COHERENCE OF THE DIGITAL ECONOMY AND SHARING ECONOMY AS CONTRIBUTORS TOWARDS SUSTAINABLE DEVELOPMENT IN MALAYSIA.

by

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Presented to the
FACULTY OF ECONOMICS AND BUSINESS
in Fulfillment of the Requirement for the Degree of

MASTER OF SCIENCE
(Development Economics)

2026

UNIVERSITI MALAYSIA SARAWAK

DECLARATION

I hereby declare that the work presented in this thesis was conducted in full compliance with the regulations of Universiti Malaysia Sarawak (UNIMAS). Except where proper acknowledgment is given, this work is solely the effort of the author. This thesis has not been accepted for the award of any other degree and is not being **concurrently** submitted for any other academic qualification.

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ACKNOWLEDGMENT

This thesis would not have been possible without the support and encouragement of several individuals to whom I am deeply grateful.

First and foremost, I extend my heartfelt appreciation to my supervisor, whose unwavering guidance and insightful feedback have been instrumental in shaping my research. His encouragement to delve deeper into the field of economics has pushed me beyond my limits, broadening my perspective and refining my analytical skills.

I am also profoundly grateful to my parents for their unwavering moral support, especially during the most challenging times. Their belief in me has been a source of strength, and their continuous encouragement has kept me motivated throughout this journey.

Lastly, to my partner, who has been my pillar of strength, thank you for always encouraging me to keep going. Your unwavering support, patience, and faith in me have been invaluable, making this journey more bearable and meaningful.

To all who have been a part of this journey, thank you for your kindness, encouragement, and belief in my work.

Coherence of the Digital Economy and Sharing Economy as Contributors Towards Sustainable Development in Malaysia

ABSTRACT

This study examines the coherence between the digital economy and the sharing economy as contributors to sustainable development in Malaysia. Grounded in Schumpeter's theory of innovation and creative destruction, the research employs bibliometric analysis, systematic literature review, and econometric modeling to analyze data from 1995 to 2022. Findings indicate that digitalization fosters economic growth, innovation, and employment, while the sharing economy enhances resource efficiency and environmental sustainability. However, challenges such as digital divide and regulatory gaps hinder full integration. The study advocates for strategic policies to strengthen digital infrastructure, promote inclusive participation, and align economic activities with sustainability goals.

Keywords:Digital Economy, Sharing Economy, Sustainable Development, Innovation, Economic Growth.

Keserasian Ekonomi Digital dan Ekonomi Perkongsian sebagai Penyumbang kepada Pembangunan Lestari di Malaysia

ABSTRAK

Kajian ini meneliti keserasian antara ekonomi digital dan ekonomi perkongsian sebagai penyumbang kepada pembangunan lestari di Malaysia. Berasaskan teori inovasi dan pemusnahan kreatif Schumpeter, kajian ini menggunakan analisis bibliometrik, tinjauan literatur sistematik, dan pemodelan ekonometrik untuk menganalisis data dari tahun 1995 hingga 2022. Dapatan menunjukkan bahawa pendigitalan merangsang pertumbuhan ekonomi, inovasi, dan pekerjaan, manakala ekonomi perkongsian meningkatkan kecekapan sumber dan kelestarian alam sekitar. Walau bagaimanapun, cabaran seperti jurang digital dan kelemahan peraturan menghalang integrasi penuh. Kajian ini mencadangkan dasar strategik untuk memperkukuh infrastruktur digital, menggalakkan penyertaan inklusif, dan menyelaraskan aktiviti ekonomi dengan matlamat kelestarian.

Kata Kunci:Ekonomi Digital, Ekonomi Perkongsian, Pembangunan Lestari, Inovasi, Pertumbuhan Ekonomi.

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CHAPTER 1:

INTRODUCTION

1.1 Background of Study

The growth and development of digital technologies have instigated and stimulated radical changes in the global economy, urging all stakeholders of the economy to rethink their position and participation in this digitally fuelled revolution. The discussion on digital integration is severely incomplete without bringing up the Fourth Industrial Revolution, commonly dubbed as 4IR. The transition of the global economy into 4IR, a technology-reliant economy, is merely an extension and culmination of its antecedents, past revolutions which equally transformed the global economy through its individual focus. However, merely discussing the progress of change and impact of the digital transformation covers only one facet of the subject matter. An economic introspection is necessary to understand the viability of this transformation in the long term and how it affects sustainable development.

Seeping into practically all aspects of the economy, digital integration or adoption is a holistic revolution, taking over from the older economic systems through change in known information (Ojanperä et al., 2019). This then funnels the discussion into the digital economy (DE), a form of economy birthed from rapid and holistic digital adoption across sectors and industries. For the purposes of clarity throughout this paper, the terms "digital adoption" and "digitalization" are used interchangeable on the basis of their definitions. Taking over from the traditional system is the digital aspect encompassing high technology usage and digitalisation of both the supply and demand side economic activities. Digitization and digitalization have become the core interests of this industrial revolution, a by-product of rapid globalization. Digitization refers to the uploading of known information and data into the digital sphere while the digitalization refers to the integration of technologies which support digital use (OECD, 2020). Defining digital adoption, it refers to the use of a certain form of technology, as is discussed by Jahanmir and Cavadas (2018). There is a strict distinction between the digital economy and terms such as digitalization and digital adoption which have been defined above. The digital economy is commonly seen to be defined based on the context of its application as a generalised set framework of the digital economy has yet to be formulated to be adopted globally (Sergushina et al., 2021) but is generally measured through ICT and macroeconomic indicators.

As is the basis of any efficient economic activity, knowledge and technique allow said activity to occur and this rings true too for our current global economy. The digitized information has minimal barriers in its circulation, filling in informational gaps where necessary and motivating digitalization. Having established what fuels the digital economy, we see the centre of this transformation are active players such as device connectivity through Internet of Things (IoT), digital models, and intensifying data usage (OECD, 2015) paired high paced proliferation in the economy, thus motivating economic growth due to digitalization (Bukht & Heeks, 2017). These support factors enable the digital economy to keep up with growing market demands and day-to-day needs of the economy, thus prolonging the viability of this transformation and consequently making it sustainable.

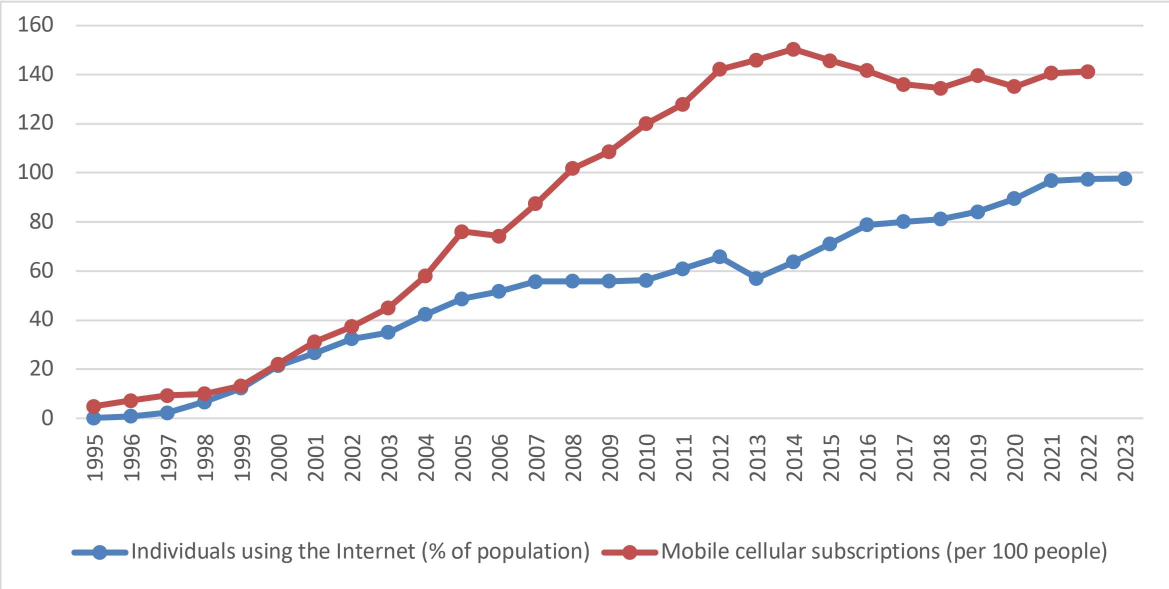
The talk of holistic digitalization brings into discussion Schumpeter's (1942) theory of creative destruction. A concept to be discussed in detail in later sections, creative destruction explains the organic assimilation of newer systems which are able to contribute its maximum capacity and possibilities compared to the inferior system which outlived its long-term viability and relevance. Yet again, this is linked back to the core of the discussion at present, of how digitalization and a new faction of the economy, the digital economy, affect sustainable development.

The questions are valid, but not much can be explored before understanding the concept of sustainable development. The growth and development of digitization and digitalisation need to be measured against a vector, which in current trends and global issues is the topic of sustainable development. Current talks of sustainable development on the basis of the Sustainable Development Goals (SDGs) as put forward by the United Nations (2015) covering socioeconomic progression for holistic and collective development through every layer of society, globally. Spanning across socioeconomic and ecological sustainability, the talk about sustainable development has experienced a linkage towards digitization and digitalization in terms of efficiency of resource allocation and utility for long run economic growth and ecological preservation (Li et al., 2021; Pouri & Hilty, 2018). The introduction of the SDGs provides more tangible indicators to measure the progress of the global economy towards these goals which advocate for sustainability in all aspects of its definition.

For example, the digital economy, with its resource efficiency and innovation potential, holds promise for promoting sustainable energy use. OECD (2012) reports that maximising utilisation of high technology could significantly reduce global emissions if paired with additional investments dedicated in the effort against environmental destruction. This is evident in Malaysia where production sees scale economies through optimized energy input (The World Bank, 2021).

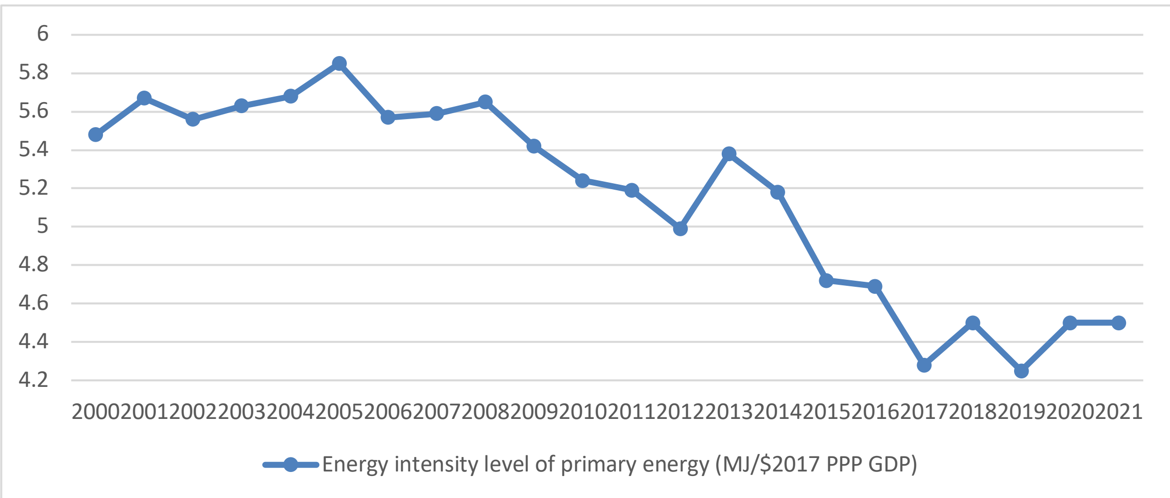
The use of the SDGs as a basis for measuring sustainable development can be paired with other vectors to understand factors that influence sustainable development, such as the digital economy. The multifaceted linkage and complexity can be established through comparisons between SDG 8 (economic growth and decent work) and SDG 13 (climate action) indicators with digital economy indicators proxied by ICT measures in Malaysia, such as individuals using the Internet and mobile cellular subscriptions.

Figure 1-1:
Data trend of individuals using the Internet (% of population) and mobile cellular subscriptions (per 100 people) in Malaysia



Malaysia's digitalization, potentially aligning with Schumpeter's creative destruction theory, hinges on robust infrastructure and adoption. Key ICT indicators in Figure 1.2 show somewhat steady growth, reflecting internet penetration and basic digital adoption. This empowers both citizens with information access and businesses to embrace digital solutions. Widespread digital adoption across the economy holds promise for reducing the environmental impact of energy in Malaysia.

Figure 1-2:
Malaysia energy intensity level of primary energy (MJ/$2017 PPP GDP)



Malaysia's increasing digitalization boosts demand for a digital economy. To meet this demand and prevent environmental burdens, efficient energy use is crucial. While energy intensity is decreasing, as in Figure 1.3, faster digital adoption could further improve it. Furthermore, digitalization and sustainable practices, contrary to fears, can create jobs. The ILO estimates 24 million global green jobs by 2030 (International Labour Organization, 2018), and Malaysia's MyDigital plan aims for 500,000 new digital jobs by 2025 (Economic Planning Unit, Prime Minister's Department, 2021).

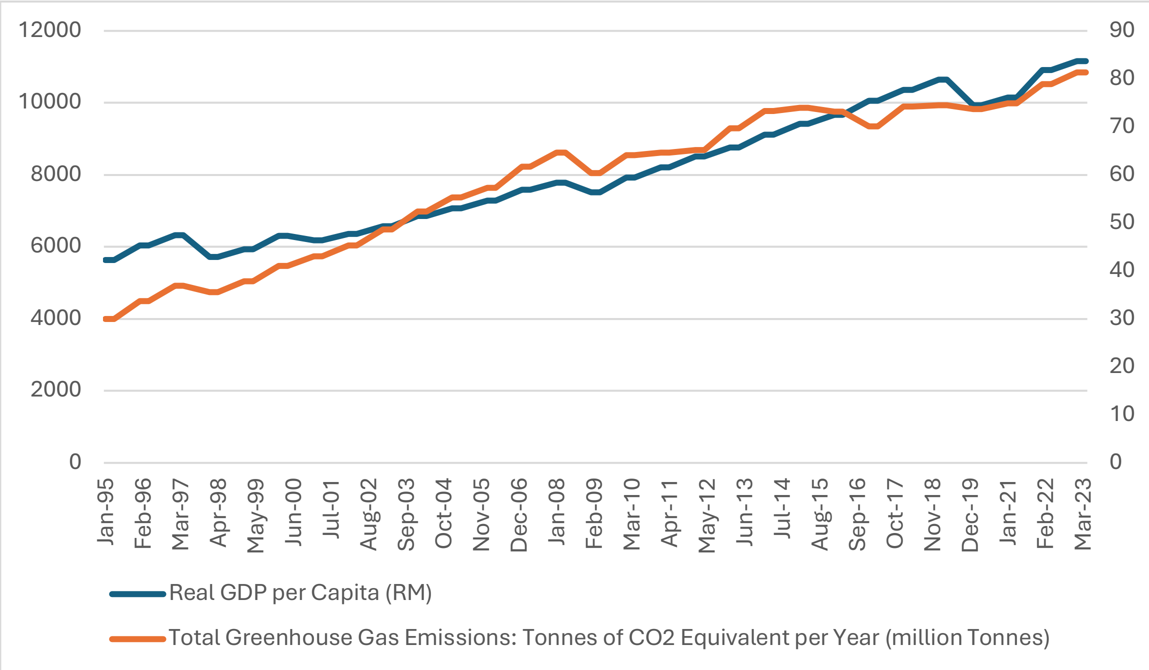
On another tangent, resource scarcity historically drives unsustainable consumption, but the digital economy holds potential for efficient practices and economic growth. Growth in global population paired with ever-increasing insatiable desires gave rise to unsustainable and destructive consumption patterns with severe stress on the environment (Parikh et al., 1991). A consensually adopted solution is the digital economy and in tackling the issue of resource scarcity, the sharing economy (SE) came to be. A foundational understanding of the sharing economy is such that the sharing economy can be understood as a digitally facilitated, peer-to-peer system in which individuals share the use of underutilized goods or services through an intermediary platform, typically without transferring ownership (Schlagwein et al., 2020). However, with recent developments and transformation in the global economy, especially with the digitalization of it, the sharing economy can now be interpreted as the platformization of the market to increase and maximise the utility of an asset based on a shared network. This interpretation of the economy is commonly measured through consumption fuelled by digitalization which is generally seen through e-commerce data (Boar et al., 2020; Daunorienė et al., 2015; Hernandez-Carrion, 2021; Trabucchi et al., 2019; Yeganeh, 2021). However, defining the SE is not a straightforward task. The definition of the Sharing Economy is fluid because the market it operates in is constantly changing. This results in two main perspectives: a narrow view that focuses on specific aspects, and a broader view that encompasses a wider range of activities (Tham, Lim, & Vieceli, 2022).

Despite still being a highly disputed and controversial area of interest (Dabbous & Tarhini, 2021), the ability of the sharing economy to create value from underutilized assets and through reusage of assets has led to empirical research proving its ability to promote sustainable development and energy efficiency in the economy. The rise of digital globalization triggered a domino effect, leading to social and cultural shifts, evolving public attitudes, and ultimately, the birth of entirely new ways we consume goods and services. Studies on the sharing economy's development reveal it as a culmination of these complex, intertwined changes – technological advancements, economic transformations, social trends, and even environmental concerns all playing a role (Lyaskovskaya & Khudyakova, 2021). The origination of the sharing economy is further supported by the findings of Tham, Lim, & Viceli (2022) discussing how our societal mindset is shifting, with the concept of ownership taking a backseat to prioritizing a desired lifestyle. Soaring costs of living have made access and affordability more important than outright possession, especially when considering the high price of acquiring and maintaining assets. This trend, coupled with technological advancements, fuels the rise of sustainable practices to reduce waste and redundancy in resource use, making a more mindful approach not only environmentally responsible, but economically advantageous.

An understanding of how the digital economy and sharing economy are connected needs to be established. Understanding the two areas separately forms a strong basis of today's economy, a digitalized economy functioning beyond personal relationships and small social groups. The digitalized commerce, while in its early stages was limited to temporal, geographical, and social limitations now has evolved beyond those constraints, all of which has been enabled by digital platforms which are a culmination of the use of ICT infrastructure and network in the economy (Pouri & Hilty, 2021). As will be explored further within this study, the relationship between the digital economy and sharing economy is such that ICT or digital platform infrastructure has created a confluence between the two where the digital economy is fuelling and enabling the contemporary sharing economy.

For the purposes of this study, the DE and SE are examined against SDG 8 (Decent Work and Economic Growth) and SDG 13 (Climate Action) under the United Nations Sustainable Development Goals framework (United Nations, 2015a). In operationalising these goals, GDP per capita, defined as the total economic output per person in a given year, is used as the dependent variable for SDG 8, while greenhouse gas (GHG) emissions, expressed in tonnes of CO_2 equivalent, serve as the dependent variable for SDG 13. These indicators are among the official metrics designated to measure progress on their respective goals by the United Nations and Malaysia's SDG monitoring systems, ensuring alignment with internationally recognised benchmarks (United Nations, 2023; Department of Statistics Malaysia, 2023). GDP per capita is widely accepted as a proxy for overall economic performance and average material well-being, making it suitable for assessing whether DE and SE contribute to sustained, inclusive economic growth (World Bank, 2024). In contrast, GHG emissions capture the aggregate climate-forcing impacts of national economic activity, reflecting energy consumption, industrial processes, agriculture, waste and land use, all of which are central to understanding climate action outcomes (Intergovernmental Panel on Climate Change, 2022). This alignment with official SDG indicator sets ensures that the study's findings are both conceptually grounded and policy relevant.

Figure 1-3:
Trend of GDP per capita and GHG Emissions



In the case of Malaysia, both indicators have shown persistent upward trends over recent decades, as seen in Figure 1.3. Data from the CEIC Data platform indicate that Malaysia's GDP per capita has grown steadily over recent decades, reaching upper-middle-income status and reflecting sustained economic development and structural transformation. At the same time, Malaysia's GHG emissions remain relatively high relative to its level of development, driven largely by fossil-fuel-based energy generation, industrial activity, and transport. Official national statistics and environmental accounts compiled by the Department of Statistics Malaysia further corroborate the rising trend in greenhouse gas emissions across major sectors of the economy (DOSM, 2023). These concurrent trends demonstrate the challenge Malaysia faces in decoupling economic growth from environmental impact, making GDP per capita and GHG emissions particularly suitable dependent variables for the empirical analysis in this study. By focusing on these indicators, the research not only adheres to recognised SDG measurement frameworks but also engages directly with Malaysia's development context and policy priorities.

1.2 Problem Statement

The rapid rise of the digital economy (DE) and sharing economy (SE) has transformed how economic value is created, exchanged, and consumed. These transformations are widely associated with gains in efficiency, innovation, and market access, yet their implications for sustainable development remain insufficiently understood, particularly when assessed through measurable economic and environmental outcomes. In the Malaysian context, the central challenge lies in determining whether the expansion of the DE and SE contributes to sustained economic growth, as reflected in GDP per capita, while simultaneously supporting climate action, as reflected in GHG emissions measured in tonnes of CO_2 equivalent.

The overarching problem addressed in this study is the lack of empirical clarity on how the DE and SE influence Malaysia's sustainable development performance along these two dimensions. While prior research generally reports a positive association between digitalisation and economic growth, the extent to which this growth translates into improvements in GDP per capita without exacerbating environmental pressures remains inconclusive. In Malaysia, this uncertainty is particularly relevant given the country's steady economic expansion alongside persistently high emissions intensity, raising concerns about whether current growth trajectories are environmentally sustainable.

From an economic perspective, the long-term viability of digitalisation as a new growth system depends on its ability to generate inclusive and sustained improvements in income levels. Although the prospect of digitalisation as a driver of economic growth is positively reviewed in the literature (Baranov, 2022), Malaysia's digital transformation remains uneven, particularly on the supply side. Micro, small and medium enterprises (MSMEs), which account for 97.4% of total business establishments in Malaysia (Department of Statistics Malaysia, 2022), play a critical role in determining whether digitalisation translates into broad-based gains in GDP per capita. However, despite their economic significance, digital adoption among MSMEs remains largely basic, with approximately 77% of SMEs still operating at an early stage of digitalisation as of 2020 (SME Corp Malaysia, 2021). This raises a key concern as to whether the current structure and depth of the DE and SE are sufficient to meaningfully enhance income growth at the national level.

From an environmental perspective, Malaysia faces mounting pressure to align economic development with climate commitments. Despite global and national efforts to moderate emissions growth, Malaysia's GHG emissions remain closely tied to fossil-fuel-based energy generation, industrial activity, and transport. This has contributed to the country's relatively weak performance in achieving SDG 13, as reflected in its declining SDG Index ranking (Sustainable Development Solutions Network, 2024; SDG Transformation Center, 2024). While policy frameworks such as the SDG Roadmap for Malaysia Phase II (2021–2025) outline pathways toward improved sustainability outcomes (Ministry of Economic Affairs, 2022), there is limited empirical evidence on whether the DE and SE contribute to emissions reduction or merely coexist with emissions-intensive growth patterns.

Compounding this issue is a conceptual and empirical gap in the literature concerning the relationship between the DE and SE themselves. Existing studies often treat the two as separate domains, with the sharing economy examined largely within the confines of platform-based consumption and asset utilisation. Yet, the SE fundamentally relies on digital infrastructure and ICT-enabled platforms provided by the DE, suggesting an interdependent relationship that may jointly influence economic output and environmental outcomes. The absence of empirical analysis that simultaneously examines the DE and SE in relation to GDP per capita and GHG emissions limits understanding of whether these economic transformations function as complementary mechanisms for sustainable development in Malaysia.

Accordingly, this study addresses a critical gap by empirically investigating the extent to which the digital economy and sharing economy contribute to Malaysia's sustainable development outcomes, specifically through their impact on GDP per capita and GHG emissions. By explicitly linking digitalisation and platform-based economic activity to these two core indicators of SDG 8 and SDG 13, the study seeks to clarify whether the DE and SE support a pathway of economic growth that is both income-enhancing and environmentally sustainable.

1.3 Research Questions

The digital age has ushered in a revolution in how we access goods, services, and information. The sharing economy, a product of this revolution, thrives on digital platforms connecting individuals to share resources and skills. However, in Malaysia, the rapid growth of digital and sharing economies has not been accompanied by a consistent framework for measuring their sustainability. While these economies offer potential for economic innovation and resource efficiency, there is a lack of comprehensive metrics to assess their environmental, social, and economic impacts effectively. This gap impedes the ability of policymakers, businesses, and civil society in Malaysia to ensure that digital transformations contribute positively to the nation's SDGs.

Sustainability metrics are essential to evaluate how well the digital and sharing economies align with Malaysia's SDGs. These metrics help in quantifying the impact of these economies on areas including reducing carbon emissions, managing electronic waste, ensuring fair labour practices, and promoting economic inclusivity. Without these metrics, the long-term viability and potential negative impacts of these economic models may go unchecked, potentially leading to environmental degradation, social inequality, and economic instability. This also means those without IT miss out on crucial opportunities for education, work, and social interaction, worsening social inequality (Zhang, Jin, & Peng, 2018). The primary challenge is the lack of standardized methodologies to develop and implement these metrics consistently across different sectors of the digital and sharing economies. Furthermore, data availability and reliability are major issues, as many digital and sharing economy platforms are not transparent with their operational data, complicating efforts to assess their true sustainability impacts. Reynolds, Henderson, and Norris (2021) put forth the argument which describes the benefits of digital infrastructure and technology in supplementing the economy, however, without tackling the barriers to penetration, its benefits fall moot.

Therefore, this study creates relevance to the current state of the national economy by investigating the following key issues:

i. How do the digital economy and sharing economy influence Malaysia's long-run and short-run economic performance (SDG 8), as measured by GDP per capita, and do these effects exhibit asymmetry between positive and negative shocks?

ii.What is the long-run and short-run relationship between the digital economy, sharing economy, and Malaysia's environmental sustainability outcome (SDG 13), as measured by greenhouse gas emissions (tonnes of CO_2 equivalent)?

iii.What are the causal directions among the digital economy and sharing economy proxies in Malaysia, and how do these dynamics interact with investment, labour participation, and greenhouse gas emissions over time?

By investigating this issue, this research aims to shed light on the complex relationship between the digital divide and the sharing economy and how it contributes to the nation's sustainable development.

1.4 Research Objectives

The research objectives are intended to be the main guiding framework of this study and outright states the purpose of this study.

i.Examine the impact of the digital economy and sharing economy on SDG 8 outcomes in Malaysia, as measured by GDP per capita.

ii.Examine the impact of the digital economy and sharing economy on SDG 13 outcomes in Malaysia, as measured by greenhouse gas emissions (tonnes of CO_2 equivalent).

iii.Assess the directional relationship between the digital economy and sharing economy using Granger causality and Toda–Yamamoto causality tests.

1.5 Significance of Study

This study is significant in advancing understanding of how the DE and SE contribute to SDG 8 and SDG 13 in the Malaysian context. By explicitly examining these two goals, the study narrows the sustainability discourse to the core development challenge facing Malaysia: achieving sustained economic growth while managing greenhouse gas emissions.

From an economic perspective, the study contributes to the literature by empirically assessing whether the expansion of the DE and SE is associated with improvements in GDP per capita, a key indicator of income growth and economic well-being under SDG 8. Given Malaysia's ongoing digital transformation and the central role of digitalisation in national development strategies, the findings provide evidence on whether digital and platform-based economic activities translate into tangible economic gains at the national level.

From an environmental perspective, the study is significant in evaluating the relationship between the DE and SE and greenhouse gas emissions (tonnes of CO_2 equivalent), the primary indicator used to assess progress under SDG 13. As Malaysia continues to face emissions growth alongside economic expansion, this study provides empirical insight into whether digitalisation and sharing-based models contribute to emissions reduction, emissions intensification, or neutral outcomes.

In addition, this study contributes methodologically by jointly analysing the DE and SE rather than treating them as isolated phenomena. By examining their causal relationship, the study clarifies how digital infrastructure and platform-based consumption interact and whether their interaction reinforces or constrains progress toward SDG 8 and SDG 13 outcomes. This integrated approach enhances the relevance of the findings for policymakers by providing evidence-based insights into how digitalisation strategies can be aligned with both economic growth and climate objectives in Malaysia.

1.6 Scope of Study

This study focuses on examining the role of the DE and SE in contributing to sustainable development outcomes in Malaysia, with specific emphasis on SDG 8 and SDG 13. The scope of the study is defined along thematic, geographical, temporal, and methodological dimensions.

Thematically, the study is confined to analysing how indicators representing the DE and SE influence two key sustainable development outcomes: GDP per capita, as a proxy for economic growth under SDG 8, and GHG emissions measured in tonnes of CO_2 equivalent, as a proxy for climate action under SDG 13. Other dimensions of sustainable development and SDGs are not examined in this study in order to maintain analytical focus and empirical clarity.

Geographically, the study is limited to Malaysia, reflecting the country's ongoing digital transformation, its reliance on digital and platform-based economic activities, and its policy commitment to balancing economic growth with emissions mitigation.

Temporally, the study employs time-series data covering the period from 1995 to 2023, capturing Malaysia's transition from the early stages of digitalisation following the establishment of the MMC to the more mature phase of digital and platform-based economic activity in recent years. This period allows for the assessment of both short- and long-run relationships.

Methodologically, the study adopts a quantitative econometric approach, utilising non-linear ARDL (NARDL) and autoregressive distributed lag (ARDL) frameworks, along with causality tests, to examine relationships and directional effects. The scope excludes firm-level, sector-specific, or qualitative analyses, as well as consumption-based emissions accounting, focusing instead on national-level indicators due to data availability and consistency.

1.7 Organization of Study

This thesis is organised into five chapters, each structured to address the research objectives systematically.

Chapter 1: Introduction outlines the background of the study, problem statement, research questions, objectives, significance, and scope. It establishes the motivation for examining the DE and SE in relation to SDG 8 and SDG 13 in the Malaysian context.

Chapter 2: Literature Review presents a comprehensive review of existing literature on the DE, SE, and sustainable development. This chapter employs bibliometric analysis and a systematic literature review to identify key themes, theoretical foundations, empirical findings, and research gaps, culminating in the development of the study's conceptual and theoretical framework.

Chapter 3: Research Methodology details the research design, data sources, variable selection, model specification, and empirical testing procedures. It explains the econometric techniques used to analyse the relationships between the DE, SE, GDP per capita, and GHG emissions.

Chapter 4: Empirical Results reports and interprets the findings from the econometric analyses, including unit root tests, long-run and short-run estimations, diagnostic tests, and causality results. The chapter presents results corresponding directly to each research objective.

Chapter 5: Discussion and Summary discusses the key findings in relation to the research objectives and existing literature, outlines policy implications for Malaysia, highlights limitations of the study, and suggests directions for future research.

CHAPTER 2:

LITERATURE REVIEWS

2.1 Introduction

The state of literature in relevance to the Digital Economy (DE) and Sharing Economy (SE) have seen significant increase in research volume, spanning across various research areas, which will be systematically analysed in later portions of this section. Being in the midst of the Fourth Industrial Revolution has caused drastic socioeconomic implications namely consumption patterns, economic performance due to digitalisation, and even an increasing focus on the consequential effects on sustainability (Li et al., 2021; Pouri & Hilty, 2018; Sun et al., 2022; Vishnevsky et al., 2021). The process of digitization in the global economy has driven a radical and holistic change in global economic activities, mainly due to the efficiency and speed in managing data and information and cost reductions (Wysokińska, 2021). The literature review will be conducted through bibliometric analysis and a Systematic Literature Review to capture a more holistic representation of the research environment and existing body of knowledge with regards to the DE, SE, and Sustainable Development.

To build an efficient empirical model to be used for estimations in the later portions of this paper, a good grasp on the definition of the DE and SE are needed to set the bounds of the empirical model. Thus, this paper also explores the various definitions of these respective sectors, especially regarding sustainable development and uses it as a basis for the empirical model employed in this paper. The purpose of exploring the various definition of the DE and SE is also to establish the inclusion and exclusion of markets and industries to allow for a more accurate measurement of the performance of these digital sectors in the economy.

Defining the DE is an ever-present issue within that sector of the economy as the span of its involvement can be seen throughout the entire economy and poses the problem of inclusion. While each domestic economy may have a proposed definition of their digital economy, a generalised set framework of the digital economy has yet to be formulated to be adopted globally (Sergushina et al., 2021). The SE, however, has been consensually defined to be an economic implementation which is based on transactions of goods and services performed among compeers with the use of digital technologies (Dabbous & Tarhini, 2021; Daunorienė et al., 2015; Hernandez-Carrion, 2021; Mi & Coffman, 2019; Yeganeh, 2021).

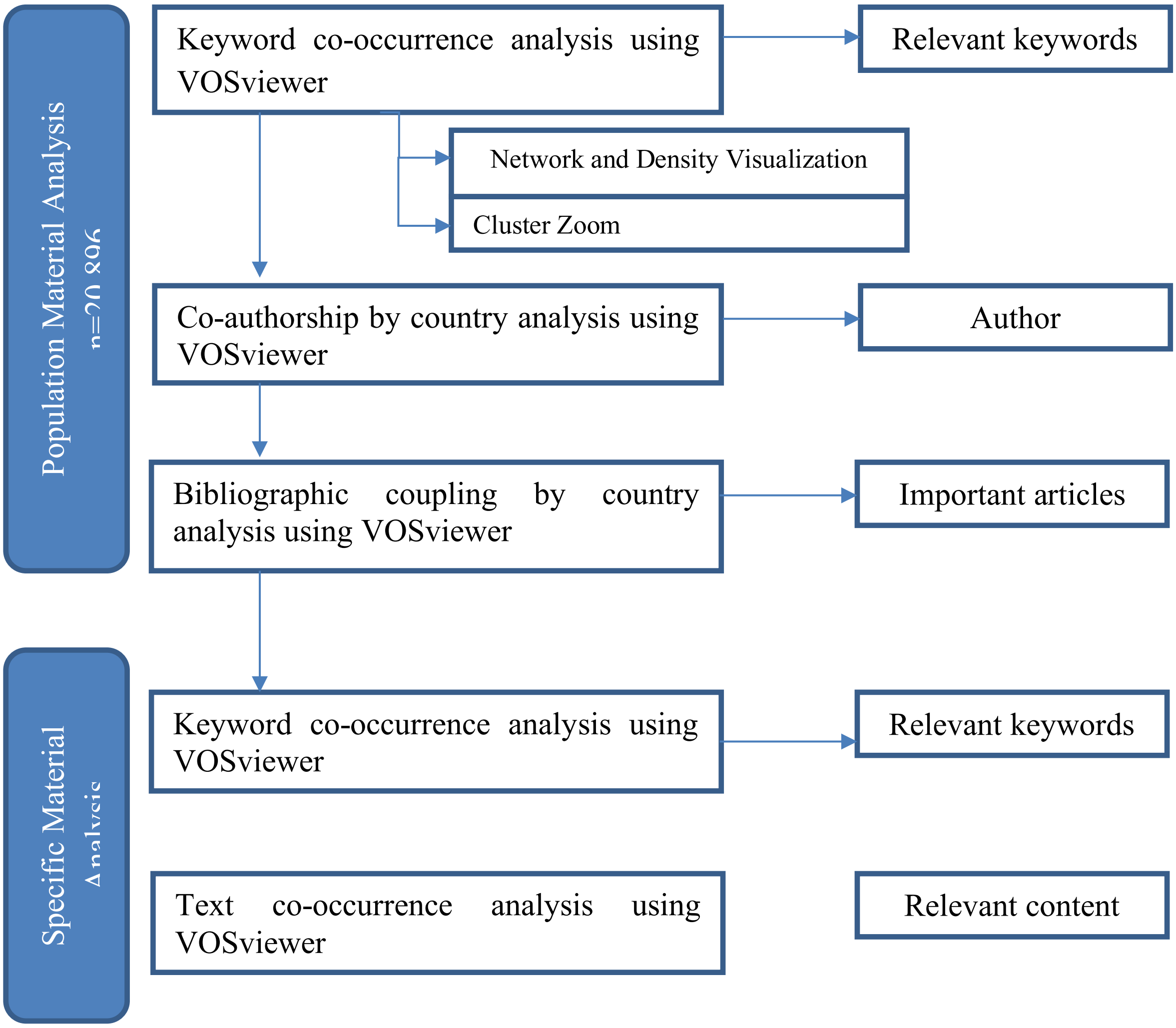
Thus, this portion of the study is dedicated to further exploring what is currently known on the DE and SE, with reference to sustainability, while identifying the gaps to be filled. The information extracted from the chosen literature are used as a basis of research in studying the coherence of the DE and SE as contributors towards sustainable development. The space of digitalisation will be broken down to investigate the determinants of the DE and SE respectively as well as how the DE and SEs play as factors of sustainable development.

2.2 Resources

The literature obtained and analysed for review in this study are obtained from credible sources and using multiple methods in order to obtain said literature. In terms of sources, this study utilised dedicated platforms containing academic literature which are Web of Science and ProQuest to sieve through and select the relevant literature. As for methods, the study employed a Systematic Literature Review (SLR) method along with the ancestry method, deemed efficient methods to systematically search, filter, and pick out the necessary and relevant materials for this study. The ProQuest and Web of Science are input into the VosViewer analytical system through BibTeX and RIS file formats which contain detailed information on the set of literature processed. The information utilised in the literature review was extracted and reviewed on 19th January 2025.

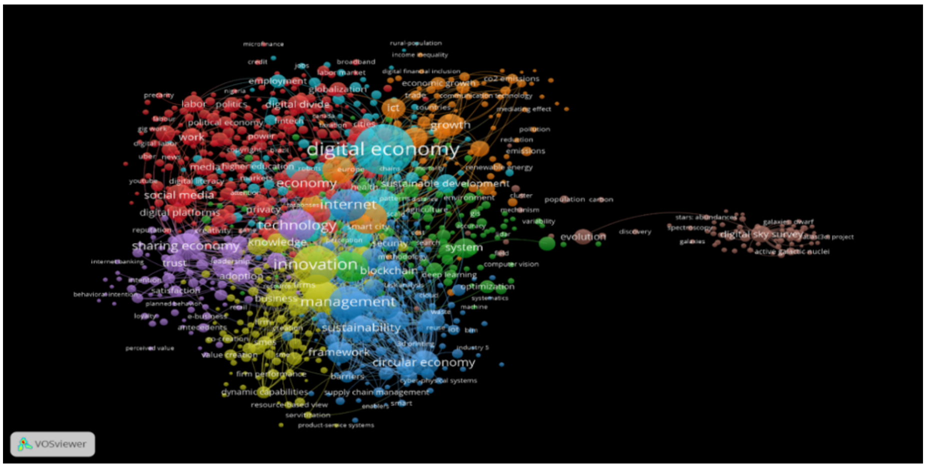
2.3 Bibliometric Analysis

Figure 2-1:
Bibliometric analysis flow diagram



Bibliometric analysis involves a methodical examination of literature sourced from the DE search results, followed by a detailed analysis of a selected subset of literature. This analysis aims to investigate the connections between DE, SE, and Sustainable Development. The term "DE" is utilized as a guiding concept for conducting the literature search and exploring digitalization. The process follows a structured methodology that begins with an analysis of the entire literature pool and then focuses on a specific sample. By interpreting the outcomes presented through visualizations, the interrelationships among DE, SE, and Sustainable Development are objectively examined.

Figure 2-2:
Co-Occurrence Network Visualization (n=25,991)



Source: VosViewer

Figure 2-3:
Co-Occurrence Density Visualization (n=25,991)

Source: VosViewer

In Figures 2.2 and 2.3, there are illustrations of keyword co-occurrence extracted from the literature encompassing the DE population. These visualizations depict distinct clusters of keywords, notably including terms like "digital economy," "sharing economy," and "sustainability." The purpose of observing these network visualizations is to uncover the connections between subjects and prevalent topics discussed collectively in the literature. The interlinked nature of these prominent themes, as evident from the numerous connections, substantiates the presence of a relationship among DE, SE, and sustainability within a shared context. This substantiates the relevance of referencing this study to demonstrate their interplay.

Figure 2-4:
DE Cluster Network Visualization, n= 715 links, 6,280 total link strength, 2,051 occurrences

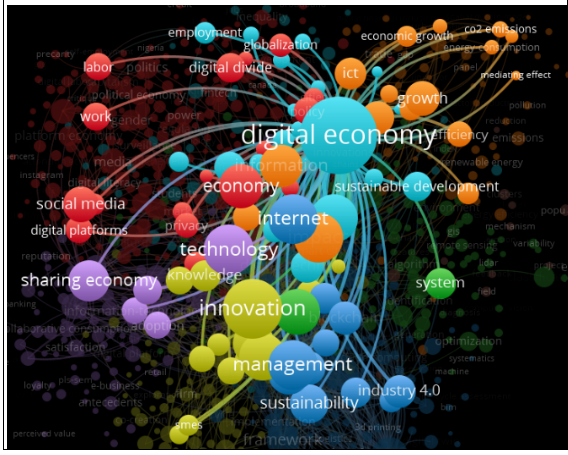


Figure 2-5:
SE Cluster Network Visualization, n= 582 links, 3,168 total link strength, 595 occurrences

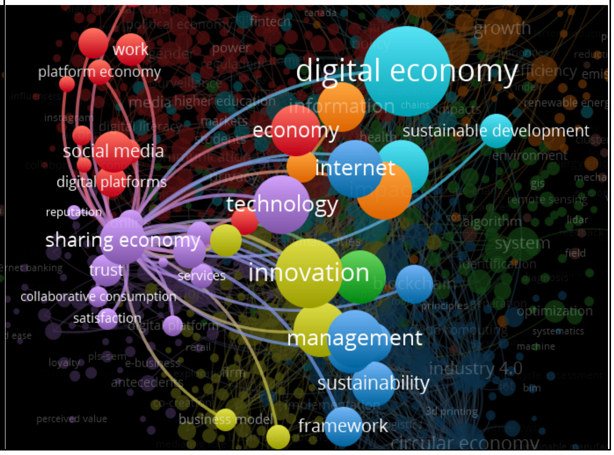
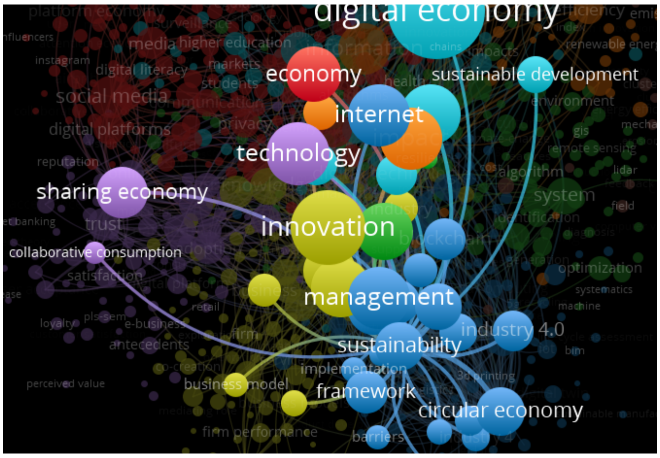


Figure 2-6:
Sustainability Cluster Network Visualization, n= 613 links, 3,179 total link strength, 532 occurrences



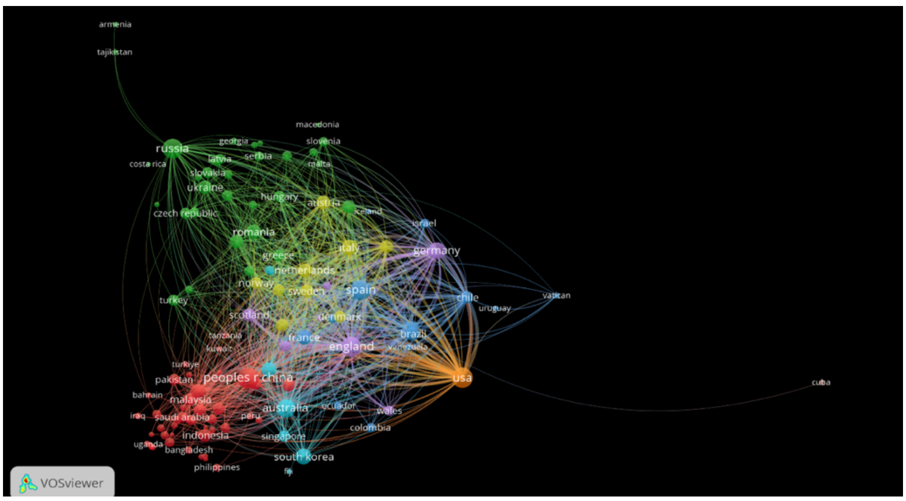
Upon closer examination of the clusters in the Co-Occurrence Network Visualization, it becomes evident that distinct terms pertinent to the DE, SE, and Sustainable Development are distinguishable based on the varying colours assigned to these clusters. The general overview of the network visualization is to see the existence of elements or clusters within the same environment which then requires for a narrowed scope at the clusters of interest for a more micro understanding of the relationships. The DE cluster is noted with a teal-coloured accent while the SE and Sustainable Development are denoted with purple and blue respectively. The most observable point from Figures 2.4, 2.5, and 2.6 is such that the DE and SE are common topics of discussion in the context of sustainability and vice versa as explained by the networks and prominence of topic reflected by the term's bubble size.

The density visualization, on the other hand, denotes the weightage of keywords which is a reflection of the frequency occurrence of the term. This information is referenced as a form of trend analysis of research areas based on the hotspots in the visualization. The darker hue or saturation of yellow around a term indicates a higher weightage or occurrence. There is a coherence in findings between the network visualization and density visualization which show subject matter focus in past literature on the SE, sustainability, and the circular economy.

Further notable observations from the Figures above show a large spread of terms and their co-occurrences in relationship to the terms in question in this paper. This suggests a growing diversity of subject matter research which have a linkage to or a basis in digitalisation. There appears to be a significant volume of nodes and recurring terms within the network visualization of the literature population pool.

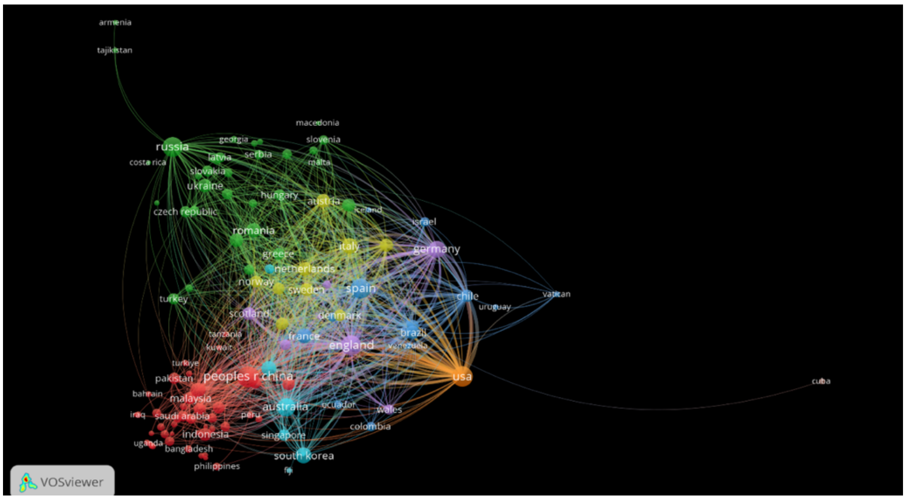
The employment of bibliometric analysis within this study introduces a unique analytical approach that encompasses various dimensions or aspects, including, but not confined to, textual analysis, keyword co-occurrence, co-authorship, and bibliographic coupling. These analytical dimensions provide a more profound comprehension of the interconnection between DE, SE, and sustainable development, along with an assessment of the strength of their interrelationships. The outcomes of the ongoing bibliometric analysis unveil a substantial and varied body of research investigating the nexus of digitalization and sustainable development.

Figure 2-7:
Co-Authorship by Country Network Visualization (n=25,991)



Source: VosViewer

Figure 2-8:
Bibliographic Coupling Network Visualization (n=25,991)



Source: VosViewer

Figures 2.7 and 2.8 show the correlation of the literature through co-authorship and bibliographic coupling analysis based on source countries. These figures visualize the growing attention of digitalisation around the world which consequently have an impact on the volume of scholarly discourse contributed to the domestic and global literary space. A frequent topic discussed is the reliance of economies on their domestic digital economy contributions to overall GDP along with other relevant macro and microeconomic variables (Ojanpera et al., 2019). Furthering this topic of discussion, Bukht and Heeks (2017) question the accuracy of measurement frameworks adopted by national economies in measuring their digital economy as the lack of homogeneity in measurement globally could wrongly portray the digital economy environment.

The realm of literature showcases collaborative endeavours evident as seen in the collaborative authorship of research papers as well as linkage of literature towards one another, revealing the interconnected nature of established scholarly works and discussions concerning digitalization and sustainable development. The degree and intensity of this relationship are assessed by examining the interlinking network lines and the thickness of these lines in both analyses. The outcomes substantiate the escalating interest in the domain encompassing DE, SE, and sustainable development, which is characterized by a worldwide experience of their application and phenomena. This, in turn, calls for a multitude of contributions from a diverse array of intellectual viewpoints. The global collaboration tackles new paradigms through the expansion of research areas with digitalisation at its core, further contributing information to the existing body of knowledge.

2.4 Systematic Literature Review

Table 2-1:
Search criterion and method for article selection from ProQuests and Web of Science Database

Search methods	**ProQuest database**	**Description**
Keywords and filters were used in the initial search for articles		"Sharing economy" was used along with the filters mentioned below.
Key filters were used to filter the relevant records	567,108 records	The types of articles were in English and full-text versions of: Scholarly Journals, Dissertations/Theses, Books, or Conference Papers/Proceedings.
Selection criteria was used to determine the final sample	17 articles	Selected articles were read and filtered from the database based on the factors in relation to sharing economy and sustainable development.
Keywords were used in the initial search for articles	36,090 records	The keyword "sharing economy" was applied.
Key filters were used to filter the relevant records	12,063 records	The articles were English, open-access versions of: Book Chapters, Books, Review Articles, or Articles.
Selection criteria was used to determine the final sample	27 articles	Selected articles were read and filtered from the database based on the factors in relation to sharing economy and sustainable development.
Keywords were used in the initial search for articles	25,991 records	The keyword "digital economy" was applied.
Key filters were used to filter the relevant records.	10,165 records	The types of articles were English, open-access versions of: Book Chapters, Books, Review Articles, Articles, or Proceedings Papers.
Selection criteria was used to determine the final sample	40 articles	Selected articles were read and filtered from the database based on the factors in relation to sharing economy and sustainable development.
Total	**84 articles**	

The quest for literature pertinent to the DE, SE, and Sustainable Development, germane to this study, was executed on ProQuest and Web of Science scholarly databases to ensure a comprehensive scope of outcomes. The preliminary search was centered on keywords such as "Digital Economy" and "Sharing Economy," with the application of relevant filters to sift through the extensive volume of literature, as illustrated in Table 2.1.

The ProQuest platform was utilized only for the search of the sharing economy whereas Web of Science was used for the search of Digital Economy and Sharing Economy as the research started with searches on ProQuest but was moved to Web of Science for a larger research pool access. This process aimed to eliminate literature not pertinent to the subject matter. Subsequent refinement was carried out by evaluating abstracts and content to enhance precision and alignment with the focus of this study, resulting in a collection of 84 articles. This curated selection constitutes the literature sample pool, derived from the broader population pool of n=25,991 used in the aforementioned bibliometric analysis.

2.4.1 Selection Overview

Figure 2-9:
Selection Process Overview

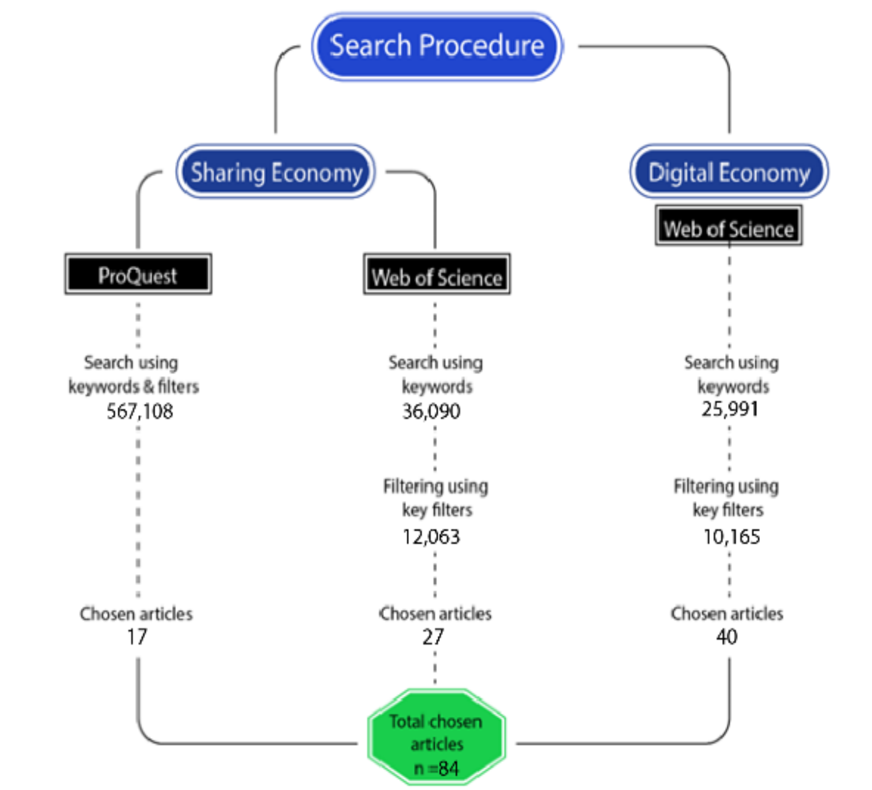
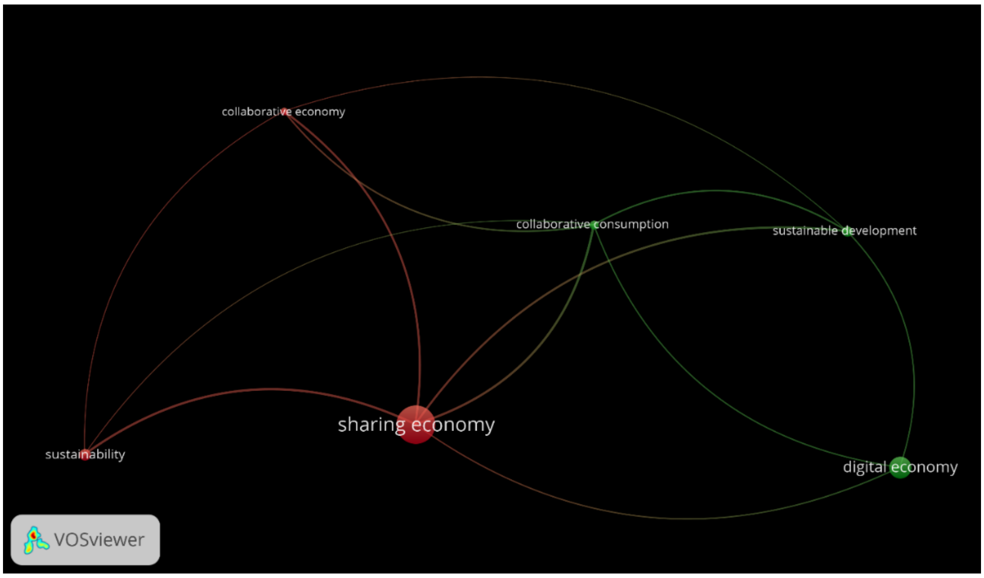


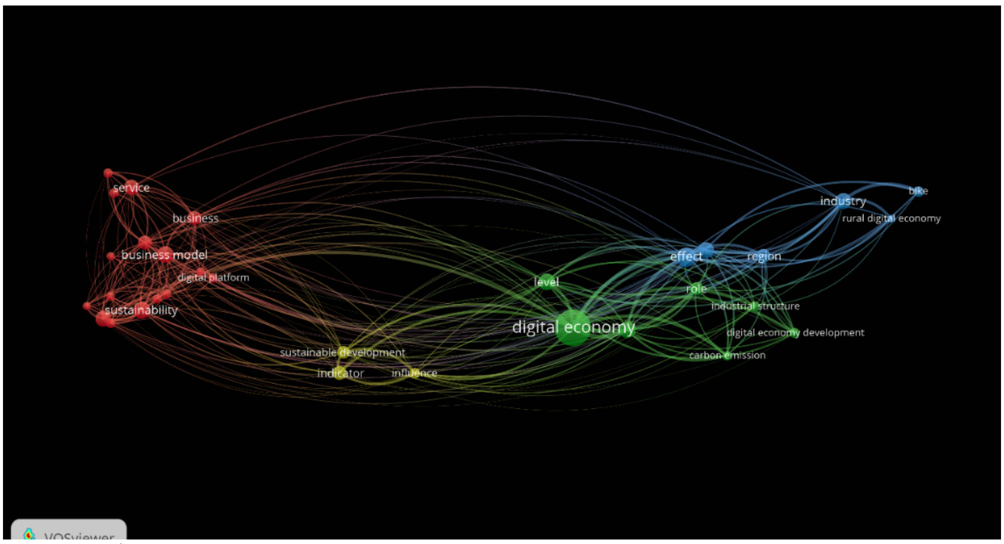
Figure 2-10:
Keyword Co-Occurrence Network Visualization, n=84



Source: VosViewer

A clear pattern emerges in the keyword terms within the selected articles concerning the DE, SE, and sustainable development. Figure 2.10 illustrates a network visualization wherein the minimum occurrence threshold is set at 10, highlighting the most frequently employed keywords. This depiction reveals that terms like SE, DE, and matters related to sustainability, among others, hold the highest prevalence within this targeted realm of research. These keywords essentially delineate the scope of the current study's subject area, forming its defining field or sub-field. The visualization of the sample set, comprising 84 specifically chosen articles, indicates a substantial relevance to the study's focus, underscoring that most of this set aligns with the study's objectives.

Figure 2-11:
Text Co-Occurrence Network Visualization, n=84



Source: VosViewer

When analysing the frequency of textual data within the sample pool of articles, Figure 2.11 reveals the presence of three primary clusters of terminology: Economy, Digital Economy, and Sustainability. Notably, a significant difference between the network visualizations depicted in Figures 2.10 and 2.11 is the absence of the term "sharing economy" within the co-occurrence of text data. A plausible explanation for this discrepancy could be attributed to the infrequent repetition of discussions specifically centered around the sharing economy. While the SE draws in consumers through its inherent advantages, thus integrating them into a digitalized form of the economy, the underlying foundation of this space is motivated and driven by digital infrastructure (Pouri & Hilty, 2018). The foundational importance of this form of infrastructure supersedes the SE and feeds mainly into the DE, contributing to the absence of a separate cluster for the term "sharing economy" in the co-occurrence analysis.

Figure 2-12:
Number of publications by year, n=84

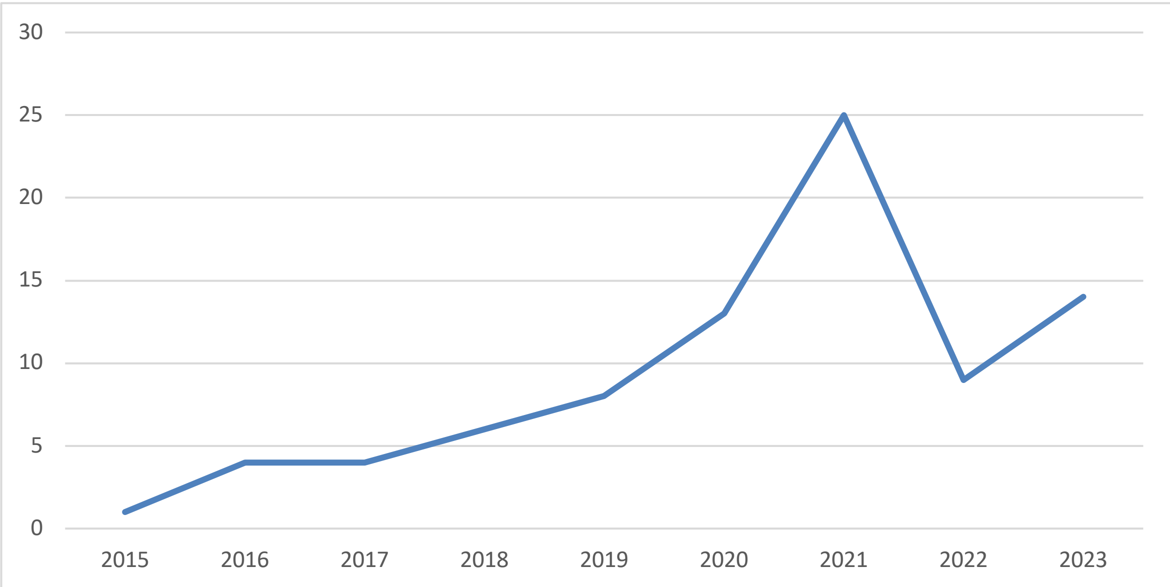


Figure 2.12 presents a visualization of the publication trend based on the volume of publications extracted from the selected literature for review. The earliest article meticulously chosen for inclusion in the literature review dates back to 2015. A discernible upsurge in publications is noted between 2015 and 2018, with a particularly notable surge in 2019. This remarkable spike can be attributed to the escalating global attention and emphasis on the digitalization of the economy, as well as the corresponding relevance of these innovative economic forms. This phenomenon swiftly transitioned the focus toward the realms of digitalization and sustainable development, reflecting the urgency for acknowledgment and response from both the global and domestic economies. The study also acknowledges the notable drop in volume of publications in 2021 which is likely due to the occurrence of the COVID-19 pandemic which halted global processes.

Even though the present study was conducted in the first half of 2023, it's evident that scholars have already displayed a burgeoning interest in the fields of DE and SE, as evidenced by the significant volume of publications addressing these subjects. The imperative need for digitalization is instigating a new era of continuous integration and innovation within the economic landscape, giving rise to a transformative phase wherein all strata of society are compelled to either embrace and adapt to these changes or face the risk of falling behind.

The bibliographic analysis employed in this study operates as a macro-level reflection, capturing patterns within the literature landscape of the designated areas of emphasis. The analytical dimensions within the bibliometric analysis incorporate variables such as keywords, text content, and pertinent information extracted from the literature. These variables serve as inputs for trend analysis, complementing the examination of relevant subject matters and associated areas of interest.

By employing this analytical approach on the literature, the outcomes are illustrated through the formation of clusters, thereby offering a more lucid representation of the dE, SE, and sustainable development ecosystem. This methodology enhances our understanding of the intricate relationships and interdependencies within these domains, providing a comprehensive insight into their dynamics.

However, it's important to note that this study doesn't solely encompass a macro-level examination. It also incorporates a Systematic Literature Review, which offers a micro-level analysis of the literature's contents. Through a rigorous selection proces, the extensive collection of past literature sample extracted from the population pool undergoes a series of filters to identify the most pertinent literature, serving as key points of reference for this study.

The bibliographic analysis and systematic literature review exhibit discernible differences in their analytical outcomes. Nevertheless, the fundamental purpose of both approaches aligns, as they are equally essential in mapping the literary landscape surrounding digitalization and sustainable development. While the bibliographic analysis provides a broad view on a macro scale, the systematic literature review delves into the finer details on a micro scale.

The simultaneous utilization of both methodologies follows a funnel-like approach to the literature review. The analysis initiates with a larger population of literature, subsequently narrowed down by stringent field-specific criteria and filters. As evident in Figures 2.10, 2.11, and 2.12, the initial collection of 25,991 articles, obtained from a comprehensive search of the digital economy, is systematically reduced to a refined sample of 84 articles.

Instead of implementing the bibliometric analysis and systematic literature review independently from each other, this study utilizes both approaches to analyse and extract holistic information from the sample pool of literature.

2.5 Analysis

2.5.1 Digital Economy and Sharing Economy

The pace of global economic advancement is currently accelerating, particularly in connection to the digital economy. This surge is rooted in the rapid exchange of information and the seamless integration made possible by easy accessibility across markets, sectors, and industries (Kruljac, 2021). As a consequence, this development exerts a substantial and positive influence on total factor productivity (Tian & Liu, 2021). Empirical evidence supporting this relationship commonly employs econometric regression techniques, where ICT-related indicators are used to explain variations in productivity and output, demonstrating that efficiency gains and improved resource allocation act as the primary transmission mechanisms through which digitalisation supports economic growth (Tian & Liu, 2021; Kruljac, 2021). The shift towards an economy driven by information has also spurred the necessity and evolution of information and communication technology (ICT) infrastructure. This framework creates a socioeconomic context that places emphasis on the adoption of the aforementioned digital infrastructure (Baranov, 2022).

This shift towards digitalization's socioeconomic benefits is particularly pronounced in the realm of accessibility, extending to both producers and consumers. As a result, it influences the dynamics of supply and demand, leading to notable implications for employment. This impact is observed even within a society characterized by gender inequality, income disparities, and urban-rural divides (Wysokińska, 2021). Empirical studies examining these dynamics typically rely on macroeconomic and labour-market indicators alongside digital connectivity measures, showing that digitalisation can mitigate structural inequalities by expanding access to markets and employment, although the magnitude of these effects varies by domestic context and level of digital readiness (Wysokińska, 2021).

Even as contemporary discussions revel in the perks of the digital economy, especially in the age of Industry 4.0, its dark side, with unresolved challenges, needs equal attention. A pivotal hurdle rests in defining it, a constantly shifting target due to varying national landscapes. As the tech revolution unfolds and advanced systems like Big Data and the Internet of Things weave themselves into the fabric of economies, numerous studies and economies elevate the role of ICT infrastructure as a defining characteristic, or at least a vital component, of digitalization (Abendin & Duan, 2021; Baranov, 2022; Chinoracky & Corejova, 2021; Jiang, 2020; Kurniawati, 2022; Y. Li et al., 2021; Su et al., 2021).

Uneven access to robust digital measurement tools across economies exposes a critical missing piece in the digital ecosystem. This calls for the development of a flexible and responsive framework, as the OECD (2020) emphasizes. Deciding what data to include and exclude to accurately depict the digital environment is a multifaceted challenge, shaped by a web of internal and external factors (Bukht & Heeks, 2017). This methodological challenge is reflected in empirical studies, where the choice of digital economy indicators, often centred on ICT infrastructure and platform penetration, directly shapes the observed economic and environmental outcomes, reinforcing the importance of contextualised indicator selection highlighted by Bukht and Heeks (2017) and the OECD (2020).

Driven by insights from Bukht and Heeks' (2017) study, we see a clear connection between the digital economy's definition and its boundaries. This concept evolves into the idea of a segmented digital economy, with three distinct stages: the core, the general, and the fully digitized. The growing dominance of digital platforms as the next phase of economic integration points towards a more refined definition, one that now encompasses the digital economy's engagement with the sharing economy.

A significant concern identified in this study pertains to the intersection between the sharing economy and the digital economy. Botsman (2015) established the sharing economy as a system that assigns value to underutilized assets through a decentralized network, deviating from the conventional economic model driven by capital accumulation and pricing. Upon a comprehensive exploration of the literature related to the sharing economy, it becomes evident that the definition of this economic facet has evolved to adopt a more tangible framework, with variations that align with the distinct characteristics of different economies. In a general sense, the sharing economy operates on the principles of collaborative exchange of goods and services facilitated by digital platforms (Boar et al., 2020; Daunorienė et al., 2015; Hernandez-Carrion, 2021; Trabucchi et al., 2019; Yeganeh, 2021). As posited by Lyakovskaya and Khudyakova (2021), the abstract nature of the sharing economy results in an insignificant influence of the SE on sustainable development due to the lack of fixed indicators to measure it. The consequence is such that the DE indicators have been applied to the measurement of the SE despite being insufficient and inaccurate for that sector. As a result, empirical analyses of the sharing economy frequently rely on indirect proxies such as platform-based consumption or digital transaction data, limiting the ability to isolate the independent effects of the SE on sustainable development outcomes (Lyakovskaya & Khudyakova, 2021; Boar et al., 2020; Hernandez-Carrion, 2021). However, the common understanding of the SE is such that it is based on socioeconomic factors, such as trust and also technological factors (Tham, Lim, & Vieceli, 2022).

In the context of the modern sharing economy, another significant aspect to consider is the recurring role of digitization as a catalyst for its existence. Liu & Chen (2020) put forth the notion that the sharing economy thrives on the generation of value and utility from underutilized assets, facilitated through digital platforms. This viewpoint resonates with the perspectives presented by Daunorienė et al. (2015), Dabbous and Tarhini (2021), and Bai & Velamuri (2021), united by a shared understanding, they see peer-to-peer systems as the engine of the sharing economy, fueled by digital networks that optimize resource utilization, facilitate swifter trade, democratize data and information, and inject increased velocity into economic transactions.

Initially, technology's role in the sharing economy was seen as bridging the gap between business-to-business and peer-to-peer interactions through telecommunications. This simplified the model to three core elements: service providers, users, and digital platforms (Šiuškaitė et al., 2019). Despite the inherent socio-economic disparities and human nature's innate constraints in embracing such a market model, the adoption and evolution of digital platforms function as governance mechanisms that coordinate the market and its activities (Bai & Velamuri, 2021). A typology study on the Sharing Economy by Liu et al. (2020) reinforces the idea that internet-mediated platforms are integral for the functioning of the Sharing Economy.

Despite differences in how the digital economy is conceptualized, a common thread emerges: the centrality of technological adoption, particularly through widespread and reliable digital infrastructure. This alignment finds further support in the realm of the sharing economy, where empirical research illuminates the critical role of digital platforms in effectively bridging the gap between the digital and sharing spheres, fuelling its modern-day operations.

By examining the interplay between the digital and sharing economies, this analysis culminates in the powerful concept of the DSE. Pouri and Hilty (2021) describe it as the point of convergence, where the technical prowess of the digital economy merges with the social capital of the sharing economy. This resonates with the DSE's unique position as a specialized subset of the digital economy, seamlessly integrating its tools into the existing sharing economy framework. As Park and Armstrong (2017) explain, the DSE manifests in two forms: through broad thematic overlaps between the two economies and through specific instances. However, the crucial insight lies in the undeniable influence of the internet and digital platforms on driving consumption in the apparel market, providing compelling evidence for the intertwined nature of the digital and sharing economies, as seen in this study.

This analysis seeks to illuminate the intricate relationship between the digital and sharing economies, exemplified by the concept of the DSE. However, it recognizes that despite this shared representation, fundamental differences in their underlying nature maintain their individual identities.

Tying back to the research issue, the relationship between the DE and SE also has a significant tie-in with the state of digital divide in the country. While the technological capabilities and social capital are merged into a singular working, it also incites the question of penetration rate of the technological capabilities and the corresponding social capital contributing to the DSE. As examined within this stream of the literature review, the initial role of the sharing economy was to utilize technology to bridge business-to-business and peer-to-peer gaps through telecommunications. With the adoption of digital platforms growing to be a form of governance mechanism of the market, the linear relationship of the DE and SE is evident, where the higher penetration of technological capabilities and digital platforms, the higher the contribution of social capital and participation in the contemporary sharing economy or the DSE.

2.5.2 Digitalisation and Sustainable Development

Tangentially, there has been an increase in discourse on digitalisation and sustainable development. The 2030 Agenda for Sustainable Development along with the 17 Sustainable Development Goals (SDGs) by United Nations (2015a) paved the way for sustainable development discourse. As part of the scholarly discourse and research conducted on digitalization as well as the DE and SE, sustainable development commonly manifests its role in the form of sustainable economic growth and also its contributions to environmental concerns. However, the broad nature of sustainable development requires a measurable vector to quantitatively observe the effects of the digital economy and sharing economy towards sustainable development. Thus, the use of the UN SDGs has become prolific as an avenue of measurement such as in the works of Wysokińska (2021), Pouri and Hilty (2018), and Lyaskovskaya and Khudyakova (2021). The 17 SDGs, in the context of research, are commonly seen individually based on the interest of the research and are unique to that research. This is reflected in this study where the vector of measurement is based on SDGs 8 and 13.

The juxtaposition of digitalisation and environmental sustainability is evident as meeting the environmental standards of some countries would result in a transaction cost increase for all parameters of a product's life cycle (Vishnevsky et al., 2021). The ecosystem disruptions from the development and usage of the digital innovation are also a perceived risk. However, the negative aspects do not outweigh the positive impact of digitalisation. The reflection of the relationship of digitalization and ecological sustainability is not directly observable but rather seen through proxies such as carbon emissions. Consequently, empirical studies predominantly apply panel and time-series regression methods using carbon emissions, emissions intensity, and energy intensity as dependent variables, consistently finding that digitalisation can reduce environmental pressures through efficiency gains and technological upgrading, while acknowledging heterogeneity across countries and sectors (Enochsson et al., 2021; Li et al., 2021; Z. Li et al., 2021; Lyu et al., 2023; Ma et al., 2023; Meng et al., 2023; Zeng et al., 2023; Lv et al., 2023; Ma et al., 2023). In the case of wastewater discharge, Sun et al. (2022) discussed the influencing factor of digitalisation of the economy as a driver to develop the industrial structure as a means of efficiency and reducing polluting emissions into the environment.

While a consensus on the precise impact of digitalization on environmental sustainability remains elusive, primarily due to the diverse determinants influenced by domestic contexts, Curtis and Mont (2020) present a thought-provoking perspective. They propose that the symbiosis between the sharing economy and digitalization does not inherently guarantee sustainability. Rather, a collaborative endeavour is imperative to effectively instil environmental and market sustainability attributes within the framework of Sharing Economy Business Models (SEBMs).

On the opposite end of the spectrum, discussions delve into the realm of sustainable economic development, a broad and all-encompassing horizon. The existing body of research on this subject tends to examine specific parameters in isolation, aiming to dissect how these elements collectively contribute to potential economic advancement. One pivotal factor within this context is the transformation of consumption patterns, which is a consequence of the pervasive impact of digitalization on conventional systems.

The rapid and widespread adoption of digital technologies, coupled with active engagement in the sharing economy, has served as a potent catalyst in amplifying the reuse and optimization of utility from existing resources. This significant shift has substantially diverted attention away from non-renewable resources within the consumption ecosystem (Pouri & Hilty, 2018). The transition toward consumption patterns cantered on reutilization and utility maximization, among other factors, holds the potential to address the prevalent economic concern of resource scarcity. This shift could potentially bolster the sustainability endeavours within digitalized markets (Barbu et al., 2018), offering a potential solution to the ongoing challenge of resource scarcity through sustainable practices and economic advancement. This is supported by the trend in literature on how digitalisation could be the solution to resource scarcity and inefficient allocation. Shen, Yang, and Wang (2022) and Tian et al. (2023) point out that the efficiency derived from the integration of digitalization led to the alleviation of resource allocation and mismatch.

The discourse surrounding the contribution of digitalization, whether within the sharing economy or digital economy, encompasses a range of factors spanning social, economic, ecological, and technological dimensions, all of which underscore the benefits derived from digitalization's evolution (Šiuškaitė et al., 2019). As previously discussed, the shift in consumption patterns reverberates across the socioeconomic landscape, ecological aspects, and the development trajectory of digital markets, offering a prospect of enduring sustainability.

On the supply side of the digitalization equation, discussions centre on its role in sustainable economic development. The spillover effect of technological progress amplifies the capacity of business activities and production, diversifying their scope and scale while concurrently reducing costs across various tiers. This confluence results in the creation of opportunities for development and expansion of economic activities (Bonciu & Bâlgăr, 2016).

Contrary to unsubstantiated assertions that mechanization and digitalization across sectors erode employment prospects, digitalization actually stimulates employment absorption. This occurs through the growth of industries and sectors that necessitate a greater pool of human capital to support their expansion. This employment absorption becomes a vital factor integrated into digitalization-related metrics, calculations, and considerations (Chinoracky & Corejova, 2021; Jiang, 2020; Z. Li et al., 2021; Pouri & Hilty, 2018; Su et al., 2021).A macro-outlook on the effects of digitalisation on economic growth can be sectorally as well, promoting the sustainability of the sector by increasing the quality of governance and increasing freedom of trade (Tang, 2023) all based on the importance of Internet penetration (Konnikov et al., 2020; Kruljac, 2021). The U-shaped return of digitalisation stimulates innovation and entrepreneurship, reducing knowledge gaps, cost burdens, and digital orientation of firms, ultimately leading to an increase in the nation’s GDP (Capello, Lenzi, & Panzera, 2023; Amoah et al., 2023; Chen et al., 2023). The impact of digitalisation may not be directly apparent but can commonly be seen through greater efficiencies, improved processes and better data management, all of which enable sustainability objectives and diminishes negative effects from the disruptive nature of digitalisation (Wynn & Jones, 2022; Rutkowska-Gurak & Adamska, 2019).

Thus, the analysis and dive into the link of digitalization and sustainable development has mixed results where the relationship between digitalization and ecological sustainability is not directly observable and its link to economic development has certain benefits across the economy. This addresses the second research question in which a question of the role of the digital economy and sharing economy towards the sustainability of traditional businesses is questioned. With evidence of digitalization, the basis of the digital economy and sharing economy, having measurable and observable significant impact on the economy, its adoption and integration into businesses as well as participation in digital networks does have a degree of sustainability on businesses. Inversely, the absence of its adoption and participation in a digitally fuelled economy will be a lag factor for traditional businesses, causing them to lose competitive advantage against more resilient businesses which adapt to the changing economic environment.

Irrespective of the domain, the role of knowledge and skills is pivotal in the advancement of any sector or industry. This sentiment holds true regardless of the field's nature. In the context of delineating the infrastructure of the platform economy, Plewnia and Guenther (2017) underscore the critical importance of education within the framework of digital infrastructure. This education aspect gains heightened significance when it comes to shaping and mapping the trajectory of digitalization.

In discussions pertaining to digitalization, particularly in the context of sustainable development, the role of education manifests diversely. However, there is a consensus surrounding its portrayal as a key social factor. Referring to the overarching concept of the Sustainable Development Goals (SDGs), the literature unanimously acknowledges the positive impact of digitalization, notably within the sharing economy domain. This impact aligns with the goal of reducing disparities in education, thereby fostering human capital investment (Boar et al., 2020; Dabbous & Tarhini, 2021; Perkumienė et al., 2021). Another form on capacity building through knowledge development is the socioeconomic awareness on ecological concerns that have prospective positive impact. The rapid spread of digitalization is due to environmental awareness (Curtis & Lehner, 2019) as well as the perceived value received when actively contributing and participating in the DE and SE which include cost reduction and the willingness to share (Bonciu & Bâlgăr, 2016; Choi & Choi, 2020; Lyaskovskaya & Khudyakova, 2021).

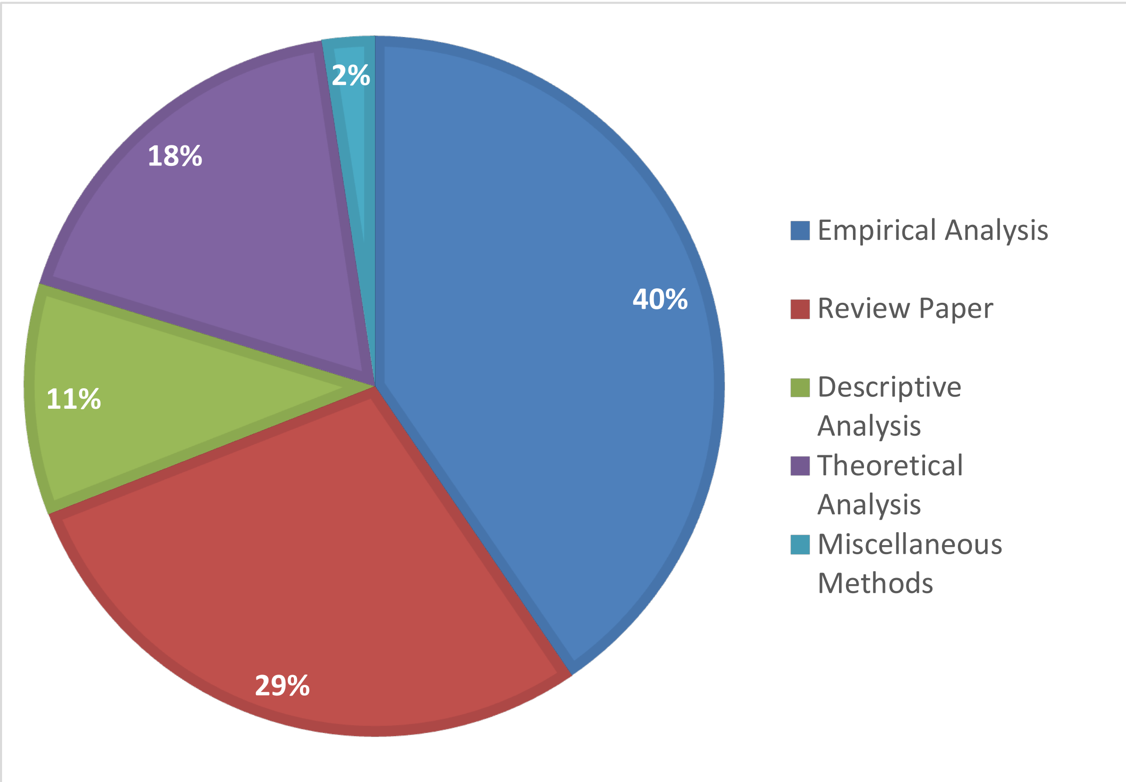
Readiness in the spatial context of digitalisation requires attention as well. The readiness, awareness and trustworthiness of a digitally driven service is a pre-requisite for faster expansion, given that it is supported by proper information network infrastructure and talents in IT (Eyupoglu & Kaya, 2020; Li et al., 2023). The influencing factors which affect digitalisation in the context of spatial distribution often refers to the endowment and the externalities which affect the location (Hellwig, 2023), be it the concentration of education, especially tertiary ones, population size, or even industry-specific externalities. Consequently, location becomes a great influencing factor on the probability of SME digital technology adoption. With existing urban-rural gaps, the concentration of digital adoption is obvious, but exceptions may exist with encouraging business environments (Holl & Rama, 2023).

Tying it all together is the factor of governance in the face of digitalisation. The digital adoption by businesses have commonly seen U-shaped pattern where initial cost increase is necessary with slow returns in the future. Thus, to alleviate or minimize the trade-offs between opportunities and costs, the affected regions require prompt and educated policy responses and interventions (Capello, Lenzi, & Panzera, 2022). Putting it under the microscope requires an examination into which type of governance is best suited for digitalisation or the digital sharing economy, where it provides maximal opportunities for businesses and the economy to flourish (Palm, Sodergren, & Brocken, 2019) but also avoids the formation of a collective or cartel which eventually ends up in monopolies and oligopolies having majority market share and control of prices (Erickson & Sorensen, 2016).

2.5.2.1 Methodological Summary of Past Research

Due to the abstract nature of the Digital Economy in the global and domestic economy, methodologies adopted in the analysis of Digital Economy with respect to specific research areas a broad in range and varied in approaches. Spanning across quantitative, qualitative, theoretical, and other types of approaches, this study takes all aspects into consideration in deciding upon the methodology, data and variables used for the analysis. Based on the literature from the literature review chapter, the study has identified several categories of approaches used in the discussion and analysis of research papers in relation to digitalisation.

Figure 2-13:
Past literature methodology breakdown, n=84



An extension of the extraction and content analysis conducted in the earlier chapter, the methodologies employed in the chosen relevant literature can be observed as a reference to this study. The breakdown of the types of methodologies used are illustrated in Figure 2.13. Considering the abstract and broad nature of the research area, the majority of chosen literature have utilized a literature methodology as a means of reviewing the existing body of knowledge and identifying the gaps and opportunities in general or specific to a region. Empirical analysis is just below review papers in methodology popularity where the majority of papers utilize a form of regression in their analysis. A variety of regression forms can be observed such as time series and panel data regression (Konnikov et al., 2020; Abendin & Duan, 2021; Li, Li, & Wen, 2021; Su, Su, & Wang, 2021; Sun et al., 2022; Li, Liu, & Ni, 2021), LP Semiparametric method (Tian & Liu, 2021), and Bayesian regression (Yin, Kirkulak-Uludag, & Chen, 2021).

After careful evaluation and consideration of possible avenues in terms of methodologies, this study adopts a quantitative approach through econometric empirical modelling to test and estimate the relationships proposed in the conceptual framework. Under the umbrella term of quantitative research methodology, past literature has adopted varied techniques such as panel data analysis (Abendin & Duan, 2021; Dabbous & Tarhini, 2021), other regression methods (Li et al., 2021; Tian & Liu, 2021), and other quantitative methods such as index evaluation, multivariate statistical analysis and structural equation modelling (Chinoracky & Corejova, 2021; Choi & Choi, 2020; Kholiavko et al., 2020; Li et al., 2021; Li et al., 2021; Su et al., 2021; Tian & Liu, 2021; Vishnevsky et al., 2021). A time series testing would allow for the analysis of the digital and sharing economy towards sustainable development from a temporal paradigm.

On the basis of actually measuring the digital economy, sharing economy, and sustainable development, the literature review, as mentioned in prior sections of this study, adopt varied indicators for each area, based on data availability and domestic circumstances. The generic analysis of the performance of individual digital economy is conducted through the measurement of performance of ICT indicators with respect to macroeconomic indicators. As for the sharing economy, the primary form of measuring it, with the knowledge that the sharing economy globally is still in its infancy, is through analysis of consumption data. This includes the analysis of consumption observed through digital platforms which are commonly proxied by national digital transactions data.

Finally, in tackling sustainable development, the primary form of measuring and observing global and domestic progress towards sustainability goals is through the UN SDGs. For the purposes of this study, focus is placed on SDGs 8 and 13 which are to promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all; and take urgent action to combat climate change and its impacts.

The methodology relevance is such that the findings of the literature review are used as the basis and point of reference for this study’s direction.

2.6 Theoretical Framework

This study is anchored in two complementary theoretical foundations that explain the emergence, expansion, and sustainability implications of the digital economy (DE) and sharing economy (SE): Schumpeter's Theory of Innovation and Creative Destruction, and Green Economy Theory. Together, these frameworks provide an integrated basis for analysing how digitalisation-driven economic transformation influences economic growth and environmental sustainability outcomes in Malaysia.

2.6.1. Schumpeterian Theory of Innovation and Creative Destruction

The development of the digital economy and sharing economy as dominant contemporary economic systems can be theoretically explained through Joseph Schumpeter's theory of innovation as the primary driver of economic growth. Schumpeter (1934) conceptualised economic development as a dynamic process driven by innovation, entrepreneurship, and technological change, where new combinations of production methods disrupt existing economic structures. Innovation, in this context, functions as the central mechanism through which productivity gains, structural transformation, and long-term economic growth occur.

Building on this foundation, Schumpeter's later articulation of creative destruction (Schumpeter, 1942) emphasises that new economic systems inevitably replace older, less efficient ones once their utility is exhausted. Economic systems that are able to fully exploit technological advancements and adapt to evolving market conditions emerge as dominant, while those that fail to do so decline. This theoretical perspective is highly relevant to the current global and Malaysian context, where traditional production and consumption models are increasingly displaced by digitalised, platform-based systems.

Within this framework, the digital economy represents a manifestation of creative destruction, where digital technologies, data-driven processes, and platform infrastructures redefine competitiveness, efficiency, and value creation. Similarly, the sharing economy operates as an extension of this innovation-driven transformation by enabling new modes of asset utilisation, peer-to-peer exchange, and market coordination through digital platforms. Rather than price mechanisms alone determining market outcomes, technological capability and digital integration increasingly shape productivity, competitiveness, and economic growth.

For this study, Schumpeterian theory provides the theoretical justification for examining GDP per capita as an outcome of DE and SE development. If digitalisation and platform-based economic activity function as innovation-driven systems, their expansion should be reflected in improved productivity and income growth, consistent with SDG 8. At the same time, creative destruction implies transitional costs and uneven impacts, which supports the study's empirical investigation into the magnitude and direction of these effects in Malaysia.

2.6.2. Cobb–Douglas Production Function and Solow Growth Theory

This study is also grounded in the Cobb–Douglas production function and the Solow growth model, which provide a well-established theoretical basis for analysing the relationship between production factors, technological progress, and economic outcomes. The Solow growth model (Solow, 1956), extending the Cobb–Douglas framework, conceptualises output as a function of capital, labour, and exogenous technological progress, with long-run growth driven primarily by improvements in productivity rather than factor accumulation alone.

Within this framework, technological progress plays a central role in enhancing output per worker, making it particularly relevant to the study of digitalisation. In the Malaysian context, the expansion of digital infrastructure, increased internet usage, and the growth of platform-based economic activity reflect contemporary forms of technological advancement. These developments align with the Solow model's emphasis on productivity-enhancing technology and provide a theoretical justification for examining GDP per capita as an outcome of digital and sharing economy development.

Beyond economic growth, the Cobb–Douglas–Solow framework also supports the examination of environmental outcomes. Changes in technology and production efficiency influence not only output levels but also emissions intensity and resource use. As Malaysia continues to pursue economic growth amid rising energy demand, digitalisation may alter production processes with implications for GHG emissions. Accordingly, this theoretical perspective underpins the study's assessment of how the digital economy and sharing economy, as technology-driven forces, influence both SDG 8 (economic growth) and SDG 13 (climate action) outcomes.

2.7 Research Gaps and Original Contribution

A prevalent gap in this area of study is the lack of generalized framework to measure the digital economy and sharing economy and is commonly reliant on the circumstances of the country. In its absence, the measurement of digitalisation often falls onto the context of the domestic environment and availability of data and indicators. Thus, this study analyses the suitability of indicators to be applied in the case of Malaysia from a broad range of indicators used within other literature, consequently increasing the accuracy of the picture of analysis painted by this study. Thus, the execution of content analysis within this study in the literature review chapter has enabled the consolidation of information as well as its organization to understand the methods of measurement and usage of indicators across sectors with relation to the digital economy and sharing economy. This has enabled the fulfilment of RO1 which was intended to conceptualize the digital economy, sharing economy and sustainable development through tangible and measurable indicators and their corresponding methodologies.

A specific investigation into the broad impact of digitalization, as acted out by the digital economy and sharing economy, towards sustainable development has not yet been prolifically tested, especially with the use of specific indicators as listed within the SDGs. Hence, this study fills in another gap in the literary space through the fulfilment of RO2 and RO3. The empirical testing as put forth by these two research objectives provide quantitative backing of the relationship between the digital economy and sharing economy towards sustainable development. Existing literature posits that individually, the digital economy and sharing economy are seen to have a positive impact on sustainable development where there has been an increase in growth alongside a reduction in non-renewable energy consumption as discussed earlier. To fully understand the placement of the sharing economy and digital economy in the space of the digital revolution, this study investigates both these areas simultaneously and in relation to each other.

Finally, this study intends on establishing the relationship between the digital economy and sharing economy with quantitative backing. Through the employment of a causality test, this study establishes the relationship between the two along with the direction of relationship and strength or size of the relationship.

CHAPTER 3:

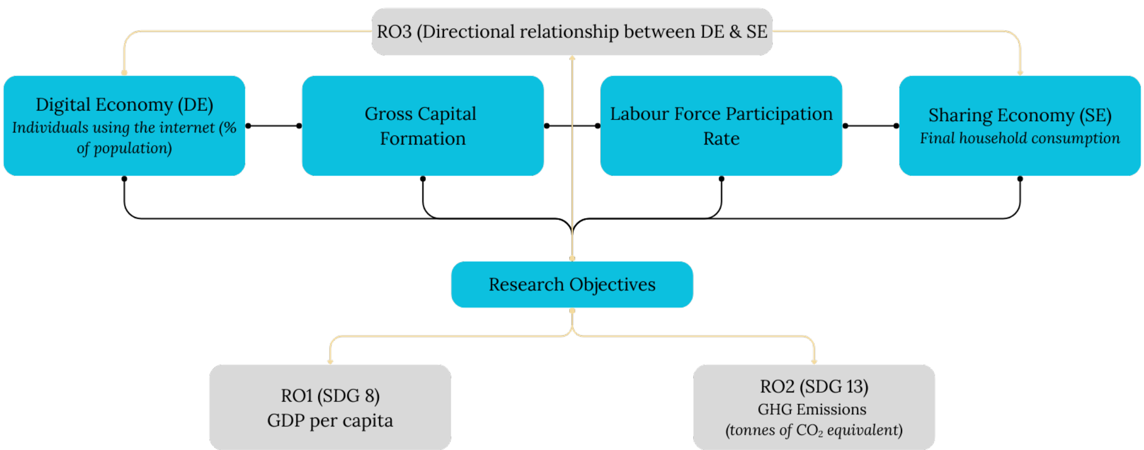
RESEARCH METHODOLOGY

3.1 Overview

This portion of the study encompasses the clarification of variables and methods used for the empirical analysis in the later parts of the study. The data and variables used in conjunction with the selected methodology and techniques are based on the information and knowledge extracted in the literature review. Detailed exploration of data sources and specific tests and empirical strategy is made in this section to provide clarity on the approach taken to the results and discussion in the following sections.

3.2 Conceptual Framework

Figure 3-1:
Conceptual framework of the study



The conceptual framework of this study is grounded in established definitions that position it as the foundation for articulating the study's rationale, core arguments, and methodological alignment. Ravitch and Riggan (2017) define a conceptual framework as a representation of the study's underlying assumptions, key components, and analytical focus, while Marshall and Rossman (2016, as cited in Drew et al., 2020) describe it as a means of linking research questions to relevant constructs and issues. In this study, the conceptual framework specifies the selected variables and their hypothesised relationships, forming the basis for empirical modelling and testing.

The framework is developed to support all three research objectives of the study. First, it conceptualises the relationships between the digital economy and sharing economy and economic outcomes under SDG 8, proxied by GDP per capita. Second, it extends this conceptualisation to environmental outcomes under SDG 13, proxied by GHG emissions measured in tonnes of CO_2 equivalent. Third, the framework incorporates the hypothesised directional relationship between the digital economy and sharing economy, recognising that digitalisation enables platform-based sharing activities. These relationships are derived from the synthesis of existing literature through the bibliometric analysis and systematic literature review presented in Chapter 2.

The literature review further indicates the presence of interlinkages among the independent variables, as well as direct relationships between the independent and dependent variables. These conceptual relationships are embedded within the framework and applied to the Malaysian context. The study then empirically tests these relationships using econometric techniques, including Granger causality and Toda–Yamamoto causality tests, to assess the nature, direction, and strength of the linkages.

3.3 Data Description

The analyses conducted in this study are informed by prior empirical literature examining the digital economy, sharing economy, and sustainable development. Accordingly, a content analysis of the existing literature is undertaken to identify indicators commonly used to represent these constructs. The indicators extracted from the literature are subsequently evaluated against the Malaysian context in terms of data suitability, consistency, and availability, resulting in a curated set of variables that align with the objectives of this study.

The empirical analysis focuses on Malaysia over the sample period 1995 to 2023, employing a quarterly frequency. The selected period corresponds with the early phase of digitalisation in Malaysia following the establishment of the Multimedia Super Corridor (MSC) in 1996, which marked a structural shift towards a digital-driven economy. The end year is determined by the most recent data availability to ensure relevance to current economic conditions. While the time span of 1995–2023 is relatively limited for time-series analysis, this constraint is mitigated through the use of quarterly data, which increases the number of observations and enhances the reliability of econometric estimation. The quarterly series are obtained from the CEIC data platform (CEIC, n.d.), where higher-frequency data are compiled and harmonised from official sources. As such, the limited length of the sample period is acknowledged as a methodological limitation, but one that is partially addressed through higher-frequency data and appropriate econometric techniques suited for small samples.

Consistent with earlier sections of the study, the digital economy is proxied by indicators related to information and communication technology (ICT), reflecting the country's level of digital penetration and accessibility. The sharing economy, based on its conceptualisation as digitally enabled consumption, is proxied by consumption-related indicators. Sustainable development is operationalised using indicators aligned with the United Nations Sustainable Development Goals (SDGs), with specific focus on SDG 8 (Decent Work and Economic Growth) and SDG 13 (Climate Action). Sub-indicators are selected based on relevance and data availability within the Malaysian context.

Accordingly, the variables employed in the study include individuals using the internet (% of population), household final consumption expenditure, total greenhouse gas emissions (tonnes of CO_2 equivalent per year), GDP per capita, gross fixed capital formation, and labour force participation rate. These variables collectively represent the digital economy, sharing economy, economic growth, environmental outcomes, and conventional production inputs.

In terms of variable justification, individuals using the internet (% of population) is used to reflect the digital economy, capturing the extent of digital penetration and accessibility within Malaysia. This indicator is widely adopted in empirical studies on digitalisation and economic performance (Abendin & Duan, 2021; Kurniawati, 2022). The sharing economy is proxied by household final consumption expenditure, reflecting consumption patterns facilitated by digital and ICT infrastructure. This approach is consistent with prior studies that operationalise sharing economy activity through consumption-based indicators (Boar et al., 2020; Hernandez-Carrion, 2021; Yeganeh, 2021). The use of consumption data in tandem with ICT indicators supports the conceptual premise that the sharing economy is enabled by digitalisation.

Finally, to address SDGs 8 and 13, the study employs GDP per capita to capture economic growth and individual economic well-being, and total greenhouse gas emissions (tonnes of CO_2 equivalent per year) to reflect climate action and environmental sustainability. These indicators are selected from the UN SDG framework and represent the most suitable proxies given Malaysia's data availability. Together, they enable a balanced assessment of the economic and environmental implications of digital and sharing economy development within the country.

In addition, this study incorporates dummy variables for the Asian Financial Crisis (AFC), Global Financial Crisis (GFC), and COVID-19 period to account for major exogenous shocks that may have introduced structural breaks into Malaysia's macroeconomic and emissions trajectories. In time-series econometric modelling, failure to control for such crisis-related disruptions can lead to biased or unstable parameter estimates by attributing shock-driven fluctuations to the explanatory variables of interest. The inclusion of crisis dummies therefore serves as an econometrically appropriate adjustment that isolates the underlying long-run and short-run relationships between the digital economy, sharing economy, and sustainable development outcomes from exceptional periods of volatility (Pesaran et al., 2001; Shrestha, 2018).

The AFC is included as a dummy variable because it represented a severe macroeconomic disruption across East and Southeast Asia, including Malaysia, characterised by financial instability, currency depreciation, and contractionary effects on investment and consumption. Similarly, the GFC is incorporated due to its global spillover effects, particularly through trade, capital flows, and financial market linkages, which may have altered Malaysia's growth and production environment. The COVID-19 dummy is also necessary, as the pandemic generated simultaneous shocks to economic output, labour markets, consumption behaviour, mobility patterns, and emissions, while accelerating digital adoption and the use of platform-based services. These crisis periods may therefore influence both GDP per capita (SDG 8) and GHG emissions (SDG 13) outcomes, as well as the relationships between digitalisation and consumption-related variables.

Overall, the inclusion of AFC, GFC, and COVID dummy variables enhances model robustness by capturing crisis-specific structural shifts and preventing these extraordinary events from confounding the estimated effects of the study's key explanatory variables. This approach improves the interpretability and stability of the ARDL/NARDL estimations and supports more reliable inference within the Malaysian context (Pesaran et al., 2001; Shrestha, 2018).

Table 3-1:
Variable Selection Summary

Variable	**Source**
Individuals using the internet (% of population)	Abendin & Duan (2021); Kurniawati (2022)
Final household consumption	Boar et al. (2020); Hernandez-Carrion (2021); Yeganeh (2021)
Tonnes of CO_2 equivalent	UN SDGs (2015a)
GDP per capita	

3.4 Model Specification

The model used in this study is based on the growth model proposed by Solow (1956) which factors in the change of technological innovation into the growth calculation of the economy. An extension of the Cobb-Douglas production function, Solow (1956) too found that the level of output from economic activity is dependent on the production factors or the inputs, namely labour and capital, which enable said economic activities. However, the growth model was not complete until the exogenous factor, technological progress, was added to reflect the change the global economy environment and technical progress.

$$Q = A K^{a} L^{b}, \qquad \text{Equation 3.1}$$

where a+b=1 to indicate the constant returns to scale and A as a multifactor productivity or the technological factor of the production function. The Cobb-Douglas production function was found to explain the rise in quantity in production and was consequently rewritten to concentrate on the output per worker which is output per capita.

$$Q / L = A K^{a} L^{b-1}, \qquad \text{Equation 3.2}$$

It is assumed that a+b=1 and a=1-b.

$$Q = A (K / L)^{a}, \qquad \text{Equation 3.3}$$

Further transformed to q = A k a

In the space of analysing the impact of capital, labour and technology on output, the model is further rewritten.

$$Q = K^{a} L^{b-1} A \qquad \text{Equation 3.4}$$

The model can be perceived as a reflection of the theoretical basis of Schumpeter (1942) as described above. The growth model takes into account any systemic change especially driven by the change in technology and how it affects the economy. Now more than ever does the change in technology and any of its corresponding effects need to be measured as the global economy makes its way through the fourth digital revolution.

Based on the theoretical foundations provided by the Cobb-Douglas-Solow growth model and Schumpeter's theory of innovation, this study derives a context-specific empirical specification tailored to its research objectives. While the empirical model employed does not replicate the classical production function in its exact form or components, it represents a theoretically informed adaptation that incorporates contemporary indicators relevant to the digital and sharing economy. In this regard, the model is retrofitted to reflect structural and technological characteristics pertinent to the Malaysian economy.

Consistent with the production function framework, economic output (Q) is operationalised through GDP per capita rather than aggregate GDP measured at constant prices. While the classical Cobb–Douglas formulation focuses on total output, this study adopts GDP per capita as it is a recognised indicator for assessing economic performance and income outcomes under SDG 8, as defined by the United Nations. The use of GDP per capita as a dependent variable in this study is consistent with empirical literature examining the economic effects of digitalisation and ICT-driven growth. Prior studies commonly employ GDP per capita to capture productivity and income effects at the population level, particularly when analysing technology-enabled economic transformation. Li (2020) finds that digital economy development exerts a statistically significant positive effect on real GDP per capita, indicating that digitalisation enhances income generation rather than merely expanding aggregate output. Similarly, Pradhan et al. (2018) demonstrate a long-run cointegrated relationship between ICT infrastructure and per-capita real GDP across G20 economies. The suitability of GDP per capita is further reinforced by causality-based studies, which show directional relationships between internet usage and per-capita income, highlighting the endogenous interaction between digital connectivity and economic performance (Sekmen, 2017; Murthy, 2021). Collectively, these findings provide strong empirical and methodological precedent for modelling GDP per capita as the economic outcome variable in studies assessing the impact of the digital economy.

In parallel, GHG emissions measured in tonnes of CO_2 equivalent per year are incorporated as a second dependent variable to represent environmental outcomes associated with economic activity. Although emissions are not a traditional output in the classical production function, their inclusion reflects contemporary extensions of growth models that recognise environmental externalities arising from capital accumulation, labour participation, and technological change. The integration of GHG emissions is therefore consistent with the study's objective of examining SDG 13 (Climate Action) and enables an assessment of whether technology-driven economic transformation, particularly through the digital and sharing economies, contributes to or mitigates environmental pressures in Malaysia.

Technological progress, which occupies a central position in both the Solow growth model and Schumpeterian theory, is operationalised through indicators associated with the DE and SE. Specifically, individuals using the internet and final household consumption are incorporated to capture the role of digitalisation and platform-enabled economic activity. This approach enables the study to empirically examine how technology-driven economic transformation interacts with capital and labour inputs to influence economic growth and environmental outcomes within the Malaysian context.

This study does not apply logarithmic transformation to the variables, as the empirical focus is on modelling the dynamic adjustment and asymmetric responses within the ARDL/NARDL framework rather than imposing elasticity-based interpretation through functional form transformation. While log transformations are commonly used to stabilise variance and linearise multiplicative relationships, they are not a mandatory requirement for valid ARDL or NARDL estimation, provided that key econometric assumptions are satisfied and the model is correctly specified (Pesaran et al., 2001; Shin et al., 2014). In addition, log transformations may not be appropriate or necessary where variables are already expressed in bounded or rate-based measures (e.g., proportions or participation rates), as taking logs can reduce interpretability and introduce scaling distortions without improving model performance.

Table 3-2:
Definition of Indicators

Proxies	Abbreviation	Unit of Measure	Period	Frequency

Dependent Variables	Real GDP per Capita	GDPPC	RM	1995-2023	Quarterly
	Total Greenhouse Gas Emissions: Tonnes of CO_2 Equivalent per Year	GHG	Million tonnes	1995-2023	Quarterly
Independent Variables	Gross Fixed Capital Formation	GFCF	RM million	1995-2023	Quarterly
	Labour Force Participation Rate	LFPR	%	1995-2023	Quarterly
	Internet Users: Individuals: % of Population	INDV	%	1995-2023	Quarterly
	Household Final Consumption Expenditure	HCONSUMP	RM million	1995-2023	Quarterly

$$GDPPC_t = \alpha + \beta_1 GFCF_t + \beta_2 \mathrm{LFPR}_t + \beta_3 \mathrm{INDV}_t + \beta_4 \mathrm{HCONSUMP}_t + \varepsilon_i \quad \text{Equation 3.5}$$

$$GHG_t = \alpha + \beta_1 GFCF_t + \beta_2 \mathrm{LFPR}_t + \beta_3 \mathrm{INDV}_t + \beta_4 \mathrm{HCONSUMP}_t + \varepsilon_i \quad \text{Equation 3.6}$$

$GDPPC_t$ = *Gross Domestic Product (GDP) per Capita*

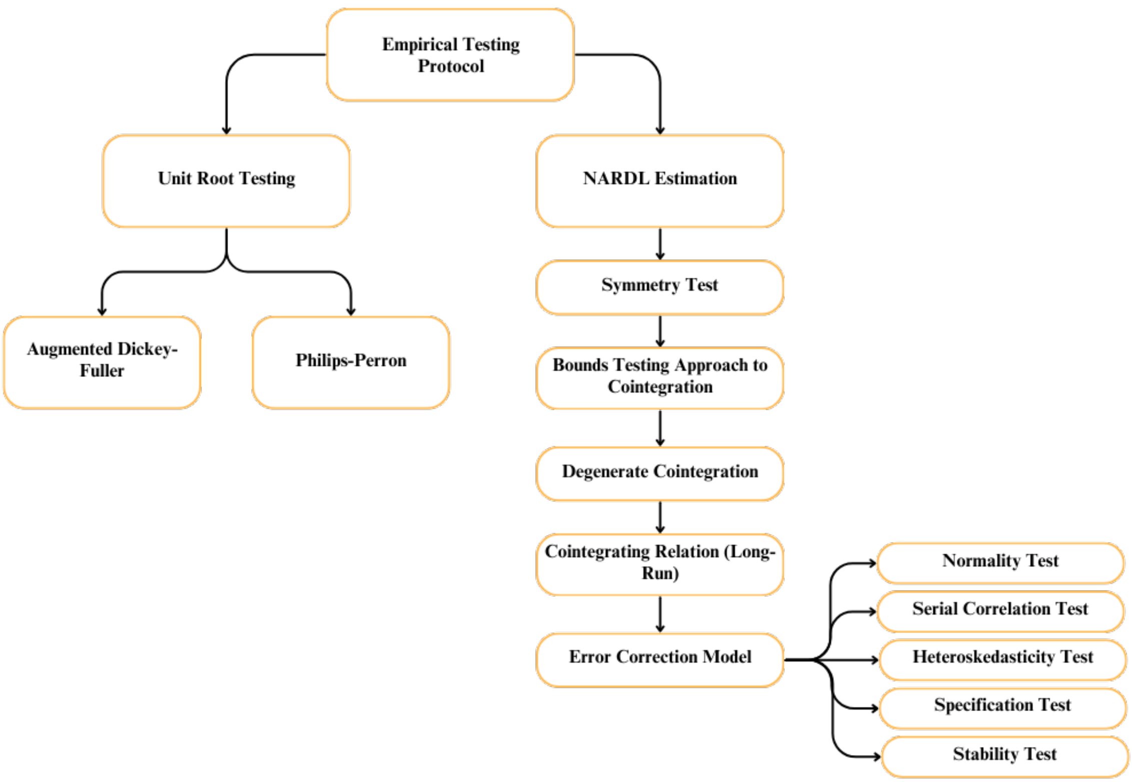
GHG = *Total Greenhouse Gas Emissions: Tonnes of CO2 Equivalent per Year*

α = *intercept term*

GFCF	=	*Gross Fixed Capital Formation*
LFPR	=	*Labour Force Participation Rate*
INDV	=	*Individuals using the internet (% of population)*
HCONSUMP	=	*Household final consumption expenditure*
ε	=	*error term*
t	=	*Time period, 1995 – 2023*

3.5 Empirical Test Protocol

Figure 3-2:
Empirical Protocol Flowchart



This section outlines the empirical strategy adopted to examine the relationship between the digital economy, sharing economy, and sustainable development outcomes in Malaysia. Guided by the study's conceptual and theoretical frameworks, a time-series econometric approach is employed to assess both the long-run and short-run dynamics between the selected variables. The methodology is structured to ensure econometric robustness and logical sequencing, beginning with tests for stationarity, followed by model specification and estimation, and concluding with diagnostic and stability assessments.

Specifically, the analysis proceeds through five main stages: unit root testing, bounds and asymmetry testing, long-run estimation, short-run dynamics, and diagnostic testing. This structured approach ensures that the statistical properties of the data are appropriately addressed before inference is made, while allowing for the identification of equilibrium relationships, adjustment dynamics, and causal interactions between the digital economy and sharing economy in relation to economic and environmental outcomes.

3.5.1. Unit Root Tests

The study uses the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) tests to analyse the stationarity of the variables in the model. The ADF test incorporates the lags of the dependent variable into the series to overcome biases, should there be any, which stem from serial correlation in the residuals of the series (Mahadeva & Robinson, 2004).

$$\Delta X_t = yX_{t-1} + \Sigma_{i=1}^{p} \beta_i \Delta X_{t-1} + \varepsilon_t \qquad \text{Equation 3.7}$$

Modelled to be an extension and improvement of the Dickey-Fuller unit root test, the PP test considers a drift and trend in the series to account for the linear time trend and is a nonparametric approach (Phillips & Perron, 1988). The linear and nonparametric nature of the test eliminates the possibility of biased results from serial correlation and heteroskedasticity.

$$\Delta X_{t-1} = \alpha_0 + yX_{t-1} + \varepsilon_t \qquad \text{Equation 3.8}$$

3.5.2. Asymmetry/Bounds Tests

This study adopts the Nonlinear Autoregressive Distributed Lag (NARDL) framework to examine the relationship between the digital economy, sharing economy, and Malaysia's SDG 8 outcome proxied by GDP per capita. NARDL is particularly suitable because it allows positive and negative changes in key variables to exert different short-run and long-run effects, which is highly relevant for digitalisation and consumption dynamics where responses are often nonlinear due to adjustment costs, structural frictions, and behavioural effects (Shin et al., 2014). In addition, NARDL retains the core strengths of the ARDL family by enabling cointegration testing and estimation with I(0) and I(1) variables, provided none are I(2), making it appropriate for the stationarity properties observed in this study (Pesaran et al., 2001).

The use of NARDL also aligns with the study's theoretical foundation. From a Cobb–Douglas–Solow perspective, output depends on factor inputs and productivity, and technology-driven change can generate uneven growth impacts depending on the economy's ability to absorb and diffuse innovation (Solow, 1956). Similarly, Schumpeterian theory emphasises that innovation-led structural transformation does not necessarily produce proportional outcomes across phases of expansion and contraction, supporting the expectation of asymmetric effects in a transitioning economy. Empirically, asymmetry is increasingly recognised as a realistic feature of digitalisation-related relationships: Mishra and Dash (2022), for example, demonstrate that ICT-related variables can exhibit asymmetric impacts on development outcomes when modelled using a nonlinear ARDL framework, reinforcing the need for nonlinear estimation when analysing technology-driven change. In parallel, the environmental burden associated with expanding digital infrastructure is well documented, where rising ICT intensity increases electricity demand and can generate spillover pressures that shape broader economic systems (Andersen & Edler, 2015).

Formally, the general NARDL model is specified as:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=0}^{q} \beta_j^+ X_{t-j}^+ + \sum_{j=0}^{q} \beta_j^- X_{t-j}^- + \varepsilon_t \qquad \text{Equation 3.9}$$

where Y_t denotes the dependent variable (GDP per capita or GHG emissions), and X_t^+ and X_t^- represent the cumulative positive and negative changes in the explanatory variables. This specification allows the long-run and short-run effects of increases and decreases in digital economy and sharing economy indicators to be estimated separately.

To test for asymmetric cointegration, the NARDL model is re-parameterised into its unrestricted error correction (bounds testing) form:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p-1} \alpha_i \Delta Y_{t-i} + \sum_{j=0}^{q-1} \gamma_j^+ \Delta X_{t-j}^+ + \sum_{j=0}^{q-1} \gamma_j^- \Delta X_{t-j}^- + \phi Y_{t-1} + \theta^+ X_{t-1}^+ + \theta^- X_{t-1}^- + \varepsilon_t \qquad \text{Equation 3.10}$$

Within this framework, three key tests are conducted. First, a bounds test for cointegration assesses the existence of a long-run equilibrium relationship among the variables. Second, Wald tests for symmetry are applied to determine whether positive and negative shocks exert statistically different effects in the short and long run. Third, degenerate cointegration tests are employed to further validate the robustness of the identified long-run relationship. Together, these tests ensure that any detected asymmetry and cointegration are statistically reliable.

Where no evidence of asymmetry is detected, the study adopts a linear ARDL bounds testing approach as a secondary empirical protocol. The general linear ARDL model is specified as:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=0}^{q} \beta_j X_{t-j} + \varepsilon_t \qquad \text{Equation 3.11}$$

and is similarly re-parameterised into an unrestricted error correction form for bounds testing. The inclusion of linear ARDL serves two important purposes. First, it acts as a robustness benchmark against the nonlinear specification, ensuring that results are not driven solely by functional form assumptions. Second, it allows long-run relationships to be identified in cases where the effects of digitalisation and consumption are symmetric rather than asymmetric. This dual-model strategy enhances the credibility and interpretability of the empirical findings.

3.5.3. Long-Run Estimation

Upon establishing cointegration, the long-run coefficients are estimated within the appropriate ARDL or NARDL framework. In the NARDL specification, long-run relationships are captured through the coefficients associated with the lagged level terms of the dependent variable and the decomposed positive and negative components of the independent variables. These estimates quantify the persistent impact of digital economy and sharing economy indicators, alongside capital formation and labour participation, on economic and environmental outcomes. The asymmetric decomposition follows Shin et al. (2014) and is represented as:

$$X_t = X_t^+ + X_t^- \qquad \text{Equation 3.12}$$

Where:

$X_t^+ = \Sigma_{j=1}^{t} \max(\Delta X_j, 0)$: Cumulative sum of positive changes in X

$X_t^- = \Sigma_{j=1}^{t} \min(\Delta X_j, 0)$: Cumulative sum of negative changes in X

This decomposition allows the long-run effects of increases and decreases in an independent variable to be estimated separately. Such differentiation is essential for capturing real-world economic relationships, where expansions in digitalisation or consumption may not mirror contractions in their effects on output or emissions.

For cases where asymmetry is not statistically supported, the long-run coefficients are estimated using the linear ARDL model. This ensures consistency in long-run inference and facilitates comparison between symmetric and asymmetric specifications across the two models examined in the study: one addressing sustainable economic growth and the other addressing sustainable ecological outcomes.

3.5.4. Short-Run Estimation

To analyse short-run adjustments toward long-run equilibrium, the study estimates an Error Correction Model (ECM) derived from the selected ARDL or NARDL specification. The ECM captures both short-run dynamics and the speed of adjustment following short-term shocks, with a statistically significant and negative error correction term confirming the stability of the long-run relationship. The short-run NARDL specification is expressed as:

$$\Delta X_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \sum_{j=0}^{p} \gamma_j^{+} \Delta X_{t-j}^{+} + \sum_{j=0}^{p} \gamma_j^{-} \Delta X_{t-j}^{-} + \phi Y_{t-1} + X_{t-1}^{+} + \theta^{-} X_{t-1}^{-} + \varepsilon_t \quad \text{Equation 3.13}$$

Where γ_j^+ and γ_j^- represent the short-run effects of positive and negative changes, and θ^+ and θ^- represent the corresponding long-run effects.

The examination of short-run dynamics provides insights into how quickly economic and environmental outcomes respond to changes in digitalisation, consumption, capital, and labour inputs. Together with the long-run estimates, this analysis enables a comprehensive assessment of both immediate and persistent effects, directly supporting the study's research objectives.

3.5.5. Diagnostic Tests

The empirical analysis is also put through a series of diagnostic checks which are intended to investigate if the empirical model and assumptions made about the series is consistent with the actuality of the recorded data (Ferre, 2009). In ensuring that the model fits the basic econometric assumptions, the diagnostic checks which will be conducted are as listed in Figure 3.2. With the exception of the Stability Tests, the diagnostic checks will be based on the following hypotheses:

H_0 = There is no diagnostical error in the model

H_1 = There is diagnostical error in the model

Another novel element in this study is the usage of the Toda-Yamamoto Granger Causality, an extension of the general Granger Causality test. This form of causality check is based on the estimation of the Vector Autoregression (VAR) refers to the optimal lag and the highest order of integration among the variables (Dritsaki, 2017). This approach complements best the ARDL method which allows for the estimation of variables with different integrated orders within the model.

$$y_t = \mu_0 + (\sum_{i=1}^{k} \alpha_{lt} y_{t-1} + \sum_{i=k+1}^{d_{max}} \alpha_{2t} y_{t-1}) + (\sum_{i=1}^{k} \beta_{lt} y_{t-1} + \sum_{i=k+1}^{d_{max}} \beta_{2t} y_{t-1})$$

Equation 3.14

The need to use the Toda-Yamamoto Granger Causality test falls on several of its advantages over the conventional Granger Causality test, particularly when dealing with limitations in the data. Firstly, it is able to handle non-stationary data where the test addresses the management of non-stationarity such as fluctuations over time by including additional lags into the model (Inusah, 2018). Furthermore, the test integrates a varied F-statistic rather than a one size fits all number when it comes to sample sizes that are significantly small, creating the distinction between cointegration that was found in the pre-testing and causality (Narayan, 2004; Pesaran, Shin, & Smith, 2001).

CHAPTER 4:

EMPIRICAL RESULTS

4.1 Overview

The study takes on the fulfilment of the research objectives laid out in the first chapter as well as answering the research issues explained to be prevalent issues within the areas of study. Based on the data and information accumulated and found in the previous chapters, the study uses it as input to supplement the empirical analysis conducted. Furthermore, the results of the analysis discussed in this chapter will be used to elaborate and expand on the research objectives as well as explain the relationship between the Digital Economy and Sharing Economy and the DE and SE towards Sustainable Development.

4.2 Unit Root Test Results

The unit root tests chosen to understand the stationarity of the variables are the ADF and PP tests. Besides the ability of the ADF test to incorporate the lags of the dependent variable into the series to overcome biases, the test also performs well against trend-stationary alternatives (DeJong et al., 1992). Supplementing the ADF is the utilization of the PP test, designed for models that account for both gradual shifts (trends) and ongoing changes (drifts) in the data. This enables them to distinguish between data that lacks a long-term direction (nonstationary) and data that exhibits a consistent upward or downward movement (stationary around a trend) (Phillips & Perron, 1988). Ultimately, the use of two types of unit root tests is to exhibit a more robust conclusion about the stationarity of the data.

Table 4-1:
Augmented Dickey-Fuller (ADF) unit root test results

Series	Level		First Difference	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept
GDPPC	1.2203 (12)	-3.3271 (4)	-3.0216 (11)**	-3.3971 (11)
GHG	-1.1276 (0)	-2.3310 (0)	-11.7819 (0)**	-11.7868 (0)**
GFCF	-0.6166 (4)	-2.7084 (4)	-4.5499 (3)**	-4.5989 (3)**
LFPR	0.1027 (1)	-1.3099 (1)	-7.6851 (1)**	-7.8013 (1)**
INDV	-1.3.36 (4)	-2.3012 (4)	-4.0461 (3)**	-4.1235 (3)**
HCONSUMP	1.5439 (4)	-2.2109 (4)	-3.6231 (4)**	-4.3373 (4)**

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GDPPC = GDP per capita; GHG = total greenhouse gas emissions: tonnes of CO_2 equivalent per year; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

Table 4-2:
Phillips-Perron (PP) unit root test results

Series	Level		First Difference	
	Intercept	Trend & Intercept	Intercept	Trend & Intercept
GDPPC	0.5982 (3)	-3.2948 (5)	-11.9919 (3)**	-11.9040 (2)**
GHG	-1.1756 (4)	-2.1912 (5)	-11.9446 (4)**	-12.0152 (3)**
GFCF	-0.5830 (5)	-2.2419 (5)	-10.6883 (4)**	-10.6792 (4)**
LFPR	-0.2873 (9)	-1.5360 (9)	-11.2593 (9)**	-11.2620(9)**
INDV	-0.9606 (8)	-2.1517 (8)	-12.3086 (9)**	-12.3435 (8)**
HCONSUMP	2.3375 (9)	-2.0524 (9)	-12.5464 (9)**	-14.0395 (8)**

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GDPPC = GDP per capita; GHG = total greenhouse gas emissions: tonnes of CO_2 equivalent per year; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

Tables 4.1 and 4.2 present the results of the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests conducted to determine the stationarity properties of the variables used in this study. The tests are reported under both specifications with intercept and with trend and intercept, at both level and first difference.

Overall, the results indicate that all variables are non-stationary at level, as none of the series show statistical significance at the 5% level in their level form. However, after taking the first difference, all variables become statistically significant at the 5% level under both the ADF and PP tests. This confirms that GDPPC, GHG, GFCF, LFPR, INDV, and HCONSUMP are stationary at first difference, and therefore integrated of order one, I(1).

Taken together, the ADF and PP findings consistently suggest that the variables become stationary only after differencing once, and importantly, there is no indication of any series being integrated of order two. This outcome supports the suitability of the ARDL and NARDL approaches, as these methods are appropriate for modelling variables that are I(0) and/or I(1), while requiring that none of the variables are I(2).

4.3 Empirical Testing for RO1

For the purposes of this study and the fulfilment of the research objectives, the NARDL estimation is repeated twice due to the existence of two models and two dependent variables. The first is to investigate the influence in which the DE and SE have towards sustainable economic growth while the second model is to investigate the influence of the DE and SE towards sustainable ecological development. The ensuing symmetry test is conducted on the DE and SE variables which are INDV and HCONSUMP as the purpose of the study is to understand the joint effects of these variables towards economic growth and environmental sustainability as well as to understand how the positive and negative changes in these variables impact GDP per capita and total greenhouse gas emissions.

4.3.1 Symmetry Test

The NARDL estimation protocol begins with the utilisation of a symmetry test to determine if the positive and negative changes of the independent variables on the dependent variable differ or if they can be assumed to be the same, which would then call the need for a simpler model specification.

Furthermore, while the estimation output of NARDL may show asymmetry for the variables, it also allows for partial asymmetry. Thus, the need to conduct the symmetry test is justified to understand the existence of asymmetry and for the continued use of the NARDL approach. Ultimately, as put forward by Shin, Yu, and Greenwood-Nimmo (2014), asymmetry allows the NARDL model to capture non-linear dynamics, where the magnitude or direction of the relationship changes with the sign or size of the independent variable change.

Running the symmetry test for the first model in which GDP per capita is the dependent variable, the DE and SE variables were under scrutiny to capture their non-linear dynamics. The findings from the symmetry test have been captured in Table 4.3.

Table 4-3:
NARDL Symmetry Test

Variable	Coefficient	Value	p-value
	Long-Run		
HCONSUMP	F-Statistic	5.3277	0.0238**
	Chi-Square	5.3277	0.0210**
INDV	F-Statistic	4.4280	0.0388**
	Chi-Square	4.4280	0.0354**
	Short-Run		
HCONSUMP	F-Statistic	0.2682	0.6061
	Chi-Square	0.2682	0.6065
INDV	F-Statistic	5.9939	0.0168**
	Chi-Square	5.9939	0.0144**
	Joint (Long-Run and Short-Run)		
HCONSUMP	F-Statistic	3.5781	0.0329**
	Chi-Square	7.1562	0.0279**
INDV	F-Statistic	4.4555	0.0149**
	Chi-Square	8.9111	0.0116**

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

The results in Table 4.3 report the joint symmetry test, meaning the null hypothesis of symmetry is tested for both long-run and short-run effects simultaneously. For household final consumption expenditure (HCONSUMP), the test yields an F-statistic of 3.5781 ($p = 0.0329$) and a Chi-square statistic of 7.1562 ($p = 0.0279$). Since both p-values are below 0.05, the null hypothesis of symmetry is rejected. This indicates that positive and negative shocks to household consumption exert asymmetric effects on the dependent variable, implying that increases in consumption do not have the same magnitude (or adjustment pattern) as decreases in consumption.

Similarly, for individuals using the internet (INDV), the test reports an F-statistic of 4.4555 ($p = 0.0149$) and a Chi-square statistic of 8.9111 ($p = 0.0116$). These results are also statistically significant at the 5% level, meaning the null hypothesis of symmetry is rejected. This suggests that internet penetration exhibits asymmetric effects on the dependent variable, where increases in internet usage and decreases in internet usage affect the dependent variable differently across the combined short-run and long-run horizon.

Overall, the symmetry test results provide evidence that both digital economy and sharing economy proxies, internet usage (INDV) and household consumption (HCONSUMP), demonstrate nonlinear and asymmetric relationships with the dependent variable in the model. Therefore, the use of the NARDL specification is empirically justified, as a linear ARDL model would impose symmetry and potentially mask the differentiated effects of positive versus negative changes.

4.3.2 Bounds Testing Approach to Cointegration

The estimation proceeds with the bounds testing approach to cointegration to determine whether a stable long-run relationship exists among the dependent variable and its regressors, following the symmetry test results which indicate that both HCONSUMP and INDV exhibit asymmetric effects.

Table 4-4:
Results for the Bounds Testing Approach to Cointegration

Model		F-statistic
GDPPC, GFCF, D_LFPR, INDV, D_HCONSUMP		8.1003
Critical values bounds of the F-statistic: unrestricted intercept and no trend (k=5)		
Significance Level	**Finite Sample: n=107**	
	***k*=5**	
	$I(0)$	$I(1)$
90% level	2.16	3.24
95% level	2.43	3.56
99% level	2.97	4.24

The interpretation of the Bounds Testing in the NARDL approach is based on the bounds values referred against the Pesaran et al. (2001) and Narayan (2004) critical values. The critical values work with the F-statistic results to determine if the model has cointegrating variables or not. Should the F-statistic fall below the lower bound, the null hypothesis of no cointegration cannot be rejected. Alternatively, should the F-statistic be beyond the upper bound, the null hypothesis can be rejected, indicating the existence of cointegration in the model. Finally, F-statistic within the bounds is interpreted to show inconclusive results. In the case of this study and the existence of mixed symmetry, the bounds test considers the overall relationship of the variables, both for symmetric and asymmetric combined.

The bounds test results confirm the presence of cointegration in the model, as the computed F-statistic (8.1003) exceeds the upper critical bound at all conventional significance levels. This provides strong evidence of a long-run equilibrium relationship between the dependent variable and the explanatory variables, indicating that digital economy and sharing economy dynamics, together with the control variables, are cointegrated with the economic outcome in Malaysia.

4.3.3 Cointegrating Relation (Long-Run)

This section presents and interprets the estimated long-run coefficients derived from the NARDL model. These coefficients quantify the long-term relationships among the cointegrating variables, highlighting the magnitude and direction of their impact. Aligning to the core approach of the NARDL model, the analysis also examines the presence of asymmetries in the long-run impacts, providing deeper insights into how positive and negative changes in household consumption influences GDP per capita over time.

Table 4-5:
Cointegrating Relation (Long-run coefficients)

Variable	Coefficient	SE	t-statistics	p-value
GFCF	0.0320	0.0095	3.3537	0.0011**
LFPR	-1481.015	399.8333	-3.7040	0.0003**
DUMMY_AFC(-1)	771.9593	159.7645	4.8318	0.0000**
DUMMY_GFC(-1)	-346.9271	267.9394	-1.2947	0.1983
DUMMY_COVID(-1)	273.9477	185.4450	1.4772	0.1427
@CUMDP(INDV(-1))	-81.4629	34.6707	-2.3496	0.0207**
@CUMDN(INDV(-1))	-333.6070	137.3534	-2.4288	0.0169**
@CUMDP(HCONSUMP(-1))	0.0195	0.0051	3.8188	0.0002**
@CUMDN(HCONSUMP(-1))	-0.0531	0.0322	-1.6474	0.1025

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GDPPC = GDP per capita; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

As presented in Table 4.5, the long-run (cointegrating) results indicate that gross fixed capital formation (GFCF) and labour force participation rate (LFPR) have statistically significant effects on GDP per capita in the long run. A one-unit increase in GFCF is associated with an increase of 0.0320 units in GDP per capita over time, indicating that higher investment and capital accumulation contribute positively to long-run income levels. In contrast, a one-unit increase in LFPR is associated with a decrease of 1481.015 units in GDP per capita, suggesting that higher labour force participation is linked to lower long-run GDP per capita within the Malaysian context. This outcome may reflect structural labour market dynamics where increases in labour supply are not matched by proportional productivity gains, thereby reducing average output per person.

For the digital economy proxy, both the positive and negative changes in individuals using the internet (INDV) produce statistically significant long-run effects. A one-unit positive increase in internet usage is associated with a decrease of 81.463 units in GDP per capita over time, while a one-unit negative change (decline) in internet usage is associated with a decrease of 333.607 units in GDP per capita. The larger magnitude of the negative change indicates that reductions in internet penetration have a stronger adverse long-run association with GDP per capita than equivalent increases, reinforcing the presence of asymmetric long-run effects.

With respect to the sharing economy proxy, the long-run results show that only the positive change in household final consumption expenditure (HCONSUMP) is statistically significant. A one-unit positive increase in household consumption is associated with an increase of 0.0196 units in GDP per capita over the long run, implying that expansion in household consumption contributes to higher income levels over time. However, negative changes in household consumption are not statistically significant in the long run, suggesting that contraction in consumption does not produce a reliably measurable long-run effect on GDP per capita within this model.

Among the additional regressors, the long-run findings also indicate that DUMMY_AFC(-1) is statistically significant, where a one-unit increase in this dummy variable is associated with an increase of 771.959 units in GDP per capita. In contrast, the lagged dummies for DUMMY_GFC(-1) and DUMMY_COVID(-1) are not statistically significant in the long run. Overall, these results confirm that GDP per capita in Malaysia is influenced by capital formation and labour market structure, while the digital and sharing economy variables exhibit nonlinear behaviour where positive and negative movements do not exert proportionate long-run effects.

4.3.4 Error Correction Model (ECM)

Table 4-6:
Error Correction Regression Results

Variable	Coefficient	SE	t-statistics	p-value
COINTEQ*	-0.5173	0.0542	-9.5388	0.0000**
D(DUMMY_AFC)	112.8264	78.8329	1.4312	0.1562
D(DUMMY_AFC(-1))	-272.7999	85.6563	-3.1848	0.0020**
D(DUMMY_GFC)	130.1420	91.9427	1.4154	0.1607
D(DUMMY_GFC(-1))	-125.4279	91.2884	-1.3739	0.1732
D(DUMMY_GFC(-2))	-31.5772	84.8369	-0.3722	0.7107
D(DUMMY_GFC(-3))	181.4769	91.5443	1.9823	0.0508
D(DUMMY_COVID)	-65.2212	91.7644	-0.7107	0.4793
@DCUMDP(INDV)	-28.4966	34.9900	-0.8144	0.4178
@DCUMDN(INDV)	30.6083	50.9859	0.6003	0.5499
@DCUMDP(INDV(-1))	-38.2486	31.7622	-1.2042	0.2320
@DCUMDN(INDV(-1))	174.9238	53.0062	3.3000	0.0014**
@DCUMDP(INDV(-2))	-3.9611	31.8305	-0.1244	0.9013
@DCUMDN(INDV(-2))	158.0648	53.0180	2.9813	0.0038**
@DCUMDP(INDV(-3))	31.53712	32.5829	0.9679	0.3359
@DCUMDN(INDV(-3))	140.1734	53.0619	2.6416	0.0099**
@DCUMDN(HCONSUMP)	0.0536	0.0127	4.2119	0.0001**
@DCUMDP(HCONSUMP(-1))	0.0266	0.0058	4.5708	0.0000**
@DCUMDN(HCONSUMP(-1))	0.0390	0.0125	3.1155	0.0025**
@DCUMDP(HCONSUMP(-2))	0.0269	0.0056	4.7807	0.0000**
@DCUMDN(HCONSUMP(-2))	0.0395	0.0128	3.0919	0.0027**

@DCUMDP(HCONSUMP(-3))	0.0316	0.0054	5.8548	0.0000**
@DCUMDN(HCONSUMP(-3))	0.0341	0.0129	2.6456	0.0098**
@QUARTER=1	203.1579	95.5553	2.1260	0.0365**
@QUARTER=2	184.8707	85.8825	2.1526	0.0343**
@QUARTER=3	114.4939	86.1053	1.3296	0.1873
C	12330.37	1306.960	9.4343	0.0000**
@TREND	30.9826	3.3341	9.2924	0.0000**

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GDPPC = GDP per capita; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

As the results of the Bounds Testing explained the existence of cointegration within the model, the study further investigates the relationship amongst the variables to find out their relationship in the long run as well. The error correction term (ECT) reflects the NARDL model's ability to adjust towards a long-run equilibrium relationship between the variables. With the existence of significant long run relationships revealed by the bounds test, the ECT helps quantify how quickly the model corrects deviations from that equilibrium through short-run adjustments (Pesaran, Shin, & Smith, 2001; Nkoro & Uko, 2016).

The ECT from the NARDL estimation confirms the presence of a statistically significant long-run relationship among the variables in this study, as reported in Table 4.7. The ECT coefficient of -0.5173 indicates that deviations from the long-run equilibrium resulting from short-run shocks are corrected at an adjustment speed of approximately 51.73% per quarter, implying that just over half of any disequilibrium is eliminated within one period. The negative and highly significant ECT further supports the stability of the model, confirming that the system converges back to its long-run equilibrium path following temporary disturbances.

4.3.5 Diagnostic Tests

Table 4-7:
Diagnostic Test Results

Jarque-Bera Normality Test	9.0899 (0.0106)**
Breusch-Godfrey Serial Correlation LM Test	2.2440 (0.0731)
Heteroskedasticity Test: ARCH	1.1409 (0.1053)

Ramsey RESET Test	3.5739 (0.0627)
CUSUM Test	Stable
CUSUM of Squares Test	Stable

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significant at the 5 percent level.

The diagnostic tests conducted to supplement the NARDL regression is with the purpose of assessing the validity and reliability of the estimated model. These tests ensure the model meets the underlying assumptions required for accurate interpretations and reliable inferences.

Figure 4-1:
CUSUM Stability Test

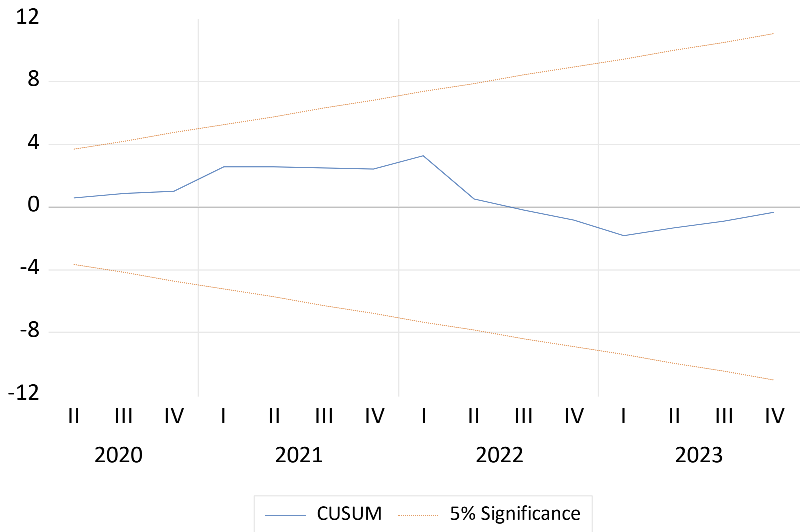
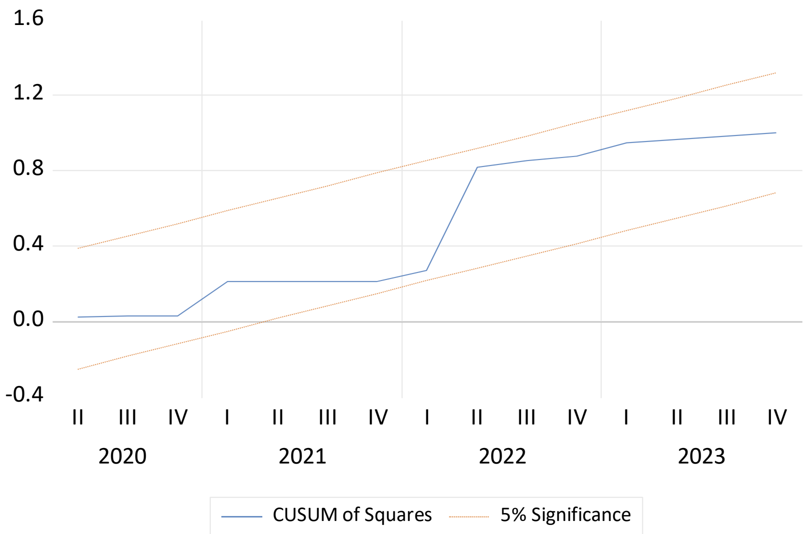


Figure 4-2:
CUSUM of Squares Stability Test



Although the diagnostic results indicate that the residuals deviate from normality, this does not invalidate the estimated ARDL/NARDL models or undermine the reliability of the main findings. In applied time-series econometrics, residual non-normality is common in macroeconomic datasets, particularly where the sample is affected by structural shifts and episodic shocks. Importantly, the assumption of normally distributed errors is not a strict requirement for obtaining unbiased and consistent coefficient estimates in OLS-based models, as normality mainly affects exact small-sample inference rather than the consistency of the estimators (Williams et al., 2020). In addition, the ARDL framework is widely applied due to its robustness in modelling mixed integration orders and estimating both short-run and long-run relationships, and it does not rely on strict residual normality as a primary condition for model validity (Pesaran et al., 2001; Shrestha, 2018).

The remaining diagnostic tests collectively confirm that the estimated model is well specified and statistically reliable. The serial correlation test indicates no evidence of autocorrelation in the residuals, as the null hypothesis of no serial correlation cannot be rejected, implying that the dynamic structure and lag selection adequately capture the time-dependent behaviour of the variables. Similarly, the heteroskedasticity test suggests that the residual variance is constant, as the null hypothesis of homoskedasticity cannot be rejected, supporting the efficiency of the estimated coefficients and the validity of the standard errors. In addition, the Ramsey RESET test fails to reject the null hypothesis, indicating no functional form misspecification and providing further assurance that the model is appropriately specified. Finally, the CUSUM and CUSUM of Squares (CUSUMSQ) stability tests remain within the 5% critical boundaries throughout the sample period, confirming parameter stability and indicating that the estimated long-run and short-run relationships do not exhibit structural instability over time. Collectively, these diagnostic outcomes support the robustness of the ARDL/NARDL estimations and strengthen confidence in the interpretation of the empirical results.

4.4 Empirical Testing for RO2

The NARDL estimation was replicated for the fulfilment of RO2 which investigates the joint impact of the DE and SE towards ecological development. The NARDL model is structured where the total greenhouse gas emissions in the country is used as the dependent variable, reflecting SDG 13. The investigation into RO2 begins with the NARDL protocol of symmetry test to understand the linearity of the variables in the model.

The findings of the symmetry test for the second NARDL model in which total greenhouse gas emissions is the dependent variable has contrasting results in comparison to the symmetry test of the first model. It is found that there is no asymmetry in the NARDL model, implying that the positive and negative changes in individuals using the internet and household consumption similarly affect greenhouse gas emissions. Given the lack of asymmetry, the NARDL model does not provide additional explanatory power compared to a standard ARDL model in this instance. Consequently, further analysis could focus on the symmetric relationships within the standard ARDL framework, which this study will use to understand the impact of the DE and SE on ecological preservation in the long run.

4.4.1. ARDL Estimation Results

4.4.1.1. Bounds Testing Approach to Cointegration

Table 4-8:
Bounds testing approach to cointegration

Model	**F-statistic**	
GHG, GCM, LFPR, INDV, HCONSUMP	9.6260	
Critical values bounds of the F-statistic: unrestricted intercept and no trend (k=5)		
Significance Level	**Finite Sample: n=108**	
	***k*=5**	
	I(0)	*I*(1)
90% level	1.92	2.89
95% level	2.17	3.21
99% level	2.73	3.90

The estimation for Model 2 proceeds with the ARDL bounds testing approach to cointegration to determine whether a long-run equilibrium relationship exists between GHG emissions (tonnes of CO_2 equivalent) and the selected explanatory variables. The bounds test results provide strong evidence of cointegration, as the computed F-statistic of 9.6260 exceeds the upper critical bound at all conventional significance levels. This indicates the rejection of the null hypothesis of no cointegration and confirms the presence of a stable long-run relationship between GHG emissions and the digital economy proxy, sharing economy proxy, and the control variables included in the model.

Accordingly, the existence of cointegration justifies the estimation and interpretation of both the long-run coefficients and the associated error correction model (ECM), allowing the study to evaluate how changes in digitalisation, consumption behaviour, and production-related factors influence environmental outcomes in Malaysia over both the long and short run.

4.4.1.2. Cointegrating Relation

Table 4-9:
Cointegrating Relation (Long-run coefficients)

Variable	Coefficient	SE	t-statistics	p-value
GFCF(-1)	0.0001	7.42E-05	1.4752	0.1433
LFPR(-1)	-3.6303	3.0294	-1.1983	0.2336
INDV(-1)	2.0735	0.2217	9.3522	0.0000**
HCONSUMP(-1)	-3.84E-05	4.57E-05	-0.8399	0.4030
DUMMY_AFC(-1)	9.3543	3.9037	2.3962	0.0184**
DUMMY_GFC(-1)	-6.3061	6.2467	-1.0095	0.3152
DUMMY_COVID(-1)	4.1868	2.4370	1.7179	0.0889
C	80.0794	47.0392	1.7023	0.0918

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GHG = total greenhouse gas emissions: tonnes of CO_2 equivalent per year; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

As presented in the long-run cointegrating relationship in Table 4.9, the results indicate that among the core explanatory variables, individuals using the internet (INDV) is the most influential determinant of GHG emissions (tonnes of CO_2 equivalent) in the long run. A one-unit increase in INDV is associated with an increase of 2.0735 units in long-run GHG emissions, and this relationship is statistically significant at the 5% level. This suggests that greater internet penetration, used as a proxy for digital economy expansion, is associated with higher long-run emissions in Malaysia, potentially reflecting the emissions-intensifying effects of increased energy demand, higher consumption activity enabled by digital connectivity, and increased digital infrastructure requirements over time.

In contrast, gross fixed capital formation (GFCF) and labour force participation rate (LFPR) do not exhibit statistically significant long-run effects on GHG emissions in this model. Although GFCF carries a positive sign and LFPR carries a negative sign, their impacts are not distinguishable from zero in the long run, implying that investment expansion and labour participation do not independently drive long-run emissions changes once the digital economy indicator and crisis controls are accounted for.

With respect to the sharing economy proxy, household final consumption expenditure (HCONSUMP) is also not statistically significant in the long run. This indicates that consumption changes, when modelled alongside internet penetration and structural shock controls, do not have a stable long-run relationship with Malaysia's total GHG emissions within the sample period. This outcome may imply that consumption effects on emissions are either indirect, absorbed through other channels, or more prominent in the short-run adjustment process rather than in long-run equilibrium.

Among the crisis controls, the Asian Financial Crisis dummy (DUMMY_AFC) is statistically significant and positive in the long run, where a one-unit change in the dummy variable is associated with an increase of 9.3543 units in GHG emissions. This suggests that the AFC period is structurally associated with a higher emissions level relative to the baseline period captured by the model. Meanwhile, the Global Financial Crisis dummy (DUMMY_GFC) is not statistically significant, and the COVID dummy (DUMMY_COVID) is not statistically significant at the 5% level, although it shows a positive association that may be indicative of a weaker or transitional long-run effect.

Overall, the long-run findings suggest that the digital economy proxy (internet usage) is the key variable associated with Malaysia's long-run emissions trajectory in this model, while capital formation, labour force participation, and household consumption do not display statistically robust long-run effects once digitalisation and structural shocks are controlled for. This supports the study's SDG 13 objective by indicating that digital economy expansion may be linked to environmental pressures in the Malaysian context, underscoring the importance of governance and energy transition pathways to ensure digital growth aligns with climate objectives.

4.4.1.3. Error Correction Model (ECM)

Table 4-10:
Error Correction Regression Results

Variable	Coefficient	SE	t-statistics	p-value
COINTEQ*	-0.5244	0.0517	-10.1367	0.0000
D(GHG(-1))	-0.0964	0.0790	-1.2199	0.2281
D(GHG(-2))	-0.0638	0.0787	-0.8103	0.4215
D(GHG(-3))	0.1615	0.0810	1.9938	0.0515
D(GHG(-4))	0.2130	0.0894	2.3825	0.0210
D(GHG(-5))	0.0432	0.0917	0.4714	0.6394
D(GHG(-6))	0.0329	0.0879	0.3748	0.7093
D(GHG(-7))	-0.3381	0.0966	-3.4985	0.0010
D(GFCF)	6.15E-05	5.16E-05	1.1916	0.2389

D(GFCF(-1))	4.98E-05	4.79E-05	1.0387	0.3038
D(GFCF(-2))	0.0001	4.14E-05	3.8441	0.0003
D(GFCF(-3))	0.0002	3.84E-05	5.9060	0.0000
D(GFCF(-4))	0.0002	5.01E-05	5.8065	0.0000
D(GFCF(-6))	0.0001	0.0000	2.5276	0.0146
D(GFCF(-7))	0.0002	0.0000	3.3859	0.0014
D(LFPR)	-6.5336	2.7552	-2.3713	0.0215
D(LFPR(-1))	-8.0424	2.5938	-3.1007	0.0031
D(LFPR(-2))	-7.7142	2.5587	-3.0149	0.0040
D(LFPR(-3))	-9.8626	2.3921	-4.1230	0.0001
D(LFPR(-4))	13.9038	2.7392	5.0758	0.0000
D(LFPR(-5))	15.0079	2.7024	5.5536	0.0000
D(LFPR(-6))	14.8277	2.7963	5.3027	0.0000
D(LFPR(-7))	18.5028	2.7697	6.6805	0.0000
D(INDV)	0.7090	0.2024	3.5036	0.0010
D(INDV(-1))	-0.4801	0.1820	-2.6376	0.0110
D(INDV(-2))	-0.5337	0.1880	-2.8380	0.0065
D(INDV(-3))	-0.0266	0.1924	-0.1382	0.8906
D(INDV(-4))	-0.7983	0.1824	-4.3758	0.0001
D(INDV(-5))	-0.8998	0.1853	-4.8571	0.0000
D(INDV(-6))	-0.8964	0.1823	-4.9185	0.0000
D(INDV(-7))	-0.8720	0.1792	-4.8672	0.0000
D(HCONSUMP)	0.0002	0.0000	3.7550	0.0004
D(HCONSUMP(-1))	0.0001	0.0000	1.4977	0.1404
D(HCONSUMP(-2))	-0.0001	0.0000	-1.6899	0.0971

D(HCONSUMP(-3))	-0.0002	0.0000	-3.9588	0.0002
D(HCONSUMP(-4))	-0.0003	0.0000	-5.5325	0.0000
D(DUMMY_AFC)	-0.9488	0.6941	-1.3670	0.1776
D(DUMMY_AFC(-1))	-5.0160	0.8650	-5.7991	0.0000
D(DUMMY_AFC(-2))	-4.2992	1.2023	-3.5757	0.0008
D(DUMMY_AFC(-3))	-3.3187	1.1378	-2.9168	0.0052
D(DUMMY_AFC(-4))	-0.9825	0.7635	-1.2868	0.2040
D(DUMMY_GFC)	2.3062	0.7291	3.1630	0.0026
D(DUMMY_GFC(-1))	0.6827	0.8507	0.8025	0.4260
D(DUMMY_GFC(-2))	1.2864	0.7944	1.6192	0.1116
D(DUMMY_GFC(-3))	2.9766	0.9045	3.2909	0.0018
D(DUMMY_GFC(-4))	0.9183	0.9218	0.9962	0.3238
D(DUMMY_GFC(-5))	2.8456	0.7650	3.7197	0.0005
D(DUMMY_GFC(-6))	2.4696	0.6964	3.5465	0.0008
D(DUMMY_GFC(-7))	1.1174	0.7139	1.5653	0.1237
D(DUMMY_COVID)	3.1842	0.7819	4.0724	0.0002
D(DUMMY_COVID(-1))	1.1498	0.9490	1.2116	0.2313
D(DUMMY_COVID(-2))	-1.1377	0.8658	-1.3139	0.1947
D(DUMMY_COVID(-3))	-2.6761	0.7279	-3.6766	0.0006
D(DUMMY_COVID(-4))	-3.7214	0.7726	-4.8169	0.0000
D(DUMMY_COVID(-5))	-0.9575	0.7833	-1.2224	0.2272

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GHG = total greenhouse gas emissions: tonnes of CO_2 equivalent per year; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

The error correction term (ECT) for Model 2 is negative and highly statistically significant, confirming the presence of a stable long-run equilibrium relationship between GHG emissions and the explanatory variables in the ARDL framework. The ECT coefficient of -0.5244 indicates that when GHG emissions deviate from their long-run equilibrium path due to short-run shocks, approximately 52.44% of the disequilibrium is corrected within one quarter. This reflects a relatively strong speed of adjustment, implying that emissions dynamics in Malaysia revert back toward long-run equilibrium fairly quickly following temporary disturbances.

The negative sign of the ECT further reinforces the stability of the model, as it indicates convergence rather than divergence, meaning that deviations are systematically reduced over time rather than amplified. Overall, this result strengthens the robustness of the long-run estimates by demonstrating that short-run fluctuations in emissions are not persistent in the presence of the long-run relationship, and that the model captures both equilibrium behaviour and the adjustment mechanism effectively.

4.4.1.4. Diagnostic Tests

Table 4-11:
Diagnostic Test Results

Jarque-Bera Normality Test	10.0906 (0.0064)**
Breusch-Godfrey Serial Correlation LM Test	1.2331 (0.3020)
Heteroskedasticity Test: ARCH	1.1429 (0.3241)
Ramsey RESET Test	0.4985 (0.4840)
CUSUM Test	Stable
CUSUM of Squares Test	Stable

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significant at the 5 percent level.

Figure 4-3:
CUSUM Stability Test

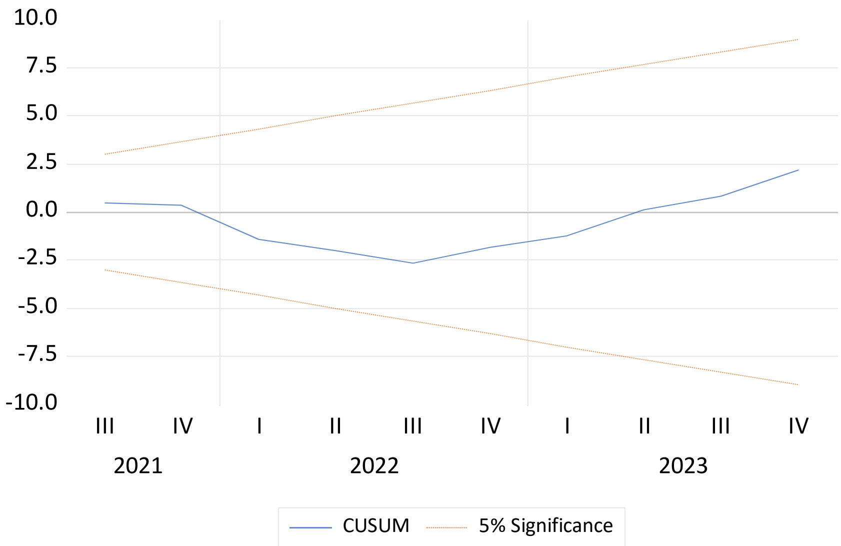
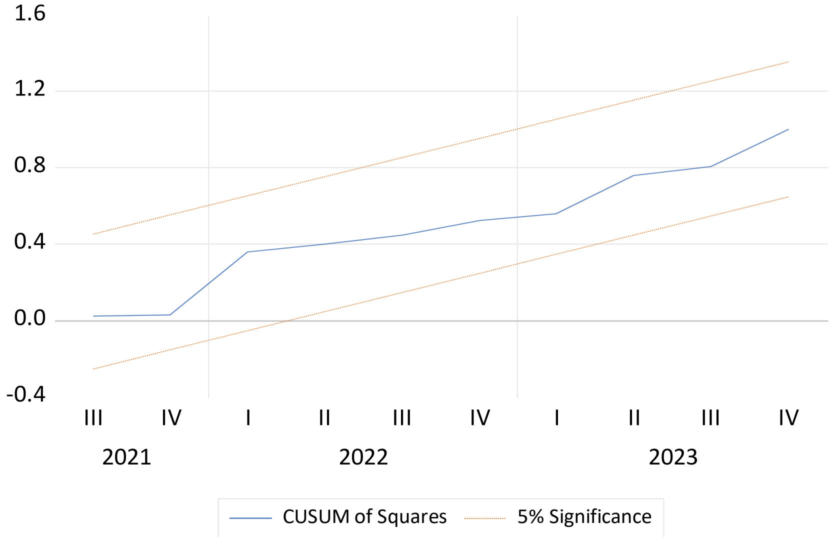


Figure 4-4:
CUSUM of Squares Stability Test



The diagnostic results for Model 2 indicate that the estimated linear ARDL model is econometrically sound, with no evidence of serial correlation, heteroskedasticity, functional form misspecification, or parameter instability. Specifically, the null hypotheses for the serial correlation and heteroskedasticity tests cannot be rejected, implying that the residuals are not systematically correlated over time and that the variance of the residuals is stable. In addition, the Ramsey RESET test fails to reject the null hypothesis, suggesting that the model is correctly specified and does not suffer from omitted nonlinearities or incorrect functional form. The stability tests (CUSUM and CUSUM of Squares) also remain within the 5% significance boundaries across the sample period, confirming that the long-run and short-run coefficients are stable and that the model does not exhibit structural instability.

The only diagnostic limitation observed is that the residuals do not satisfy the normality assumption. However, this outcome does not invalidate the model or weaken the reliability of the key findings. In applied macroeconomic time-series modelling, residual non-normality is commonly observed due to the presence of structural breaks, crisis periods, and irregular shocks that generate fat tails and skewness in the error distribution. Importantly, strict normality of the residuals is not a necessary condition for obtaining unbiased and consistent coefficient estimates in OLS-based models, and the normality assumption mainly affects exact small-sample hypothesis testing rather than the stability and consistency of parameter estimation (Williams et al., 2020). Moreover, the ARDL bounds testing framework is widely adopted due to its robustness in estimating long-run and short-run relationships with mixed integration orders, and it does not treat residual normality as a primary requirement for the validity of the modelling approach (Pesaran et al., 2001; Shrestha, 2018). Given that Model 2 satisfies the key diagnostic and stability requirements, the deviation from normality is treated as a practical characteristic of the data rather than a model failure, and the estimated ARDL results remain appropriate for interpretation in the Malaysian context.

4.4.2. Toda-Yamamoto Causality

Table 4-12:
Toda-Yamamoto Causality Test

Dependent Variable	GHG	GFCF	LFPR	INDV	HCONSUMP
GHG	-	6.8234	31.1999	28.0731	5.6833
		(0.6555)	(0.0003)**	(0.0009)**	(0.7711)
GFCF	16.0315	-	15.6673	5.8657	40.5857**
	(0.0662)		(0.0742)	(0.7533)	(0.0000)
LFPR	2.7890	3.70468	-	5.1997	14.1495
	(0.9721)	(0.9298)		(0.8166)	(0.1171)
INDV	31.6929**	15.8724	23.3147**	-	12.7231
	(0.0002)	(0.0696)	(0.0055)		(0.1755)
HCONSUMP	19.7575**	40.0310**	9.2804	27.0400**	-
	(0.0195)	(0.0000)	(0.4118)	(0.0014)	

Note: Test statistics are indicated next to the p-values in parentheses. Asterisks (**) indicate significance at the 5 percent level. Variable abbreviations are defined as follows: GHG = total greenhouse gas emissions: tonnes of CO_2 equivalent per year; GFCF = gross fixed capital formation; LFPR = labour force participation rate; INDV = individuals using the internet (% of population); HCONSUMP = household final consumption expenditure.

In fulfilment of Research Objective 3, the Toda–Yamamoto causality test was conducted to examine the directional relationships among the variables in the model. The Toda–Yamamoto approach is suitable for this study as it allows causality testing within an augmented VAR framework while accounting for the maximum order of integration among the variables, thereby reducing the risk of biased inference that may arise from pre-testing procedures. This strengthens the robustness of causal conclusions drawn from the Malaysian time-series data.

As shown in Table 4.12, the results indicate several statistically significant causal relationships involving both environmental and macroeconomic variables. First, the findings show that labour force participation rate (LFPR) Granger-causes greenhouse gas emissions (GHG), implying that changes in labour market participation precede and help predict movements in emissions. This is consistent with empirical evidence that labour force expansion may increase economic activity, energy use, and related environmental pressures, thereby influencing emissions trajectories over time (Achuo et al., 2023).

Second, the test results show that individuals using the internet (INDV) Granger-causes GHG, meaning that increases in internet penetration, used as a proxy for the digital economy, precede changes in Malaysia's emissions outcomes. This finding is corroborated by prior studies that document measurable links between internet usage and CO_2 emissions, particularly where digital infrastructure growth increases electricity demand through data centres, telecommunication networks, and end-user digital activity (Wang & Xu, 2021). Notably, the results also provide evidence of bidirectional causality between INDV and GHG, suggesting that digitalisation and emissions evolve jointly over time. This reinforces the view that digital development and environmental outcomes may form a mutually reinforcing relationship in economies experiencing structural transformation and increasing technology dependence (Wang & Xu, 2021).

With respect to the relationship between the digital economy (DE) and the sharing economy (SE) proxies, the TY results indicate that INDV Granger-causes household final consumption expenditure (HCONSUMP), showing a statistically significant causal direction from internet penetration to consumption behaviour. This finding supports the study's conceptual expectation that the digital economy enables consumption-driven and platform-enabled market activity by reducing transaction costs, increasing market access, improving information flow, and enhancing convenience in purchasing and exchange. Empirical evidence also shows that greater internet usage is associated with higher energy and consumption activity through broader digital engagement and expanded participation in online markets (Salahuddin & Gow, 2015). This result strengthens the theoretical positioning of digitalisation as an enabling condition for consumption-based economic behaviour and aligns with the conceptual premise that the sharing economy operates through digitally mediated systems.

In addition, the TY causality results reveal a strong macroeconomic feedback mechanism between investment and consumption. Specifically, household consumption (HCONSUMP) Granger-causes gross fixed capital formation (GFCF) and GFCF Granger-causes HCONSUMP, implying bidirectional causality between these variables. This reflects a mutually reinforcing relationship in which consumption demand encourages investment expansion, while capital formation strengthens productive capacity, income generation, and purchasing power, thereby increasing consumption. This finding is supported by Malaysian evidence, where Abdul Karim et al. (2010) document dynamic linkages between household consumption and fixed investment using a structural VECM approach in Malaysia.

The results also indicate that INDV Granger-causes LFPR, suggesting that growth in internet penetration precedes changes in labour force participation. This is consistent with findings that internet access and digital connectivity can influence labour market participation through improved access to job information, flexible working arrangements, and digital inclusion in economic activity (Viollaz & Winkler, 2020).

Overall, the Toda–Yamamoto causality results support the existence of meaningful directional relationships across the digital economy, sharing economy proxy, macroeconomic factors, and environmental outcomes. In particular, the results provide empirical support for the role of internet penetration not only as a driver of environmental outcomes (through its link with GHG emissions) but also as a digital enabler shaping consumption behaviour, which aligns directly with the study’s conceptual framing and Research Objective 3.

CHAPTER 5:

DISCUSSION AND SUMMARY

5.1 Introduction

This discussion and summary chapter intends to bridge the gap between the empirical findings presented in the previous chapter as well as the overarching research objectives laid out in Chapter 1. The focus of discussion is to interpret the empirical evidence from the two estimated models from the context of the research objectives, exploring the dynamics between the digital economy, sharing economy, as well as their contributions towards sustainable development. Specifically, the discussion looks into how the DE, proxied by internet usage, and the SE, proxied by household consumption, influence economic growth and environmental sustainability, aligned with SDGs 8 and 13 respectively. In furtherance, this chapter also discusses the causal relationships which exists within the two models and among the variables, revealed by the causality tests, offering insights into the directional linkages between these variables.

The implications of the findings from the estimated models are analysed to inform policy recommendations aimed at fostering a balance between economic progress and environmental sustainability. By connecting empirical evidence with the research objectives and theoretical underpinnings, this chapter not only highlights the practical significance of the findings but also sets the stage for future research in this domain.

5.2 Key Findings & Interpretation of Results

5.2.1 RO1 Discussion: Impact of the Digital Economy and Sharing Economy on SDG 8 (GDP per capita)

To address RO1, this study applies the Nonlinear ARDL (NARDL) approach to assess how the digital economy and sharing economy influence GDP per capita in Malaysia. The symmetry tests indicate that both internet usage (INDV) and household final consumption (HCONSUMP) exhibit asymmetric effects, supporting the use of NARDL to capture nonlinear responses that may be masked under linear specifications (Shin et al., 2014). The bounds test further confirms cointegration, implying a stable long-run relationship between GDP per capita and the explanatory variables.

A notable finding is that internet penetration is associated with weaker long-run GDP per capita outcomes. While counterintuitive, this aligns with evidence that in developing economies, digitalisation may be unevenly absorbed into productive sectors due to limitations in digital skills and supporting infrastructure, weakening broad-based growth benefits (Ngwenyama et al., 2006). Consistent with endogenous growth theory, digital infrastructure alone may not improve productivity unless supported by complementary investments in innovation and human capital (Romer, 1990). In addition, persistent rural–urban divides and unequal digital literacy can reduce the inclusiveness of digital gains and potentially reinforce inequality rather than aggregate growth (Hilbert, 2011).

In contrast, household consumption expansion is linked to stronger long-run income outcomes, reflecting the demand-side contribution to growth. However, the asymmetric structure also suggests that consumption dynamics may affect GDP per capita differently across phases, where contractionary movements may reflect reduced purchasing power and financial strain, consistent with findings linking debt-driven consumption patterns to weaker long-run growth performance (Piao et al., 2023). More broadly, consumption allocation decisions can shape savings–investment dynamics and long-run growth capacity, particularly in developing contexts (Deaton & Muellbauer, 1980).

5.2.2 RO2 Discussion: Impact of the Digital Economy and Sharing Economy on SDG 13 (GHG emissions)

To address RO2, the study estimates a linear ARDL model to examine the long-run and short-run determinants of Malaysia's GHG emissions, aligned with SDG 13. The bounds testing results confirm cointegration, indicating a stable long-run relationship between GHG emissions and the explanatory variables, including the digital economy proxy, sharing economy proxy, and relevant controls (Pesaran et al., 2001).

The long-run estimates show that internet usage (INDV) is the most influential factor linked to emissions, with higher internet penetration associated with higher long-run GHG emissions. This supports the view that digital expansion can intensify environmental pressures through increased electricity demand, the growth of ICT infrastructure, and digitally enabled economic activity, particularly in contexts where the energy mix remains fossil-fuel intensive (Shen et al., 2023; Andrae & Edler, 2015). In contrast, GFCF, LFPR, and HCONSUMP do not exhibit statistically meaningful long-run effects on emissions in this model, suggesting that Malaysia's emissions trajectory is more directly tied to digitalisation dynamics than to broader factor inputs or aggregate household consumption within the sample period.

The error correction results further confirm stability, indicating that deviations from long-run equilibrium are corrected relatively quickly over time. Diagnostic tests also support model reliability, showing no issues relating to serial correlation, heteroskedasticity, functional form misspecification, or parameter instability, while the only limitation remains residual non-normality, an outcome commonly observed in macro time-series models exposed to structural shocks.

5.2.3 RO3 Summary: Toda–Yamamoto Causality Results

To fulfil RO3, the Toda–Yamamoto causality test was conducted to identify the directional relationships among the digital economy proxy (INDV), sharing economy proxy (HCONSUMP), macroeconomic controls (GFCF, LFPR), and sustainability outcomes (GHG). Overall, the results indicate that internet usage (INDV) Granger-causes household consumption (HCONSUMP), supporting the study's conceptual expectation that the digital economy enables consumption-based activity associated with the sharing economy. The findings also show a bidirectional relationship between household consumption and gross fixed capital formation, suggesting a reinforcing feedback mechanism where consumption influences investment and investment simultaneously supports consumption. In addition, the causality results confirm that internet usage Granger-causes greenhouse gas emissions, reinforcing the empirical link between digital expansion and environmental outcomes, while labour force participation Granger-causes greenhouse gas emissions, indicating that labour market dynamics are also connected to Malaysia's emissions pathway. Collectively, these results highlight that digitalisation functions as a key driver within the system, shaping both economic behaviour and environmental sustainability outcomes in Malaysia.

5.3 Policy Implications

This research underscores the potential of digital and sharing economies as pivotal contributors to sustainable development within Malaysia. The findings suggest several policy implications that could enhance the efficacy and reach of these economic models, promoting sustainable economic growth and equitable development.

Government initiatives should focus on further investment in digital infrastructure to make the benefits of digital and sharing economies accessible across all regions of Malaysia, including rural and underserved areas. This could include subsidies or incentives for digital technology adoption among micro, small, and medium enterprises (MSMEs), enhancing their contributions to economic growth and sustainability. Such initiatives would help mitigate the digital divide and promote inclusive economic participation.

Moreover, comprehensive regulatory frameworks need to be developed to ensure fair competition and manage the socio-economic impacts of digital platforms and sharing economy businesses. These frameworks should aim to prevent market monopolies and ensure fair wages and working conditions for gig economy workers, addressing the new challenges posed by these business models. Regulatory frameworks should also include provisions for data protection and privacy to build trust among users and service providers.

Education and digital literacy are also critical areas of intervention. National skill development programs focusing on digital literacy should be implemented to equip the workforce with the necessary skills to participate effectively in the digital and sharing economies. These programs should be integrated into public education curriculums at all levels and include continuous adult education and training programs to ensure lifelong learning and adaptability in the workforce.

Additionally, there is a need for incentives for companies that adopt green technologies and practices. Policies could include tax rebates, grants for research and development in sustainable practices, and support for green startups. Such incentives would encourage companies to adopt more sustainable practices and technologies, reducing their environmental impact while enhancing their competitiveness.

Lastly, establishing mandatory sustainability reporting for significant digital economy players is crucial. This would help monitor their environmental impact and ensure that their operations contribute positively to the nation's sustainable development goals. Regular monitoring and reporting would also provide valuable data to inform policymaking and ensure that these businesses operate responsibly.

5.4 Future Outlook

5.4.1 Limitations of the Study

Several limitations should be acknowledged when interpreting the findings of this study. First, the analysis is constrained by data availability and coverage, particularly in relation to indicators that directly capture the operational scale of the digital economy and sharing economy. While proxies such as internet usage and household consumption provide measurable representations of these constructs, they may not fully reflect platform-level dynamics and sector-specific digital participation within Malaysia. In particular, household final consumption expenditure is a broad macroeconomic measure and may not precisely capture sharing economy activity, which is typically characterised by platform-enabled peer-to-peer exchange, asset utilisation, and access-based consumption. As such, the use of household consumption as a proxy for the sharing economy requires further refinement, and future research would benefit from more targeted indicators, such as platform transaction values, participation rates, or sector-specific sharing activity, to better reflect the true dynamics of the sharing economy. In addition, the study's dataset spans 1995 to 2023, which, while aligned with Malaysia's early digitalisation period, remains relatively limited for long-horizon time-series research. This limitation is partially mitigated by the use of quarterly frequency data, which increases the number of observations, but it does not remove all constraints linked to sample length.

Second, this study relies on quarterly data aggregated through the CEIC platform, which consolidates official statistics into harmonised time series. While this improves consistency and usability, aggregation may reduce the granularity required to observe more micro-level mechanisms, such as platform-specific consumption patterns, behavioural shifts, or digital transaction intensity. Third, although this study controls for major structural disruptions using crisis dummies, macroeconomic shocks may still introduce complexity that affects the stability of relationships over time, particularly when digitalisation accelerates unevenly across sectors. Finally, while ARDL and NARDL models are suitable for mixed integration orders and capturing nonlinear effects, the findings remain sensitive to the choice of proxies, lag selection, and structural characteristics unique to Malaysia, which may limit direct generalisation beyond the study context.

5.4.2 Recommendations for Future Research

Future research can build on this study in several meaningful ways. First, there is a strong need to improve the measurement of the digital economy and sharing economy by leveraging more granular and real-time datasets, such as platform-level data on transactions, user participation, and sectoral adoption. Collaborations with digital and sharing economy platforms could provide access to anonymised backend data, allowing researchers to move beyond proxy variables and generate more precise insights that support evidence-based policymaking. In addition, interdisciplinary research integrating economics with environmental science and technology studies would deepen understanding of how digital expansion contributes to sustainable development, particularly through energy demand, infrastructure growth, and emissions pathways

Second, future studies should examine how digitalisation and sharing-economy mechanisms diffuse into local Malaysian economies, especially across rural and underserved communities. More localised studies can explore digital inclusion strategies and assess whether digital growth leads to equitable economic upliftment or reinforces existing divides. Finally, future research could expand the methodological approach by applying alternative econometric techniques suitable for structural breaks and evolving relationships, or adopting mixed method designs that combine quantitative modelling with qualitative insights from businesses, platforms, or households. This would strengthen causal interpretation and provide richer context for how the digital and sharing economy shapes SDG outcomes over time.

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