The Impact of the Digital Economy on Economic Growth in Singapore: An Econometric Study for the Period 1998-2021

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Abstract

The study aimed to highlight the impact that the digital economy can have on economic growth in Singapore during the period 1998–2021. The econometric model includes GDP per capita as a proxy for economic growth, along with three explanatory variables: capital, human capital, and mobile phone subscriptions. The study concluded that the digital economy in Singapore has contributed to achieving the country's economic growth through a set of technologies and mechanisms that have helped create a diversified economy. Capital, human capital, and mobile phone subscriptions all had a positive effect on economic growth in Singapore during the period under study. In light of these results, the importance of these variables in the digital economy and the role they play in enhancing the country's economic growth become evident.

Keywords: Digital economy, capital, human capital, mobile phone, economic growth.

1. Introduction: In light of the economic revolution and the growing digital developments in information and communication technology witnessed by the global economy in recent years, along with their increasing use by countries around the world, what is known as the digital economy has emerged—especially after the outbreak of the COVID-19 pandemic, which had a significant impact on various economic activities worldwide. This situation forced most global companies to adopt a remote work culture, prompting most countries to race toward transitioning from a traditional economy to a digital economy, as it is considered one of the most prominent means of improving individuals' quality of life, facilitating numerous transactions, and ensuring the stability of economic growth.

Among the countries that have adopted the transition to the digital economy is Singapore, which has become a model to be emulated in embracing the digital economy with the aim of advancing its economy and achieving accelerated

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economic growth. This success is attributed to its adopted strategy, which is based on supportive legislative and institutional frameworks for the digital economy, such as the establishment of a Ministry of Digitalization and the development of digital infrastructure to ensure a high level of digitalization across various sectors—particularly economic ones—enabling the country to confront various crises. This has been achieved through investment in human capital, which has become an effective element in the digital economy and a contributor to enhancing economic growth rates.

A. Research Problem: Through this research paper, we attempt to answer the following question: To what extent does the digital economy affect economic growth in Singapore during the period 1998–2021?

B. Hypotheses:

- There is a positive relationship between (capital, human capital, and mobile phone subscribers) and economic growth in the long run in Singapore during the period 1998–2021.
- There is a positive relationship between (capital, human capital, and mobile phone subscribers) and economic growth in the short run in Singapore during the period 1998–2021.

C. Study Objectives: The study seeks to achieve the following objectives:

- To identify the theoretical literature on the digital economy and economic growth;
- To understand the relationship between the digital economy and economic growth;
- To attempt to measure the impact of the digital economy on economic growth in Singapore during the period 1998–2021;
- To propose recommendations and suggestions for the transition to a digital economy in order to achieve economic growth.

D. Significance of the Study: The importance of this study lies in highlighting the reality and mechanisms of the transition toward the digital economy and its impact on economic growth in Singapore during the period 1998–2020. This is due to the growing global interest in digital transformation in the economic field.

E. Study Methodology: To achieve the objectives of this study, the descriptive–analytical approach was adopted through describing the study variables (digital economy and economic growth). In addition, the econometric approach was used to measure the impact that the digital economy can have on economic growth in Singapore during the period 1998–2021.

1. Theoretical Foundations of the Study Variables

1.1 The Digital Economy: The term "digital economy" first appeared in 1995, coined by the Canadian author Don Tapscott in his book published in English, *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*. Subsequently, the concept was addressed by many writers and researchers who differed in their terminology: some referred to it as the Internet economy, others as the knowledge economy, and others as the information economy, among other names. One of its most important characteristics is the transformation of goods and products from a tangible physical form into a digital form, making them easier to store as numerical data and enabling them to be exchanged in the digital marketplace.

1.1.1 Concept of the Digital Economy:

There are multiple definitions of the digital economy, the most prominent of which are the following: In 2013, the European Commission defined the digital economy as the economy built on and connected to the Internet and all related digital activities. In 2016, the G20 provided a broader definition of the digital economy to include all economic activities that use digital information and knowledge (Doubabi & Belmahdi, 2022).

- The digital economy is defined as "an economy that is based on digital information technology and employs information and knowledge in its management as the new resource of the revolution and a source of inspiration for new innovations" (Kabir & Boualaqa, 2021).
- The digital economy is "the interaction, integration, and coordination between information technology and communication technology on the one hand, and the national and international economy on the other, in a manner that achieves immediate transparency and accessibility of all prevailing indicators for all economic, financial, and commercial decisions in the state over a given period" (Al-Najjar, 2007).

The digital economy does not merely represent the use of computers to perform traditional or manual tasks. Rather, it plays a prominent role in revealing all opportunities and urgent needs to organizations and individuals, encouraging them to use digital technologies in order to perform these tasks more efficiently, with higher quality, in a shorter and faster time frame, and with outputs that are entirely different from what existed previously (Al-Kawaz & Nagham, 2021).

According to the researchers, the digital economy is a knowledge-based economy that does not rely on traditional capital; its sole capital consists of information, creativity, and innovation. It is based on ideas and creativity rather than physical assets. It provides benefits to citizens by facilitating access to various services needed from different institutions and administrations, and it also simplifies government transactions in a faster, clearer, and more transparent manner. It has become an inevitable necessity that cannot be dispensed with or bypassed due to the deep integration of information and communication technologies in human life. It is termed the "digital economy" to refer to the economy based on the Internet and the web, dealing with digital data, digital information, and digital companies. Moreover, it generates wealth through intangible, knowledge-based processes and services, relying on human competencies.

1.1.2 Characteristics of the Digital Economy:

The digital economy is characterized by a set of features, most notably the following (Kharoubi, 2022):

- The digital economy enables the creation of appropriate technologies to establish virtual markets and enterprises in which the boundaries of time and place are eliminated, such as e-commerce, which offers many advantages including cost reduction, increased efficiency, and speed;
- The digital economy is characterized by the creation of information, which gives information technology a fundamental role in increasing economic growth rates and domestic and international e-commerce. The Internet also affects the methods of conducting commercial transactions and work;
- The digital economy enables control over information and its effective use and employment in serving economic decisions and policies;
- The digital economy is one in which the application of tax laws and tariff and non-tariff restrictions is difficult.

1.1.3 Requirements of the Digital Economy:

The World Bank has provided a general framework through which clear strategies for digital transformation processes can be developed, as follows (Qarin, 2022):

- The existence of an economic and institutional system that provides incentives for the use of available knowledge;
- The availability of skills and human resources necessary for creating, using, and sharing knowledge;
- The availability of a dynamic information infrastructure to facilitate the dissemination and processing of information;

- The provision of a highly efficient innovation system for institutions, research centers, consultants, and other organizations, enabling access to knowledge repositories, the absorption of these innovations, their adaptation to local needs, and the creation of new technologies.

1.1.4 Drivers of the Shift toward the Digital Economy:

There are many drivers and justifications for the transition toward the digital economy, the most important of which are the following (Qarin, 2022):

- The growing role of knowledge as a key source of wealth and a main generator of added value;
- Markets and products have become more globalized;
- Increased reliance on the information and knowledge revolution in production, as in advanced economies more than 70% of workers are knowledge workers;
- The increasing spread of networks such as the Internet has made the world resemble a single village more than ever before;
- The emergence of the concept of intellectual capital based on knowledge and learning;
- The liberalization of global trade and the expansion of opportunities for foreign direct investment;
- Intensified competition in the business environment, which has forced institutions to search for new ways to increase efficiency, including the use of new markets.

1.1.5 Pillars of the Digital Economy:

The digital economy is based on four main pillars, as follows (Zawatnia, 2022):

- Technical infrastructure and equipment;
- The existence of a regulatory legal environment for the digitalization sector;
- The ability of the financial sector to provide and develop investments and venture capital to support and promote smart ideas;
- Real capital represented by human resources concerned with the education and training sector.

With regard to the role of the global communications network (the Internet) within the digital economy, this network is considered one of the most important technological revolutions of the modern era. It has led to fundamental transformations in all areas of life, especially in the economic field. The current era has become the era of the Internet economy, and the Internet has become the foundation upon which all transactions in the digital age are based, particularly with the spread of globalization and the internationalization of production and markets—that is, within the framework of the digital economy.

The Internet is also considered one of the most important automated means in the field of information exchange and the completion of commercial operations and transactions, as it provides numerous advantages that have greatly influenced methods of managing both the international and domestic digital economy, as well as the management of multinational corporations in their various forms. Consequently, it affects the life of the individual, the family, and society, and is considered a gateway for accessing vast amounts of information (Fawzi Al-Jundi & Ahmed Hanfi, 2022).

2.1 Economic Growth

2.1.1 Concept of Economic Growth:

There are numerous definitions of economic growth, including the following:

According to Osama Bashir Al-Dabbagh and Atheel Abdul-Jabbar, economic growth is "the continuous increase in an economy's capacity to produce the goods and services desired by society. Since the productive capacity of the economy depends on the available resources in both quantity and quality, it also depends on the level of available resources and technology. The process of economic growth fundamentally involves an increase in the quantity of these available resources as well as an improvement in their quality" (Al-Dabbagh & Atheel Abdul-Jabbar, 2016).

Salman Al-Dulaimi defines economic growth as "the increase in the size of gross national product or gross domestic product over a specific period of time, most often measured annually" (Salman Al-Dulaimi, 2015).

The Relationship between the Digital Economy and Economic Growth:

The digital economy represents a new approach to conducting economic activities through the use of digital technology, represented by the global network of communications and information (the Internet), computer technologies, and smartphones, with the aim of increasing and improving economic growth by developing various economic sectors. This is in addition to producing intangible digital goods, such as software, using digital technological and computer-based tools and methods.

The digital economy also represents a new stage in the evolution of economic systems, as it is based on and driven by human knowledge. It is an advanced phase of the knowledge economy and depends on the extent of technological penetration into economic activities and sectors, as well as the degree to which countries benefit from the technological and information revolution and the new industries, discoveries, and advanced technologies it has generated.

Among the theories that explain long-term growth is the neoclassical growth theory, which emphasizes that growth results from economic activities that generate knowledge and new technological development. In the long run, the rate of economic growth and the growth rate of output per capita depend on the growth rate of total factor productivity, which is in turn determined by the rate of technological progress.

Most growth theories are expressed using the following equation:

$Y = A K$, where **A** represents the factor affecting technology, **K** includes the factor influencing economic growth, and **Y** represents output. Endogenous growth theories further emphasize the importance of savings and investment in human capital to achieve rapid growth in developing countries. The models of Romer (1986), Lucas (1988), and Romer (1990) are among the classical growth models (Abdulrahman Faraj, 2022).

2. Measuring the Impact of the Digital Economy on Economic Growth in Singapore (1998–2021)

2.1 Presentation of the Methodological Framework of the Econometric Study:

To conduct the study, it is necessary to identify the spatial and temporal boundaries, determine the variables related to the study and their sources, and specify the statistical programs and tools used in the analysis.

Design of the Econometric Study:

This study focuses on measuring the impact of the digital economy on economic growth in Singapore. The study period was estimated at 24 years, spanning from 1998 to 2021, due to the availability of data during this period and the emergence of the digital economy in its early years. The study variables were selected based on previous studies and economic theories.

2.1.2 Description of Study Variables and Specification of the Mathematical Form of the Model:

Based on economic theory and growth-explaining theories, it is evident that not all variables influencing economic growth can be included. Therefore, previous studies on the subject were consulted, through which a set of digital-economy-related variables that may affect economic growth were identified.

Description of the Study Variables:

The dependent variable to be estimated in this study is GDP per capita, representing economic growth in Singapore during the period 1998–2021, denoted by **GDPp**.

The explanatory variables adopted in this study were determined based on various economic theories, in addition to previous studies that addressed the impact of the digital economy on economic growth. Accordingly, a set of variables was selected, taking into account data availability across different statistical sources. These variables are:

- **(LK):** Represents the logarithm of capital.
- **(LHC):** Represents the logarithm of human capital.
- **(LMC):** Represents the logarithm of mobile phone subscriptions, defined as subscriptions that provide access to the public switched telephone network using cellular technology. This indicator applies to all mobile cellular subscriptions offering voice communication services. It excludes data-only subscriptions, USB modem subscriptions, subscriptions to public mobile data services, private trunked mobile radio, public payphones, paging services, and telemetry services.

Specification of the Mathematical Form of the Model:

This model aims to study and identify the most important variables that affect economic growth in Singapore. It is based on economic theory and previous studies. Accordingly, the model can be written in the following form:

$$\boldsymbol{LGDPp = f(\ LK, LHC, LMC)}$$

The study relies on time-series data for the variables included in the model over the period 1998–2021.

Table 1: Information on the Data Used in the Estimation Process

Variable Symbol	Variable Name	Variable Type	Source
LGDPp	GDP per capita representing economic growth	Dependent	World Bank Database, World Development Indicators (2022)
LK	Capital	Independent	–
LHC	Human capital	Independent	–
LMC	Mobile phone subscriptions	Independent	–

Source: Prepared by the researchers based on the study data.

According to the study methodology, the mathematical form of the model can be rewritten as follows:

$$\boldsymbol{FLGDPP_t = a_0 + \sum_{i=1}^{m} a_{1i}\, LK_{t-i} + \sum_{i=0}^{m} a_{2i}\, LHC_{t-i} + \sum_{i=0}^{m} a_{3i}\, LMC_{t-i} + \varepsilon_t \ldots\ldots (01)}$$

2.2 Testing the Stationarity of Time Series

The examination of time-series stationarity is a preliminary step that must be addressed before applying the ARDL methodology. The stationarity of the time series was examined using both the Augmented Dickey–Fuller (ADF) test, in order to eliminate autocorrelation of errors, and the Phillips–Perron (PP) test, to further confirm the degree of stationarity of the time series. The PP test is particularly suitable when the sample size is small and is used to validate the results of the ADF test.

Table 2: Results of the Unit Root Test for the Study Variables at Level and First Difference

At Level

Variables	PP Test	ADF Test	Result
LGDPP	(various model values shown)	(various model values shown)	Non-stationary
LK	(various model values shown)	(various model values shown)	Non-stationary
LHC	(various model values shown)	(various model values shown)	Non-stationary
LMC	(various model values shown)	(various model values shown)	Non-stationary

At First Difference

Variables	PP Test	ADF Test	Result
d(LGDPP)	Significant at 1%	Significant at 1%	Stationary
d(LK)	Significant at 1% / 5%	Significant at 1% / 5%	Stationary
d(HC)	Significant at 1%	Significant at 1%	Stationary
d(MC)	Significant at 1% / 5%	Significant at 1% / 5%	Stationary

*** Significant at 1%, ** significant at 5%, * significant at 10%.
[] Indicates the probability value (p-value), which represents the level of significance corresponding to the t-value of the variable with one lag.

Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendix (01).

After conducting the stationarity tests for the studied variables using the Phillips–Perron (PP) test, the results presented in Table 2 indicate that the time series of all model variables are non-stationary at level and contain a unit root, i.e., they are integrated of order I(1). However, the variables become stationary at the first difference, meaning that the data are free from unit roots and do not suffer from spurious regression, and thus are integrated of order I(1).

2.3 Estimation and Diagnostic Testing of Model Quality and Results

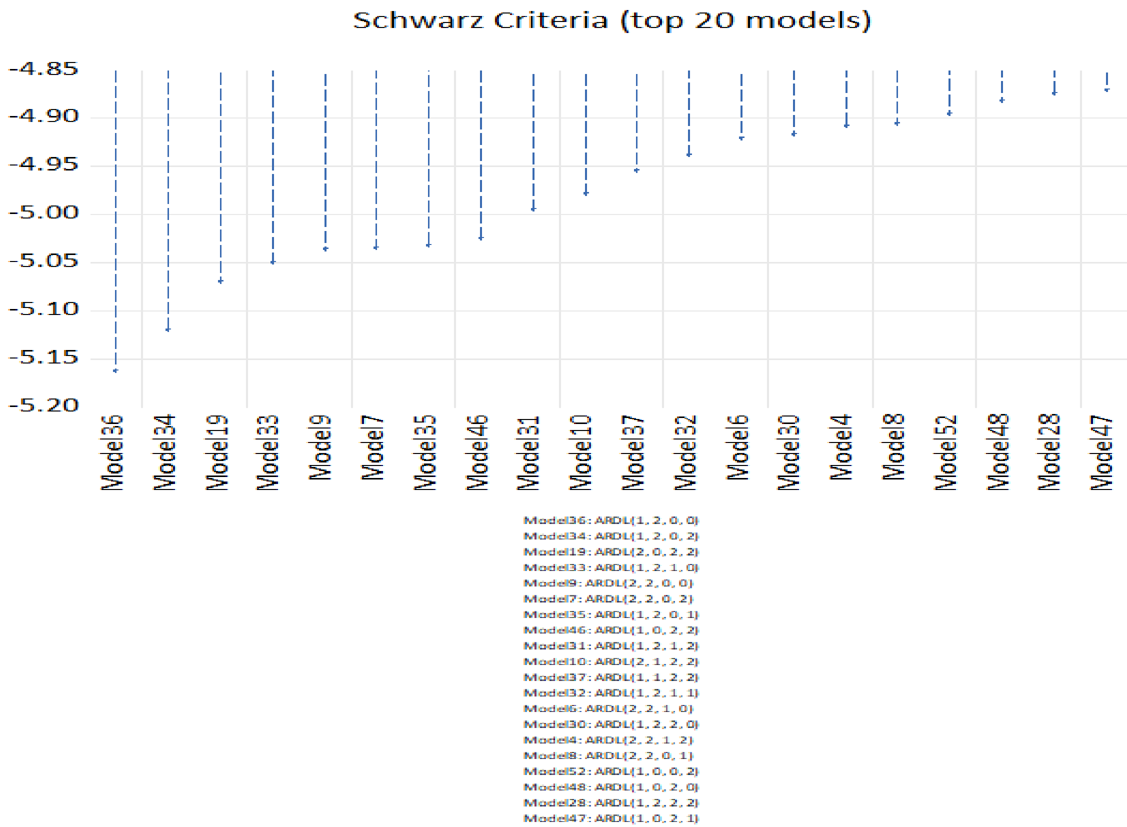
2.3.1 Model Estimation:

After confirming that the series are not integrated of order two, we proceed to the second step, which involves determining the optimal lag length and conducting the bounds test, as follows:

Determination of the Lag Length for the ARDL Model:

Based on the automatic selection feature in the EVIEWS 12 software, and by setting the maximum number of lags while maintaining the maximum amount of information, the following lag orders were obtained according to the ordering of variables in the mathematical specification of the ARDL model. See Figure 1.

Figure 1: Values of Information Criteria across Different Models



Source: Prepared by the researchers based on outputs from EVIEWS 12.

Table 3: Results of Estimating the Autoregressive Distributed Lag (ARDL) Model (Cointegration)

ARDL (1,2,0,0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LGDPp(-1)	0.787	0.116	6.762	0.000
LK	0.218	0.089	2.464	0.025
LK(-1)	-0.512	0.118	-4.349	0.000
LK(-2)	0.330	0.079	4.151	0.001
LHC	-0.000	0.096	-0.006	0.995
LMC	0.064	0.028	2.233	0.039
C	0.189	0.399	0.475	0.641

R^2 = 98.59%
F-statistic = 198.618
P(F-statistic) = 0.000000

Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendix (02).

After estimating the ARDL(1,2,0,0) model, we observe a high explanatory power of the model. As shown in Table (03), the value of the R-squared reached 98.59%, indicating that the independent variables explain 98.59% of the variations in economic growth. In addition, most of the variables are statistically significant, as indicated by their probability values being less than 0.05, with the exception of the human capital variable (LHC), which is not statistically significant. Accordingly, the model is statistically acceptable overall and highly significant, and it can be relied upon for planning and forecasting purposes in the future. This is further confirmed by the probability value of the Fisher test, estimated at P(F-Stat) = 0.000000, which is less than 10%.

Results of the Bounds Test:

In the bounds testing stage, the presence or absence of cointegration (a long-run equilibrium relationship) among the variables is verified. This is done by comparing the calculated Fisher F-statistic for the long-run coefficients with the tabulated critical F-values. The results are presented in Table 4 below:

Table 4: Results of the Bounds Test

Test Statistic	Statistic Value	Number of Variables
F-Statistic	11.379	3

Critical Values

Significance Level	Lower Bound (I0)	Upper Bound (I1)
10%	2.37	3.20
5%	2.97	3.67
2.5%	3.15	4.08
1%	3.65	4.66

Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendix (03).

As shown in Table 4 above, the calculated F-statistic value of 11.379 exceeds the upper bound of the critical values at all levels of statistical significance. Accordingly, the null hypothesis is rejected and the alternative hypothesis is accepted, indicating the existence of a long-run cointegration relationship between the independent variables and the dependent variable.

Estimation of the ARDL Error Correction Model:

After confirming that the time series of the variables are not integrated of order two, and given that the bounds test results also indicate the existence of a long-run relationship among the variables, the cointegration relationship of the autoregressive distributed lag (ARDL) model was estimated. This relationship can be mathematically expressed as follows

$$LGDPP_t = a_0 + \sum_{i=1}^{m} a_{1i}\, LK_{t-i} + \sum_{i=0}^{m} a_{2i}\, LHC_{t-i} + \sum_{i=0}^{m} a_{3i}\, LMC_{t-i} + \varepsilon_t \ldots\ldots\ldots (02)$$

Results of Estimating the ARDL Model in the Long Run:

By applying the ARDL methodology using the EVIEWS 12 software, the estimated long-run results obtained are presented in Table 5.

Table 5: Estimated Long-Run Coefficients of the ARDL Model

Long-Run Relationship

Variable	Coefficient	Std. Error	t-Statistic	Prob.

LK	0.339	0.088	3.867	0.004**
LHC	0.506	0.115	4.411	0.001**
LMC	0.215	0.041	5.306	0.000**
C	-0.671	0.809	-0.828	0.429**

**** Significant at 5%, * significant at 10%**
Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendix (04).

Based on Table 5, which presents the estimated long-run coefficients, the results indicate the following:

- **Capital variable (LK):** The probability value is 0.004, which is less than the 5% critical level. Therefore, the coefficient of LK is statistically significant in the long run. The positive sign indicates a direct relationship between capital and GDP per capita (economic growth) in the long run. An increase in capital by one unit leads to an increase in economic growth in Singapore by **0.339 units**.

- **Human capital variable (LHC):** The probability value is 0.001, which is less than the 5% critical level, indicating that the coefficient is statistically significant in the long run. The positive sign reflects a direct relationship between human capital and GDP per capita (economic growth) in the long run. An increase in human capital by one unit leads to an increase in economic growth in Singapore by **0.506 units**.

- **Mobile phone subscriptions variable (LMC):** The probability value is 0.000, which is less than the 5% critical level, indicating that the coefficient is statistically significant in the long run. The positive sign shows a direct relationship between mobile phone subscriptions and GDP per capita (economic growth) in the long run. An increase in mobile phone subscriptions by one unit leads to an increase in economic growth in Singapore by **0.215 units**.

5.3.2 Results of Estimating the ARDL Model in the Short Run:

Table 6 summarizes the results of estimating the ARDL model in the short run.

Table 6: Short-Run Estimated Coefficients of the ARDL Model

Short-Run Relationship

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LK)	0.218	0.065	3.337	0.004**
D(LK(-1))	-0.330	0.069	-4.746	0.000**
CointEq(-1)*	-0.213	0.039	-5.460	0.000**

R^2 = 64.52%

**** Significant at 5%, * significant at 10%**
Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendix (05).

From Table 6 above, and by first examining the relatively high value of the coefficient of determination, this indicates the good explanatory power of the model. The independent variables explain 64.52% of the variations in economic growth, reflecting a strong relationship between the explanatory variables and the dependent variable.

Regarding the impact of the variables on economic growth, most of them are statistically significant, although they differ in the nature of their relationships, as follows:

- **Capital variable D(LK):** The probability value for capital D(LK) is estimated at 0.004, which is less than the 5% critical level, indicating that the coefficient is statistically significant. The positive sign indicates a direct relationship between capital D(LK) and current economic growth in the short run. An increase in capital by one unit leads to an increase in economic growth in Singapore by **0.218 units**.

- **Lagged capital variable D(LK(-1)):** The probability value for the lagged capital variable D(LK(-1)) is estimated at 0.000, which is less than the 5% critical level. Therefore, the coefficient is statistically significant. The negative sign indicates an inverse relationship between lagged capital D(LK(-1)) and GDP per capita (economic growth) in the short run. An increase in D(LK(-1)) by one unit leads to a decrease in economic growth in Singapore by **0.330 units**.

- **Error correction coefficient CointEq(-1):** The probability value is 0.000, which is less than the critical level, indicating that the coefficient CointEq(-1) is statistically significant. The negative sign of the coefficient is consistent with econometric theory, as it represents the speed of adjustment from the short run to the long run. It indicates the magnitude of change in the dependent variable resulting from a one-unit deviation of the independent variable in the short run from its long-run equilibrium value. The coefficient value shows that the deviation is corrected by **0.213 units annually**, meaning that the speed of adjustment from the short run to the long run is very rapid.

6.3.2 Diagnostic Testing of Model Quality and Obtained Results

After completing the estimation of the parameters of the economic growth model for Singapore, the quality of the model is verified by carrying out the following steps:

Model Diagnostic Tests:

To ensure that the model is free from econometric problems, the main diagnostic tests used to assess the accuracy of the model are summarized in the following table. The results of the econometric diagnostic tests are as follows:

Table 7: Summary of Model Diagnostic Test Results

Test	Null Hypothesis (H_0)	Statistic	Value	Probability
Breusch–Godfrey Serial Correlation LM Test	No serial autocorrelation in regression residuals	F-Statistic	1.372	0.284
		Obs*R-squared	3.711	0.156
Breusch–Pagan–Godfrey Heteroscedasticity Test	Homoscedasticity of errors	F-Statistic	1.054	0.427
		Obs*R-squared	6.507	0.369
Jarque–Bera Normality Test	Residuals are normally distributed	Jarque–Bera	1.465	0.481
Ramsey RESET Test	Model is correctly specified	t-Statistic	1.152	0.266
		F-Statistic	1.326	0.266

Source: Prepared by the researchers based on outputs from EVIEWS 12, Appendices (6–7–8–9).

After estimating the ARDL model, the results of the diagnostic tests indicate the following:

- The serial correlation test of residuals shows that the probability value of the F-statistic equals 0.284, which is greater than the 0.05 significance level. Therefore, we accept the null hypothesis that there is no serial autocorrelation problem in the residuals of the regression equation.

- The heteroscedasticity test indicates that the probability value of the F-statistic equals 0.427, which is greater than the 0.05 significance level. Thus, we accept the null hypothesis of homoscedasticity of residuals.

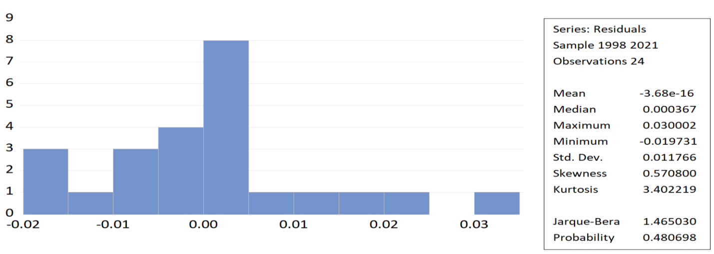
- Regarding the normality of random errors, this test depends on the probability value of the Jarque–Bera statistic. The null hypothesis, which states that the residuals of the estimated model are normally distributed, is accepted when the Jarque–Bera probability value is greater than 0.05. If it is less than 5%, the alternative hypothesis is accepted. Table (07) shows that the Jarque–Bera probability value equals 0.481, which is greater than the 0.05 significance level. Therefore, we accept the null hypothesis that the residuals are normally distributed.

- The Ramsey RESET test indicates that the model does not suffer from a functional form misspecification problem. This is evidenced by the probability value of 0.266, which is greater than the 5% significance level. Hence, we accept the null hypothesis (H_0) stating that the estimated model is correctly specified and reject the alternative hypothesis (H_1), which states that the estimated model is misspecified.

Overall, the results indicate that the model is free from econometric problems.

Normality Test of Residuals:

Figure 2: Normality Test of Residuals

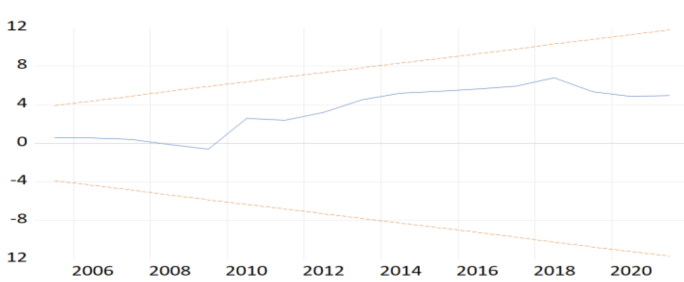


Source: Prepared by the researchers based on outputs from EVIEWS 12.

C. Structural Stability Test of ARDL-ECM Coefficients:

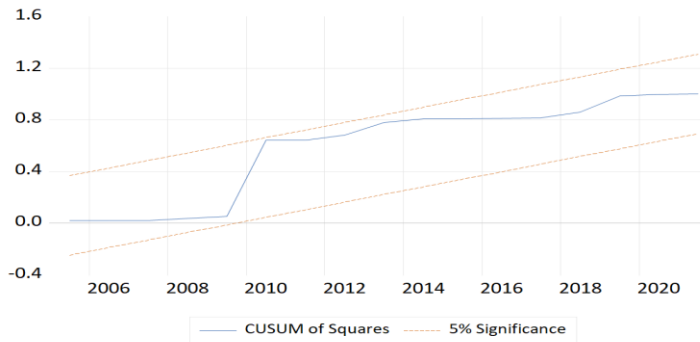
To test the stability of the model, the Cumulative Sum of Squares of Recursive Residuals (CUSUM) test was conducted. The results are as follows:

Figure 3: CUSUM Test to Verify the Stability of the Estimated Model Coefficients in the Long Run



Source: Prepared by the researchers based on outputs from EVIEWS 12.

Figure 4: CUSUM Test to Verify the Stability of the Estimated Model Coefficients in the Short Run



Source: Prepared by the researchers based on outputs from EVIEWS 12.

3. Analysis of Results:

- After estimating the ARDL(1,2,0,0) model, a high explanatory power of the model is observed, as indicated by the R-squared value of 98.59%. This means that the independent variables explain 98.59% of the variations in economic growth. Moreover, most variables are statistically significant, as reflected by their probability values being less than 0.05. Accordingly, the model is statistically acceptable overall and highly significant, and it can be relied upon for planning and forecasting future outcomes. This is further confirmed by the probability value of the Fisher test, estimated at P(F-Stat) = 0.000000, which is less than 10%.

- **Capital variable (LK):** The probability value is 0.004, which is less than the 5% critical level, indicating statistical significance in the long run. The positive sign reflects a direct relationship between capital and GDP per capita (economic growth) in the long run. An increase in capital by one unit leads to an increase in economic growth in Singapore by **0.339 units**. This is attributable to the importance of capital formation in promoting economic growth, as physical capital is a key component in increasing production and productivity. Although the results indicate a modest increase in economic growth, the role of physical capital remains crucial in enhancing growth. Therefore, the hypothesis is accepted.

- **Human capital variable (LHC):** The probability value is 0.001, which is less than the 5% critical level, indicating that the coefficient is statistically significant in the long run. The positive sign indicates a direct relationship between human capital and GDP per capita (economic growth) in the long run. An increase in human capital by one unit leads to an increase in economic growth in Singapore by **0.506 units**. This reflects the increasing reliance of the Singaporean government on the information and knowledge revolution in production. In addition, most of the workforce relied upon in Singapore's long-term strategy consists of knowledge workers, along with the financial sector's ability to provide and develop investments and venture capital to support innovative ideas. Many economic theories and previous studies also agree on the existence of a positive relationship between openness and economic growth. Therefore, the hypothesis is accepted.

- **Mobile phone subscriptions variable (LMC):** The probability value is 0.000, which is less than the 5% critical level, indicating statistical significance in the long run. The positive sign shows a direct relationship between mobile phone subscriptions and GDP per capita (economic growth) in the long run. An increase in mobile phone subscriptions by one unit leads to an increase in economic growth in Singapore by **0.215 units**. This is due to the strong state interest and investment in the telecommunications sector, in addition to the availability of financial resources. Therefore, the hypothesis is accepted.

- **Capital variable D(LK):** The probability value for capital D(LK) is estimated at 0.004, which is less than the 5% critical level, indicating that the coefficient is statistically significant. The positive sign indicates a direct relationship between capital D(LK) and current economic growth in the short run. An increase in capital by one unit leads to an increase in economic growth in Singapore by **0.218 units**. This reflects the importance of capital formation in enhancing economic growth, as physical capital is the main component for increasing production and productivity. Although the results show a modest increase in economic growth, the importance of physical capital remains significant. Therefore, the hypothesis is accepted.

- **Lagged capital variable D(LK(-1)):** The probability value for the lagged capital variable D(LK(-1)) is estimated at 0.000, which is less than the 5% critical level. Therefore, the coefficient is statistically significant. The negative sign indicates an inverse relationship between lagged capital D(LK(-1)) and GDP per capita (economic growth) in the short run. An increase in D(LK(-1)) by one unit leads to a decrease in economic growth in Singapore by **0.330 units**. Accordingly, the hypothesis is rejected.

- Overall, the diagnostic results of the model indicate that it is free from econometric problems.

4. Conclusion:

Based on this study, it can be concluded that in the present era, economic growth increasingly depends on a key variable—namely, the transition toward the digital economy. The COVID-19 pandemic played a significant role in accelerating this shift. Among the countries that have shown strong interest in the digital economy to enhance economic growth is Singapore, which employs advanced technologies to confront future crises. The digital economy, embodied in information and communication technologies, has had a substantial impact on economic growth rates in Singapore. Accordingly, the study reached the following conclusions:

- The digital economy plays a major role in increasing opportunities for progress and prosperity and in enhancing economic growth.

- The digital economy facilitates interaction among various parties regardless of geographical distance, as it relies on advanced technological means.

- Singapore has achieved remarkable levels in the field of the digital economy at the regional and global levels and is considered among the leading countries worldwide in digital transformation.

- Capital, human capital, and mobile phone subscriptions have contributed significantly to enhancing economic growth rates in Singapore during the period 1998–2021, due to the positive relationship between these variables and GDP per capita as a proxy for economic growth.

Based on these findings, the study proposes the following recommendations:

- Formulating and implementing strategic plans to adopt the digital economy;

- Enacting strict laws and regulations to protect electronic transactions and big data;

- Investing in human capital and benefiting from foreign expertise in the use of modern technologies;

- Improving the quality of internet connectivity nationwide for countries intending to adopt the digital economy by upgrading and developing digital infrastructure, including information and communication technologies and the Internet;

- Giving due attention to the digital economy and recognizing it as a priority sector for the future;

- Encouraging countries—especially Arab countries—to benefit from Singapore's experience and global best practices in transitioning toward the digital economy in order to enhance economic growth and development;

- Establishing a dedicated ministry for digitalization in each Arab country;

- Supporting studies and research related to data content and digital content, and encouraging the establishment of software companies in coordination and cooperation with foreign companies and expertise.

List of Appendices:

Appendix No. 01: Results of the unit root test for the study variables at level and first difference.

Ethical Considerations

This study is based exclusively on secondary data obtained from publicly available and internationally recognized statistical sources. No primary data collection involving human participants or confidential information was conducted. Therefore, ethical approval from an institutional review board was not required. The research was carried out in accordance with accepted principles of academic integrity, transparency, and responsible use of data. All data sources were properly cited, and the econometric analysis was conducted objectively without manipulation or misrepresentation of results.

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Conflict of Interest

The author declares no conflict of interest regarding the publication of this article. The research was conducted independently, and no financial, institutional, or personal relationships influenced the study design, analysis, or interpretation of the results.

UNIT ROOT TEST TABLE (PP)

	At Level				
		LGDPP	LK	LHC	LMC
With Const	t-Statistic	0.3156	-0.3546	-1.5336	-13.9862
	Prob.	*0.9744* n0	*0.9027* n0	*0.5005* n0	*0.0000* ***
With Const	t-Statistic	-3.0587	-1.8224	-1.4902	-8.1715
	Prob.	*0.1373* n0	*0.6633* n0	*0.8058* n0	*0.0000* ***
Without Co	t-Statistic	12.2444	1.6985	0.3878	2.0237
	Prob.	*1.0000* n0	*0.9749* n0	*0.7883* n0	*0.9872* n0
	At First Difference				
		d(LGDPP)	d(LK)	d(LHC)	d(LMC)
With Const	t-Statistic	-6.4972	-3.8504	-4.6899	-4.5399
	Prob.	*0.0000* ***	*0.0077* ***	*0.0011* ***	*0.0016* ***
With Const	t-Statistic	-5.7715	-3.7969	-4.7418	-5.2295
	Prob.	*0.0005* ***	*0.0347* **	*0.0047* ***	*0.0016* ***
Without Co	t-Statistic	-3.6029	-3.5223	-4.7402	-4.1546
	Prob.	*0.0009* ***	*0.0011* ***	*0.0000* ***	*0.0002* ***

UNIT ROOT TEST TABLE (ADF)

	At Level				
		LGDPP	LK	LHC	LMC
With Const	t-Statistic	-0.3286	-0.2267	-1.5336	-9.1646
	Prob.	*0.9071* n0	*0.9227* n0	*0.5005* n0	*0.0000* ***
With Const	t-Statistic	-3.4759	-4.1890	-1.4902	-5.3454
	Prob.	*0.0650* *	*0.0175* **	*0.8058* n0	*0.0011* ***
Without Co	t-Statistic	3.3345	1.9192	0.3878	1.3801
	Prob.	*0.9994* n0	*0.9840* n0	*0.7883* n0	*0.9536* n0
	At First Difference				
		d(LGDPP)	d(LK)	d(LHC)	d(LMC)
With Const	t-Statistic	-5.6038	-3.7556	-4.6899	-4.2864
	Prob.	*0.0001* ***	*0.0096* ***	*0.0011* ***	*0.0028* ***
With Const	t-Statistic	-5.5310	-3.7028	-4.7418	-5.1961
	Prob.	*0.0009* ***	*0.0418* **	*0.0047* ***	*0.0017* ***
Without Co	t-Statistic	-3.5683	-3.4199	-4.7402	-2.2977
	Prob.	*0.0010* ***	*0.0015* ***	*0.0000* ***	*0.0238* **

Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant
*MacKinnon (1996) one-sided p-values.

This Result is The Out-Put of Program Has Developed By:

Appendix No. 02: Results of estimating the Autoregressive Distributed Lag (ARDL) model (cointegration)

Dependent Variable: LGDPP
Method: ARDL
Date: 04/22/23 Time: 23:09
Sample (adjusted): 1998 2021
Included observations: 24 after adjustments
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Schwarz criterion (SIC)
Dynamic regressors (2 lags, automatic): LK LHC LMC
Fixed regressors: C
Number of models evalulated: 54
Selected Model: ARDL(1, 2, 0, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LGDPP(-1)	0.787100	0.116396	6.762238	0.0000
LK	0.218155	0.088542	2.463862	0.0247
LK(-1)	-0.512040	0.117733	-4.349177	0.0004
LK(-2)	0.329574	0.079392	4.151244	0.0007
LHC	-0.000574	0.095836	-0.005994	0.9953
LMC	0.063507	0.028435	2.233403	0.0393
C	0.189241	0.398813	0.474510	0.6412

R-squared	0.985935	Mean dependent var	4.666995
Adjusted R-squared	0.980971	S.D. dependent var	0.099215
S.E. of regression	0.013686	Akaike info criterion	-5.506377
Sum squared resid	0.003184	Schwarz criterion	-5.162778
Log likelihood	73.07653	Hannan-Quinn criter.	-5.415220
F-statistic	198.6184	Durbin-Watson stat	2.061406
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Appendix No. 03: Results of the Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	11.37940	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	22		Finite Sample: n=35	
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
			Finite Sample: n=30	
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Appendix No. 04: Estimated coefficients of the ARDL model in the long run

Levels Equation Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LK	0.338974	0.087651	3.867302	0.0038
LHC	0.505567	0.114615	4.411013	0.0017
LMC	0.215153	0.040549	5.305988	0.0005
C	-0.670774	0.809993	-0.828123	0.4290

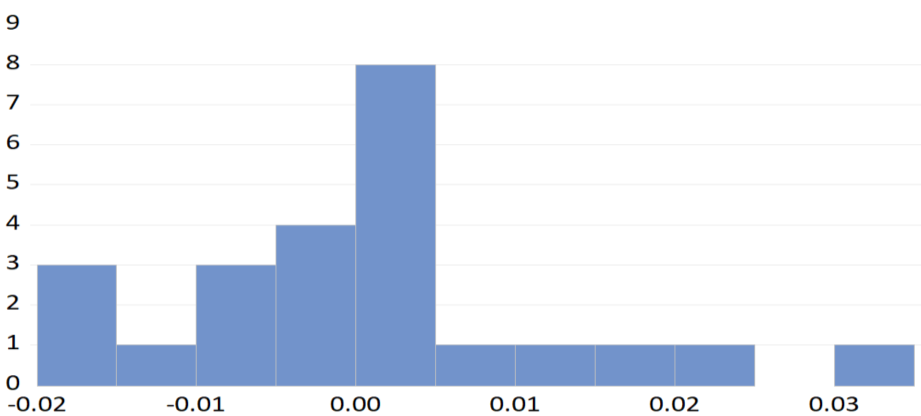
EC = LGDPP - (0.3390*LK + 0.5056*LHC + 0.2152*LMC - 0.6708)

Appendix No. 05: Results of estimating the ARDL model in the short run

ECM Regression Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LK)	0.218155	0.065371	3.337179	0.0039
D(LK(-1))	-0.329574	0.069440	-4.746175	0.0002
CointEq(-1)*	-0.212900	0.038995	-5.459740	0.0000
R-squared	0.645174	Mean dependent var		0.012681
Adjusted R-squared	0.611381	S.D. dependent var		0.019753
S.E. of regression	0.012314	Akaike info criterion		-5.839711
Sum squared resid	0.003184	Schwarz criterion		-5.692454
Log likelihood	73.07653	Hannan-Quinn criter.		-5.800643
Durbin-Watson stat	2.061406			

* p-value incompatible with t-Bounds distribution.

Appendix No. 06: Normality of residuals



Series: Residuals	
Sample 1998 2021	
Observations 24	
Mean	-3.68e-16
Median	0.000367
Maximum	0.030002
Minimum	-0.019731
Std. Dev.	0.011766
Skewness	0.570800
Kurtosis	3.402219
Jarque-Bera	1.465030
Probability	0.480698

Appendix No. 07: Test of serial autocorrelation of errors

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	1.371929	Prob. F(2,15)	0.2837
Obs*R-squared	3.711289	Prob. Chi-Square(2)	0.1564

Appendix No. 08: Test of homoscedasticity of errors

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	1.054005	Prob. F(6,17)	0.4265
Obs*R-squared	6.507310	Prob. Chi-Square(6)	0.3688
Scaled explained SS	3.921565	Prob. Chi-Square(6)	0.6873

Appendix No. 09: Model adequacy (goodness-of-fit) test

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Squares of fitted values
Specification: LGDPP LGDPP(-1) LK LK(-1) LK(-2) LHC LMC C

	Value	df	Probability
t-statistic	1.151528	16	0.2664
F-statistic	1.326018	(1, 16)	0.2664
Likelihood ratio	1.910894	1	0.1669

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