Lacity et al., 2016; Lie and Aron, 2104). The contribution of digitalization is not only limited to economic growth, productivity, or efficiency; its benefits are also transferred toward increasing the scope, scale, and speed of trade. To explain, by digitally connecting people across the world, digitalization helps the firm to bring in new products and services, and further, by introducing new and innovative digital tools, digitalization helps to facilitate payments, enable collaboration, and so on (Gonzalez, 2022) and this is not only limited to buying of goods and services but is also extended to the information and data transmission internationally. In accordance with the data from October 2023, it was observed that internet users across the globe have reached 5.3 billion, which is around 65.7% of the global population. From the use of telecommunication in daily life to the use of IT technologies and modern digital equipment for production, agriculture, healthcare, and education to further expanding its role to labour activities and conducting business using products of scientific

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and technological progress like microelectronics, digitalization plays a meaningful role in improving the quality and living conditions of the population. In one way or another, this has a significant impact on the population's quality of life (Barlybaev et al., 2021).

To maintain leadership status, digital innovation is a challenging and critical aspect for all economies (Gapsalamov et al., 2020). The G20 consists of the world's prime economies and is a global summit generating the world's GDP of more than 80%, 60% of the population, and approximately 75% of global trade. G20 members are leading innovators in education and technology production, representing almost 95% of investment in R&D and about 90% of all research articles on artificial intelligence (OECD, 2019). The potentials and problems represented by digital transformation and the technologies that followed it are more crucial and, as a result, increase the significance of policy implications that can assist nations worldwide in using such advancements and innovative technologies (OECD, 2019).

Establishing a digital economy has received special attention from the G20 countries. Starting from the early discussions on innovation policy practices in 2016 within G20 countries and the 'Next Production Revolution' for the impact of new technologies, G20 has snatched the digital technology's importance for achieving better performance and well-being and the need for a coordinated global approach. The main focus of debate in 2017 was on designing the G20 digital agenda and creating the G20 roadmap for digitalization. Then, Artificial intelligence became the topic of discussion in 2019, in which G20 demonstrated strong leadership (OECD). In 2020, the main aim of G20 was to make progress on implementing AI Principles and to broaden the horizon ranging from data to smart mobility. To enhance the economic recovery from the pandemic, the G20 countries in 2021 acknowledged the digital economy's contributing role in spurting employment opportunities and boosting market accessibility for micro, small, and medium enterprises (MSMEs) (OECD).

In this regard, we have focused on comprehending the dynamic relationship between digitization and economic expansion for G20 nations. Our research primarily contributes to the existing literature mainly in three ways. First, as far as we are aware, no research has been undertaken considering the G20 nations in mind. The G20 countries account for a sizable percentage of the global economy and understanding these countries' economic dynamics regarding digitization's role is critical for understanding global economic trends and changes. Second, we have considered the endogeneity issues in our study using the panel ARDL approach. This approach no doubt highlights the short and long run relationship between digitalization and growth in an economy but also takes care of the endogeneity issues in the model. Therefore, the results are robust and reliable. Finally, the study relating to digitization and its impact on economic growth in G20 countries gives a thorough overview of global trends, informs policy decisions, and provides practical insights for other countries seeking to leverage the benefits of digital technologies for long-term economic development.

The remaining portion of the article's material is arranged in a manner as follows The theoretical background and literature review are covered in Section 2; data and methodology are covered in Section 3, which includes a description of the variables, data sources, analytical framework, and methodology used in the study; Section 4 is devoted to the analysis and discussion of the results; Section 5 is devoted to the conclusion and policy implications derived from the study; and finally, Section 6 is devoted to the study's limitations and future scope.

2. Theoretical Background and Literature Review

Technology is the driving engine underpinning the concept of Industry 4.0, which additionally has built an important link with the circular economy's aims— facilitating economic growth whilst safeguarding the environment (Beier et al. 2020). The relationship between Digitalization and Economic Growth can be elucidated by Endogenous Growth theory, which posits that technological change, innovation, and human capital are the internal factors that drive Economic Growth (Romer 1990). These factors would reduce production expenses through education and training, raising output, and accelerating economic growth. With the rise of digitalization and technological innovation, the benefits of financial inclusion, financial literacy, and training are more accessible, especially to underserved groups in society. It can also be highly helpful in enhancing human capital (Lucas 1998). Further, the innovation diffusion theory introduced by Everett Rogers (1995) in 1962 could give grounds to establish the dynamic link between rising digitalization and its impact on economic growth. The theory mainly emphasizes the need to understand the speed with which these emerging, new, and innovative designs as well as creative ideas for upgrading technologies bring advancements into an economic system and also the major role that time plays to bring benefit to the nation and its people (Wani and Ali, 2015). In this context, this theory can be quite helpful in understanding how technological innovations can bring advancements in financial products and services and boost economic growth over time. Another possible explanation for studying the relationship between Digitalization and Economic Growth could be explained through financial development. There are several ways to achieve economic growth, including promoting various financial services and enhancing financial access, integration, mobility, and efficiency (Carkovic and Levine 2005).

Digitalization significantly enhances capital-labour productivity, reduces transaction costs, and provides global market access, making digitalization a leading driver for economic growth in developing countries (Dahlman et al., 2016). For example, the diffusion of mobile phones, mobile banking, and investments in fixed telecommunication infrastructure have helped most poor people access financial services and move from traditional agriculture-related businesses to non-agricultural businesses, reducing poverty and increasing per capita consumption. Rising innovative technologies play a very crucial part in economic growth increment for both developed as well as developing countries by matching up the demand level for digital products (ICT hardware as well as ICT software) and by helping ICT by using sectors

to increase productivity and investment (Hofman et al., 2016). With the emergence of new technological or digital tools and innovations in ICT, benefits and contributions have been percolated into all areas of our lives in the form of transformation in the level of well-being, citizens' behavior, information needs, and the way people work as well as share information (Khazheeva, 2020). From the standpoint of finances, digitalization has made financial transactions easier for businesses, financial institutions, and people (Barlybaev et al., 2021). Financial technologies, often known as fintech, have sped up financial integration by lowering expenses and expanding the possibilities for banking services to underprivileged and impoverished group, rural areas, and underserved sections of society (Asif et al., 2023). From the perspective of investment, the positive and significant impact of digitalization is not only limited to individual investors, but institutional investors like venture capital firms and private equity models also benefitted from the same in the form of finding attractive startups and high-growth firms to invest in, increased transparency and also increased accessibility to engage in the stock market without having to leave the comfort of their homes (Karan, 2023). From a retail and customer banking point of view, improvement in the banking and financial services cost and delivery has been due to the recent technological developments linked to internet connectivity and mobile phones, and this further increases the accessibility of convenient, affordable, and customized financial products and services (Ernst & Young, 2017). In turn, these services significantly influence the economy, and rising technological advancements in this sector would boost economic activities.

2.1 Empirical Literature

2.1.1. Digitalization and Economic Growth

The study by Dewan and Kraemer (2000) confirms that significant differences exist in both developed and developing countries concerning economic benefits received from investment in ICT, such that for developed countries, the effect is significant and positive. In contrast, the results are insignificant for developing countries. Because technological innovation is effectively applied to foster creativity and productivity in advanced countries. However, the efficient application of information and communications technology to promote development in poor countries may be hampered by potential issues, including inadequate infrastructure, a lack of skilled labor, or disparate economic situations (Dewan and Kraemer, 2000). Keeping in mind the economic impact of the rapid ICT spread, the study by Aker and Mbiti (2010) reveals a significant and positive outcome for the data on cell phone use in Sub-Saharan Africa, demonstrating that ICT spread and its economic effect has expanded dramatically over the years. Next, Commander et al. (2011), found a significantly positive link between digitalization and the firms' productivity using the data for Brazil and India. A report released by the United Nations in 2011 states that (a) the introduction of e-governance decreases the administrative burden, (b) using ICT for training and advisory services, and (c) mobile money services that help to save time for travel and transaction costs, are all due to increased investment in ICT. None of these services and uses are restricted to developing or emerging economies, making the impact of ICT stronger for the economic progress of developing and emerging economies than developed countries (UNCTAD, 2011). To add further, Mura and Donath (2023) confirm that growth in an economy is positively influenced by digitalization in the European Union. Elfaki and Ahmed (2024) conducted their study for selected Asian Pacific nations and reached the conclusion that the adoption of digital technology has a positive impact on economic growth. To investigate how the digital economy affects economic growth, Zhang et al. (2022) built an index of the digital economy infrastructure in Belt and Road countries using data from mobile phone subscriptions, fixed broadband subscriptions, fixed telephone subscriptions, internet users, and secure internet servers.

2.2.2 Digitalization and Financial Inclusion and Economic Growth

Daud and Ahmad (2023) also confirm the association between digitalization, financial inclusion, and rising economic growth from a macroeconomic perspective of innovation diffusion theory using the data for 84 countries. The study by Tok and Heng (2022) concludes that technological innovation in financial services significantly contributes toward reducing the digital divide between rich-poor and urban-rural, which is further associated with better economic performance. According to the study by Xi and Wang (2023), increasing the adoption and coverage of digital financial inclusion could have a major and positive impact on economic growth. The study looks into the quality of technological innovation and economic growth and confirms how digital financial inclusion affects the standard of economic growth. Liu et al. (2021) confirm the major impact that the digitalization of financial and banking services has on economic growth, and their impact has a significant Internet threshold effect. Khera et al. (2022) assess the contribution of technological innovation to financial services and innovation, and the results confirm that adopting digital technology in financial and banking services helps accelerate the goal of achieving financial inclusion. Kouladoum et al. (2022) confirm that with rising digital technology, financial inclusion has also experienced a significant improvement in Sub-Saharan Africa. Basnayake et al. (2024) conducted their study in the Asia-Pacific region to examine the impact of financial inclusion through digitalization on its economic growth. Their analysis confirmed the existence of a positive linkage among the concerned variables. Khan et al. (2022) reflect the beneficial impact of financial inclusion on economic development, poverty, sustainability, and financial efficiency for G20 countries and utilized the generalized method of moments and the autoregression distribution lag model. However, this study did not take into account the role of digitalisation along with financial inclusion. Boukhatem and Moussa (2023) examined the impact of financial inclusion and institutional quality on GDP growth. Their study incorporated three variables for the measurement of financial inclusion, i.e., domestic credit to private sector ratio, automated teller machines, and commercial bank branches. Their analysis concluded that there is no effect of these variables on economic growth and indicated that economic growth can only be facilitated by financial inclusion in nations with strong institutional frameworks.

This study differs from the large set of literature mainly in three ways. First, previous studies have primarily focused on constructing a comprehensive digitalization index to measure its overall impact on economic growth. However, the effects of individual digitalization indicators have not been adequately explored or discussed. Isolating the effect

of individual indicators can possibly help policymakers design more effective policies, as not all aspects of digitalization have an equal impact on economic growth. Few indicators, such as internet penetration or e-commerce, may have a stronger impact due to their wider access to information and reach as well as due to their broader and immediate impact on economic growth as compared to other indicators, such as secure internet servers or mobile cellular subscription or fixed broadband network. Second, our analysis focuses on the ARDL approach to find out both the short-run as well as long-run relationships among the variables in the context of G20 nations, and to the best of our knowledge, no such study has been done before keeping in mind the long-run as well as short-run relationship along with addressing the endogeneity issues. Last, from the previous studies, it was observed that numerous studies focus on the crucial part that financial inclusion performs to enhance economic growth or the impact that ICT, digitalization, and digital transformation have on economic growth and performance. But there hasn't been much discussion of how digitization along with financial inclusion affect economic growth, particularly for G20 countries, which require greater focus. G20 Countries perspective has not seen enough interest among the researchers even though the G20 consists of the world's prime economies. The G20 members are leading innovators in education and technology production, representing almost 95% of investment in R&D. In addition, regardless of numerous empirical investigations on the impact of financial inclusion and ICT on economic expansion, there has been a lack of focus on the influence of digitalization on economic growth. Therefore, our study incorporates the impact of rising digitalization on economic growth, taking into account the effect of financial inclusion.

By considering the importance of the role of digitalization on economic growth in G20 countries (United States, United Kingdom, South Africa, Türkiye, Russia, Saudi Arabia, Italy, Japan, Mexico, Germany, India, Canada, China, France, Indonesia, Argentina, Australia, Brazil, for the period 2010 to 2020, excluding European Union and Korea because of data constraints), this paper formed the research hypothesis as Hypothesis 1: Digitalization exerts a positive impact on economic growth, and Hypothesis 2: Financial inclusion exerts a positive impact on economic growth.

3. Data and Methodology

3.1 Data Sources

The analysis uses secondary data and adopts a panel data sample covering annual data between 2010 and 2020 in the case of G20 nations. The study period and sample size are determined considering data constraints for other periods and countries, and the data for secure internet servers was not available before 2010. This analysis incorporates data on the gross domestic product, digitalization, population, and investment for each of the eighteen countries. Our choice of the variables for analysis is based on the previous studies. Digitalization as proxied by secure internet servers (per 1 million people) is in line with the study of Daud and Ahmed (2023), Zhang et al. (2022), Alraja et al. (2023). Similarly, commercial bank branches per 100,000 adults as a proxy to measure financial inclusion is also shown in previous literature such as Ofoeda et al. (2024), Ozili et al. (2023), Hussain et al. (2023). We have gathered the data from the World Bank's World Development Indicator database.

We have transformed all of our data into logarithmic form because of two reasons. Firstly, it can assist in removing any seasonality that is available in the data. Secondly, every variable is in growth form and can be usefully compared with one another. The variable name and their notation are presented in Table 1. The outcome variable is the gross domestic product. The explanatory variable includes the Digitalization level of each country, which is proxied by Secure Internet servers. Each country's financial inclusion level is proxied by commercial bank branches per 100,000 adults, the population of a country, and Gross fixed capital formation for each country.

Table 1- Description of Variables

Variable	Symbol	Measurement	Sources
Gross Fixed Capital Formation	LGFCF	Gross Fixed Capital Formation (% of GDP)	WDI
Population	LPOP	total population of a country	WDI
Digitalization	LSIS	Secure internet servers (per 1 million people)	WDI
Digitalization (for robustness)	LINT		WDI
Commercial Bank Branches	LCB	commercial bank branches per 100,000 adults	WDI
Gross Domestic Product	LGDP	GDP at constant 2015 US$	WDI

Note: WDI-World Development Indicator, published by the World Bank

3.2 Analytical Framework and Methodology

Standard production function can be used to study the relationship between digitalization and economic growth. The production function is as follows:

$$Y = f\,(K\,,\,L) \qquad (1)$$

Here, output, capital and labour are represented by Y, K and L respectively. According to Daud and Ahmad (2023), level of financial inclusion and digitization in an economy affect the economic growth of a country in the long run. Hence, the present study includes the level of digitalization and financial inclusion as an important factor determining growth of a nation. Further, our study also includes Gross Fixed

capital formation and total population of a country in growth function as previous studies have found the existence of significant relationship between gross fixed capital formation and economic growth (Ali, 2015); and also, between population and economic growth (Peterson (2017); Becker et al. (1999)).

$$Y = f\ (SIS, CB, GFCF, POP) \quad 2)$$

Here, Cobb-Douglas production function is used to study the growth equation for G20 nations for period ranging from 2010 - 2020.

$$GDP_{t-1} = \alpha_t GDP_{t-1}^{\beta 1} GfCF_{t-1}^{\beta_2} POP_{t-1}^{\beta_3} SIS_{t-1}^{\beta 4} CB_{t-1}^{\beta_5} \quad (3)$$

where $\beta 1$, β_2 , β_3 , β_4 and β_5 represents the elasticity coefficients of the GDP of lagged period, gross fixed capital formation, population, secure internet servers and commercial bank branches respectively. Next, natural logarithms is taken on both sides of the equation. Logarithmic conversion of variables helps with seasonal adjustment, their magnitude change and result interpretation with the use of elasticity.

3.2.1 Panel ARDL Framework

Next, we have used the panel auto-regressive distributed lag (PARDL) model to show the dynamic relationship between digitalization and economic growth among G20 countries. We have chosen this model mainly because of three reasons. Number one, our aim is to show the impact of digitalization on economic growth both in the short-run as well as long-run respectively. Number two, this model is suitable to remove the endogeneity issues that are present in the model. Number three, this model is applicable when the variables are in the same order of mix of both I(0) and I(1) (Pesaran and Shin 1998). The panel ARDL model is explained in the following equation.

$$LGDP_{it} = \alpha_i + \sum_{i=1}^{p} \beta_1 LGDP_{i,t-1} + \sum_{i=0}^{q} \beta_2\, LGFCF_{i,t-1} + \sum_{i=0}^{r} \beta_3 LPOP_{i,t-i} + \sum_{i=0}^{s} \beta_4 SIS_{i,t-i} + \sum_{i=0}^{u} \beta_5\, CB_{i,t-i} + \mu_{it} \quad (4)$$

$$\Delta LGDP_{it} = \alpha_i + \sum_{i=1}^{p} \beta_1 \Delta LGDP_{i,t-1} + \sum_{i=0}^{q} \beta_2\, \Delta LGFCF_{i,t-1} + \sum_{i=0}^{r} \beta_3 \Delta LPOP_{i,t-i} + \sum_{i=0}^{s} \beta_4 \Delta SIS_{i,t-i} + \sum_{i=0}^{u} \beta_5\, \Delta CB_{i,t-i} + \vartheta ECM_{it} + e_{it} \quad (5)$$

Where i and t show the G20 countries and time, respectively. The long-run coefficient of the variables is presented in Equation 5 and the short-run coefficients are presented in Equation 6, and shows the error correction term.

Our choice of using panel ARDL model is based on the following advantages that this methodology possess: First, panel ARDL approach allows to examine dynamic interactions over time along with addressing long-run equilibrium relationships. Second, Panel ARDL is a useful option for analysing heterogeneous groups since it permits varying intercepts and slopes across cross-sectional units. Third, panel ARDL is also helpful when we are dealing with small-sample sizes, as is the case in our study. Further, this approach can handle both I(0) and I(1) variables, which is also the case in our study.

4. Result analysis and Discussion

Table 2 displays the findings of our investigation, which began with a summary of descriptive statistics. It depicts that the average value and standard deviation of log GDP at constant 2015 US$ for sample countries were 12.26 and 0.42, respectively. The sample featured a wide range of log GDP at constant 2015 US$, with the highest being 13.29 for the United States in 2019 and the lowest being 11.49 for South Africa in 2010. Here, we observe that the average value for the population is highest among all the variables with a standard deviation of 0.48, whereas the standard deviation for the variable secure internet servers is more than all the other variables with a mean value of 4.91. For commercial bank branches, the mean value and the value of standard deviation were found to be 1.28 and 0.23, respectively. Further, our descriptive statistics reveal that LGFCF, LPOP, LCB, and LGDP show relatively low variability (with standard deviations typically below 0.5), indicating that these variables exhibit some degree of consistency across the sample, whereas LSIS has a higher standard deviation (1.07), reflecting a more diverse range of values for secure internet servers across different regions.

In the next step, we conducted the panel unit root test to avoid spurious results. The results for the same are presented in Table 3. The finding shows that there is a mixed order of stationarity. Some of the variables, such as LGFCF, LPOP, and LGDP of G20 nations, are becoming stationary at level form, and the rest of the variables, such as LSIS and LCB, are stationary at first order difference form. Once we have confirmed the integrated form of the concerned variables, then in the next step, we have conducted the panel ARDL model, and the results for the same are given in Tables 4 and 5, respectively.

Table 2- Summary of Descriptive Statistics

Variable	Mean	Maximum	Minimum	Std. Dev	No. obs.
LGFCF	1.35	1.65	1.14	0.11	198
LPOP	8.05	9.15	7.34	0.48	198
LSIS	4.91	7.67	2.56	1.07	198
LCB	1.28	1.77	0.89	0.23	198
LGDP	12.26	13.29	11.49	0.42	198

Note 1: Author's own calculation, No. obs indicate the number of observations and Std.Dev is the standard deviation

Note 2: LGFCF, LPOP, LSIS, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of secure internet servers, log of commercial bank branches, and log of gross domestic product, respectively

Table 3- Results of Panel Unit Root Test

Variable	Level	Ist Difference	Inference
LGFCF	-4.98*** (0.00)	---	I(0)
LPOP	-2.76*** (0.00)	---	I(0)
LSIS	0.82 (0.79)	-5.02*** (0.00)	I(1)
LCB	2.41 (0.99)	-3.38*** (0.00)	I(1)
LGDP	-2.95*** (0.00)	---	I(0)

*Note 1: H_0 is the Unit root; *** indicates significant at 1 percentage level.*

Note 2: LGFCF, LPOP, LSIS, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of secure internet servers, log of commercial bank branches, and log of gross domestic product, respectively

We use the panel ARDL model mainly because of three reasons. First, our variables are in a mixed order of stationarity. Second, we aim to show the dynamic relationship among them in the short run as well as in the long run. Finally, the panel ARDL provides robust results in the case of a small sample period. In the next step, our paper shows the results of the long-run elasticity coefficients and short-run elasticity coefficients of the panel ARDL approach. The results are presented in Tables 4 and 5, respectively. The findings reveal that the variable secure internet servers exert a positive influence on GDP with a one percent significance level in the long run. But this long run impact of secure internet servers on economic growth is very small, which could be due to large expenses incurred on setting up and maintaining secure internet servers. This might shift the focus on meeting security standards rather than on developing new products and also divert resources from growth and innovative initiatives, thereby slowing or impeding economic growth. Further, this could also be due to improper knowledge regarding how to use and work with newly developed technology (Yousefi. 2011, Kumari and Singh. 2024). On the other side, the relation between the relationship between secure internet servers and economic growth is negative in the short run. This pattern may indicate a transitional phase in which the economic benefits from investments in secure servers take time to materialize i.e., from initial investment costs and adjustment periods to delayed and long-term benefits of the secure internet servers. At the initial stage, large upfront investments in infrastructure, technology, and training in order to implement secure internet servers may increase the expenses of the government and have to divert funds from other investments. This can lead to temporary decline in the GDP in the short-run. Gradually the long-term advantages of secure internet servers, such as improved customer confidence, decreased fraud, and increased efficiency can bring the potential to produce long-term economic growth. Our study's outcomes correspond with earlier research. For instance, Daud and Ahmad (2023) confirm digital technology has minimal effect on economic growth. But, if taking squared form of digital technology component into consideration, this exerts significant impact on nation's economic growth at the one percent significance level. According to Kallal et al. (2021), there is a short-term negative impact of the ICT variable on economic growth, but a long-term favourable influence, which further could be explained by the fixed cost of initial investment, followed by large scale economic growth over the period of time. Another explanation might be the phenomenon of time lag effect, according to which it takes time for benefits ICT dissemination to come around gradually (Kallal et al., 2021) and with the infrastructural improvements, the positive impacts would then be percolated to different sectors and lead to rise in economic growth. In addition, this short-term and long-term relationship between digitalization and financial inclusion is also in line with the innovation diffusion theory by Everett Rogers (1995) which emphasizes the need to understand the speed with which the technologies bring advancements into an economic system and the major role that time plays so as to bring benefit to the nation and its people.

Next, the findings reveal that, with a significance level of 1%, a negative relationship has been found over the long term between commercial bank branches and economic growth, whereas, a positive relationship occurs in the short term. This might be due to a decrease in the number of commercial bank branches for all the nations in our sample. Further, at the initial stages, increasing the number of commercial bank branches can boost economic expansion in the near future because having more branches could make banking services more accessible, making loans and credit easier for both individuals and companies. More investment and expenditure may result from this improved access, which would stimulate economic activity. Physical branches may become less relevant as financial technology, digital banking, and digital financial services become more widely used. As a result, their impact on economic growth may also diminish. Our results are corroborated by the findings of Tongurai and Vithessonthi (2018), Contreras et al. (2022), Granja et al. (2017), Kang et al. (2015), and Ranthana and Selvi (2023). In this context, Tongurai and Vithessonthi (2018) confirm that the expansion of the banking industry has an adverse influence on the progress of the agricultural and no effect on the industrial sectors. Contreras et al. (2022) corroborate the negative impact of bank failures on the increase in income disparity. This also had significant implications for local economic upsurge and economic balance or stability. Subsequently, previous studies have also identified the socio-economic impacts and financial costs that bank failures exert (Granja et al., 2017; Kang et al., 2015). Ranthana and Selvi (2023) also confirm the negative relationship between the lagged value of the number of branches and economic growth, depicting financial disintermediation efficiency and further explaining that the scarcity of bank branches would result in limited access to financial services, especially for rural and underserved regions.

Table 4- Results of Long-run Elasticity of Panel ARDL

Dependant variable-LGDP

Variable	Coefficient	t-Statistics	P-Value
LGFCF	0.28***	48.30	0.00
LPOP	2.19***	16.07	0.00
LSIS	0.018***	42.83	0.00
LCB	-0.09***	-3.82	0.00

*Note 1: *** indicates significance level of 1%.*

Note 2: LGFCF, LPOP, LSIS, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of secure internet servers, log of commercial bank branches, and log of gross domestic product, respectively

Table 5- Results of Short-run Elasticity of Panel ARDL

Dependant variable-ΔLGDP

Variable	Coefficient	t-Statistics	P-Value
ΔLGFCF	0.05	0.44	0.65
ΔLPOP	94.08	1.41	0.16
ΔLSIS	-0.02*	-1.84	0.06
ΔLCB	0.43	1.44	0.15
Constant	-4.17**	-2.21	0.02
ECM(-1)	-0.72**	-2.23	0.02
CD	32.37*** (0.00)		
Residual	I(0)		
Jarque-Bera	2.32 (0.31)		
Wald Test	42.35*** (0.00)		
Number of observations	198		

*Note: ***, ** and * show significant at 1, 5 and 10 percentage levels, respectively.*

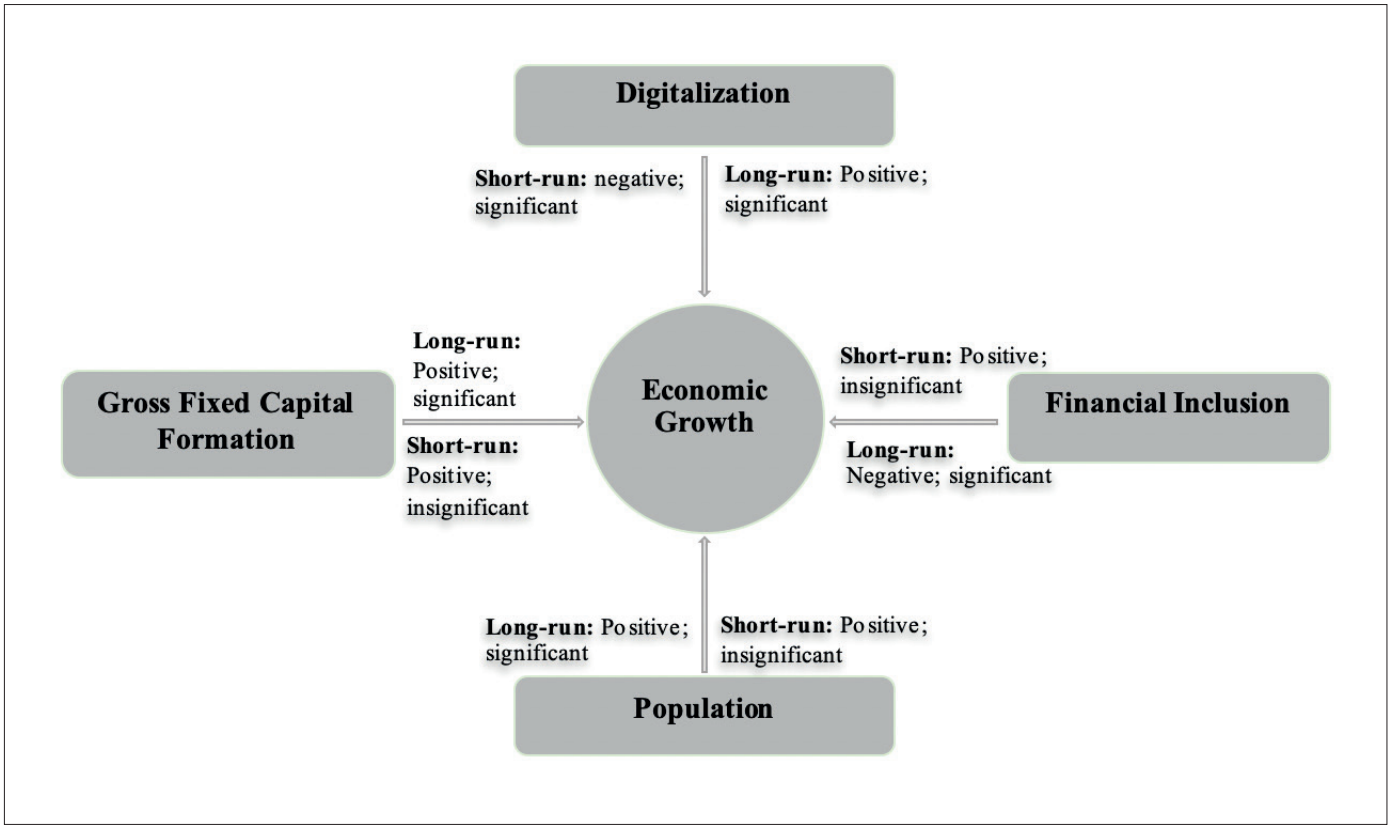
Note 2: LGFCF, LPOP, LSIS, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of secure internet servers, log of commercial bank branches, and log of gross domestic product, respectively. ECM stands for error correction model.

In addition, a positive and significant relationship has also been observed between population and GDP over the long run, whereas in the short run, our analysis does not find any significant relationship between population and economic growth. This impact in the short term can be attributed to the strain on resources and the adjustment time. Rapid population growth could strain the available resources and infrastructure, leading to issues like homelessness, inadequate public services, and unemployment that would cancel out any GDP gains and have a short-term damaging effect on economic growth. Conversely, market expansion, innovation, and entrepreneurship are responsible for the population's long-term beneficial effects on economic growth; mainly because expanding populations can increase workforces and therefore productivity. Increased population can result in increased demand for products and services, which can spur business growth and investment. This also aligns with previous literature such as Peterson, (2017) and Becker et al. (1999). It is clear that population growth plays a very important role in enhancing economic growth and also positively impacts growth in per capita output. Though, rapid population growth may have some deteriorating behavior on GDP growth in a short period. However, when these young people become productive, and with the changes in demographic dividend, the rising population's positive behavior on growth would be observed (Peterson, 2017). Similarly, Becker et al. (1999) confirm that due to more use of land and natural resources, the rising population might bring down productivity, but if investments are made towards greater specialization and knowledge enhancement, this rising population may exert a significant positive impact. In contrast, Khan et al. (2021) analysed the role of population growth and energy trilemma on economic growth. Their analysis concluded that the relationship between population growth and economic growth would only exist in the long run. However, their results conclude a negative relationship between population and economic growth because the increase in population by more than a level may lead to more consumption of natural resources and fossil fuels extraction, hence damaging the long-term growth prospects. In addition, Ajayi et al. (2024) reflect that population growth for more than optimum levels may lead to various economic repercussions and over-exploitation of mineral resources, thereby having a negative impact on economic growth.

Similarly, our analysis shows that in the long run, the relationship between gross fixed capital formation and economic growth turned out to be positive and significant. The reason can be explained as economic growth results from a rise in physical capital, human capital, and investment in technological upgradation, which contributes to higher productivity and a high level of economic growth. Further,

the increasing trend of gross fixed capital formation can improve economic growth by boosting investments and their spillover impact on knowledge, technology, and information that help expand the economy (Ali, 2015). Topcu et al. (2020) found positive impact of capital formation on economic growth for the long period in the case of high-income countries. Similar are the finding of Kesar et al. (2022) and Azam et al. (2023) for gross capital formation and economic growth. However, our study reveals insignificant relationship between gross fixed capital formation and economic growth in the short-run. This could be due to time lag and capacity utilization, wherein, fixed capital investments can take time to yield profitable results and might not pay off right away, which would explain their short-term lack of association with GDP growth. Further, an economy may not immediately see an increase in output from new capital formation if it is already running below capacity. This finding our study is line with Hartwig (2010) and Yasmeen et al. (2021). Both these studies concluded insignificant relationship between gross fixed capital formation and economic growth.

Figure 1: Findings of the study



Source: Author's own construction

Finally, we find the speed of adjustment coefficient, which is the one-period lagged error correction term, is negative and significant. Therefore, our results are stable and robust. The result shows that about 72 percent adjustment per annum is covered to converge the long-run equilibrium. The residual diagnostic test has also been conducted, satisfying all the diagnostic tests; hence, our results are reliable. In addition, we have also conducted robustness analysis by using internet users as proxy for digitalization in place of secure internet servers and again employed panel ARDL methodology for the analysis.

4.1 Robustness Analysis

We have replaced the proxy variable employed for estimating the degree of digitization in order to verify robustness. Here, for robustness, we have used internet users (per 100 people) as a proxy for digitalization. Results for the same are presented in Table 6 and Table 7, showing the long-run and short-run elasticity of Panel ARDL, respectively.

Table 6- Results of Long-run Elasticity of Panel ARDL

Dependant variable-LGDP

Variable	Coefficient	t-Statistics	P-Value
LGFCF	0.61***	4.46	0.00
LPOP	0.48	1.38	0.17
LINT	1.54***	3.77	0.00
LCB	-0.48***	-3.62	0.00

*Note 1: ***, ** and * show significant at 1, 5 and 10 percentage levels, respectively.*

Note 2: LGFCF, LPOP, LINT, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of internet users, log of commercial bank branches, and log of gross domestic product, respectively.

Table 7- Results of Short-run Elasticity of Panel ARDL

Dependant variable-ΔLGDP

Variable	Coefficient	t-Statistics	P-Value
ΔLGFCF	0.28**	2.48	0.015
ΔLPOP	9.16	1.56	0.12
ΔLINT	0.001	0.03	0.97
ΔLCB	0.07	0.44	0.66
Constant	-0.49***	-3.03	0.00

*Note: ***, ** and * show significant at 1, 5 and 10 percentage levels, respectively.*

Note 2: LGFCF, LPOP, LINT, LCG, and LGDP represents log of gross fixed capital formation, log of total population, log of internet users, log of commercial bank branches, and log of gross domestic product, respectively.

The outcomes demonstrate that, at a one percent significance level, internet users have a positive long-term impact on GDP. The results show that internet users have a negligible short-term impact on economic development (0.001). However, this impact is insignificant. This is similar to our previous result, where secure internet servers have significantly negative impact on the economic growth in the short-run and positive impact in the long-run. The outcomes we have presented support our hypothesis about the impact of digitalization on both short- and long-term economic growth. Further, the results show that at a significance level of 1%, there is a a long-term negative correlation between commercial bank branches and economic expansion, but a short-term positive correlation. To add further, a positive and non-significant relationship has also been observed between population and GDP over the short-run as well as the long-run period. Last, our analysis shows that in the long run as well as short run, the relationship between gross fixed capital formation and economic growth turned out to be positive and significant. The results obtained from robustness analysis shows that our finding in the context of examining the relationship between digitalization, financial inclusion, population growth, gross fixed capital formation and economic growth gives robust results, and these results could further be used for policy implications.

5. Conclusion and Policy implications

Throughout the last three decades, developments in technology have led to the beginning of the Fourth Industrial Revolution, or Industry 4.0. Digitalization is a foundational component of Industry 4.0, providing the necessary technological advancements and data-driven approaches that enable the realisation of smart, interconnected, and highly efficient industrial systems. Digitalization in the banking industry contributes to better financial services, processes, and products being more easily accessible, quicker to process, and safer for customers than they were in the past. With the rising trend of digitalization level, economic growth may observe a significantly positive outcome due to enhanced levels of productivity and efficiency due to less information asymmetry. Therefore, our study investigates the dynamic relationship between digitalization and economic growth for G20 nations between 2010 and 2020. Using the Panel Auto Regressive Distributive Lag model, we arrive at the long-term, positive, and substantial conclusion that digitalization and economic growth are positively correlated. In contrast, the result shows a negative relation between them for short-term. Subsequently, we discover a short run positive relation between the number of commercial bank branches and economic growth. In contrast, this influence is negative over the period of time. Furthermore, the result concludes that the impact of population and gross-fixed capital formation on economic growth is positive in the short and long run, respectively.

The finding of the paper is important in promoting digitalization and financial inclusion to ensure that banks and financial institutions can potentially help contribute to economic growth. From the policy perspective, this study suggests that, while digitization undoubtedly plays an important role in economic growth, we must also increase infrastructural investment to maintain momentum towards sustainable development. To consistently meet people's expectations for unique financial services, there is a need to speed up the innovation of finan-

cial goods and services. More precisely, bringing in technological innovation into the delivery of financial services must be associated with optimal growth performance. In addition, governments ought to encourage digital financial literacy, particularly among young people, to maximize the benefits of these digitalized services for the general public and to facilitate banking services for those living in remote areas. Policy initiatives need to be devised to increase the proliferation of financial technology in addition to traditional measures to lessen unethical behaviour, support democratic processes, manage the shadow banking sector, and minimize monetary and economic threats.

6. Limitation and Future Scope of the Study

The limitations and future scope of our study are as follows: First, our research majorly focuses on a single proxy for measuring digitalization, i.e., a secure internet server for the main analysis and internet users for robustness analysis. However, for future scope, studies could also include other variables related to digitalization, such as mobile cellular or fixed broadband subscription, and can study their individual as well as combined effects, which could help to get a more comprehensive picture of its influence on the economy's expansion. Second, our analysis is only limited to the time period ranging from 2010 – 2020 due to data constraints. Third, our study excludes the European Union and Korea because of data unavailability of secure internet servers for Korea as well as for the European Union, it comprises 27 countries of Europe, and our study already includes 3 of these countries, i.e., France, Italy, and Germany. Therefore, including the European Union in our analysis might give us biased results due to data repetition. Future studies can widen their time span and examine the relationship among the concerned variables with large data periods. Lastly, this study is limited to the panel ARDL method. The other panel data model can be used to show the dynamic relation among them.

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