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Information, Communications and Media Technologies for Sustainability: Constructing Data-Driven Policy Narratives

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Abstract: This paper introduces the idea of data-driven narratives to examine how the use of information, communications, and media technologies (ICMTs) impacts the sustainable growth of economies. While ICMTs have regularly been advocated as a policy tool for growth and development, there is a research gap in empirical studies validating how such policies may be effective. This analysis is based on historical panel data from 39 economies across the developed North (19) and developing South (20). The industry-standard Cross-Industry Standard Process for Data Mining (CRISP-DM) methodology was applied to construct narratives that weave extant theories with empirical data. The art of developing data-driven narratives is rarely addressed in previous research articles. In the narrative approach, prior research on how ICMTs and sustainable growth are quantitatively scored and measured is reviewed. Panel data from authoritative sources such as the United Nations, World Economic Forum, and Sustainable Society Index were collected, cleansed, and conglomerated for data analytics. This was followed by evidence-based reasoning to examine any possible relationships between ICMT development and the sustainable growth of economies across the "North" and "South". The findings reveal that there are differentiated outcomes in sustainable growth in high- and low-income economies. This poses legitimate questions as to whether low-income economies will be able to meet the UN's Sustainable Development Goals by 2030 through the intermediation of ICMTs. It is the intended contribution of this paper to exemplify how data-driven narratives using CRISP may construct rich stories about ICMT for sustainability for the purposes of sharing good practice as well as lessons learned.

Keywords: CRISP-DM methodology; data analytics and modeling; IT for development; sustainable development goals

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1. Introduction

This paper addresses the research question of whether and how information, communications, and media technologies (ICMTs) positively impact sustainable development. While ICMT has been advocated as a policy tool for growth and development by numerous scholars, this article will show a lack of validated policy measures. We conjecture that this is nuanced and use data-driven narratives to formulate deeper insights than what statistical analyses provide. Although our generation is characterized by digital lifestyles and the global availability and widespread use of ICMTs, it is not entirely clear that they have led to a better world [1,2]. While cutting-edge ICMTs, such as big data clouds, artificial intelligence, augmented reality, and 5G technology, can be seen as a part of a wider concern for global development, their role in facilitating sustainable development has not become an adequate driver of policy and action [3–6]. It is an untested belief that ICMT promotes long-term sustainable development. For example, Jack Ma, the founder of Alibaba, argued during the World Economic Forum 2019 that there are four "E" of sustainable development:

entrepreneurs, education, e-government, and e-infrastructure. This is true because Alibaba could not have grown in the absence of inNovemberative digital systems, platforms, and governance in China and beyond. While it is an advantage for an economy to maintain its efforts to meet the UN's sustainability goals of achieving sustainability—for instance, fossil fuels are known to be a finite resource, and if a country has no other significant exports or means of generating energy, this will prove unsustainable sooner rather than later—exploitative practices which could be unsustainable according to the UN's definition may not necessarily render an economy unsustainable. Nevertheless, sustainability aims to lessen the depletion of natural resources and maintain ecological balance whilst promoting human and economic growth [7].

While ICMT has had a significant influence on the development of economies cf. [2,8], this claim has been, however, countered by measured critiques challenging such assumptions cf. [1]. Logically, ICMT advancements enable inNovemberation, efficiency, and effectiveness in all sectors and help propel human and economic growth [9]; ICMT investments may thus be said to enable the achievement of the UN's Sustainable Development Goals [10]. The effect of ICMT on sustainable development may be investigated using a variety of research frameworks. First, there are negative effects, including manufacturing, recycling, and disposal; second, the effects caused by the implementation and application of ICMT; and third, the long-term impacts of ICMT development on socioenvironmental–economic systems. These major frameworks entail both positive and negative consequences.

As ICMT is closely linked to energy consumption, it appears to be an anomalous contributor to sustainable development. Monitoring studies in UK households have suggested that computing and consumer electronics together consume about 20–23 percent of non-heating-related electricity use [11]. This paper discusses the relationship between ICMT and energy consumption in 39 economies from 1995 to 2013. The regression test results indicate a strong relationship between ICMT development and energy productivity improvement, having included several variables, such as energy productivity index, human capital per person, ICMT, energy intensity, gross capital formation, foreign direct investments, merchandise exports/imports, and government spending. This indicates that ICMT-fostering economies are more inclined to adopt sustainable energy resources. Recent research also recommends the implementation and acceleration of ICMT in underdeveloped countries and technology transfers from developed to developing countries [12]. ICMTs have influenced energy reduction mechanisms in the manufacturing and service industries and enabled cognizance of new technical advances, social networking/and other electronic communication channels and online platforms that enable people to use new technologies and educate themselves on the impacts of such advancements cf. [10,13–20] in order of recency.

The objective of this paper is to understand how ICMT contributes to a "sustainable society" by constructing data-driven narratives (or rich stories) that do not seek to generalize a cause-and-effect model between a dependent variable (e.g., sustainable development) and a set of exploratory, independent variables. Instead, the narratives we seek to construct report interesting exceptionalism and deviations from expectations. In the parlance of knowledge management, these would be the best practice and lessons learned (from failure). The remainder of this paper is organized as follows. Beginning with the end in mind, the next section presents two key constructs: the Sustainable Society Index and the IT for Development. Section 3 chronicles theoretical concepts from the existing literature that constitute discourses on the emerging discipline known as ICMT for sustainability. Section 4 provides details of an industry-standard known as the Cross-Industry Standard Process for Data Mining (CRISP-DM) that we adopted to construct data-driven narratives that explore best practice and lessons learned from the ICMT for sustainable development experiences of some 39 countries across the development spectrum (i.e., both the so-called global North and South). In the Findings and Discussion Section that follows, we discuss the above best practice and lessons learned into policy narratives that form the basis of ideas and knowledge exchange. The paper concludes with a restatement of contributions to theory and practice.

2. Measures of ICMT for Development

The well-respected Sustainable Society Index (SSI), tracked by the Sustainable Society Foundation (SSF), was established in 2006 [7] to help stimulate and support societies in their development towards sustainability. The SSI combines three dimensions (human, environmental, and economic) and 22 indicators that contribute to the wellbeing of a collective of individuals, known as a society (http://www.ssfindex.com/, accessed on 30 November 2019) to attempt to gauge a country's propensity for sustainable growth (See Figure 1).

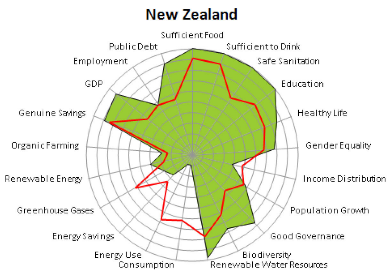

Figure 1. Sustainable Society Index (SSI) scores for New Zealand. Note: Generated with 2016 data and the ssfindex.com tool.

The United Nations (UN) 2030 Agenda for sustainable development acknowledges the potential of ICMTs and calls for significantly increased access to ICMTs, which will play a crucial role in supporting the implementation of all the sustainable development goals (SDGs). The UN further describes ICMT as a means of achieving the Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). For example, in the MDGs, ICMTs were promoted as tools to propel economic development and to fight extreme poverty [13]. From the perspective of the SSI, it asserts that to have a sustainable impact, a list of preconditions must be met, which includes but is not limited to the role of national participation; stakeholders' promotion of ICMT development and proper ICMT infrastructure; and access to knowledge-based informational systems, capacity building, training, and development. Meeting these preconditions ensures security, reliability, and confidence in using ICMT-enabled services and international cooperation to bridge the digital divide. Once implemented, these policies would have a high socio-economic impact on economies. Despite recent ongoing efforts in green computing cf. [9], the fact that ICMT advancements may cause environmental degradation by increasing electronic waste and energy usage is of great concern. Although ICMT offers solutions to alleviate such environmental impacts, its access and usage can increase energy and resource consumption, regardless of the precautions taken to ensure environmental compliance [6]. These countervailing measures must be balanced with scorecards: the SSI and the Information Communications Technologies (ICT) Development Index.

Over the past decade [7], indicators that impact the sustainability of an economy have been developed. The SSI is computed by the weighted sums of 21 selected indicators rated on a 0 to 10 scale, with 10 measuring complete sustainability (that is, all resources utilized are fully replenished). Figure 2 illustrates the method used to tabulate the mechanics of deriving the SSI from the list of 21 indicators. As observed from the list, most of the indicators relate to the human wellbeing or the environmental wellbeing dimension of the SSI.

The International Telecommunications Union, part of the United Nations, has developed an ICT Development Index [21], which comprises 11 indicators chosen primarily to assess the advancements in information and communication technologies. It is further divided into three sub-indices: access, use, and skills. Indicators include a country's mean educational enrolment, the number of broadband users, and mobile subscribers. Each indicator is assigned a weight proportional to its significance to arrive at a final index. Researchers agree that the increasing need for technology, globalization, and competition makes ICT access and usage indispensable [6].

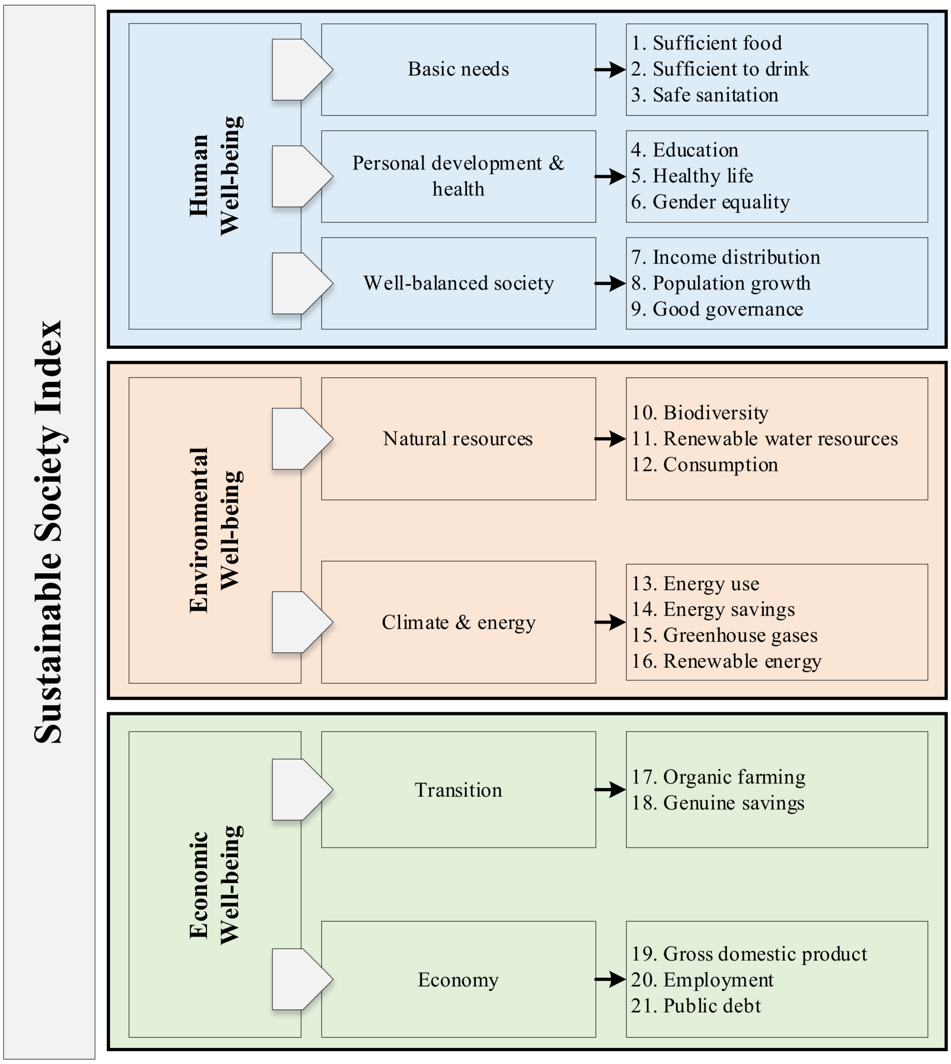

Figure 2. The conceptual framework for the Sustainable Society Index (Source: adapted and modified from reference [22]).

The Negative and Positive Impacts of ICMTs on Sustainable Development

Both perceived and actualized affordances of ICMT have both positive and negative impacts on sustainable development. Studies of references [2,23] cited in reference [24] postulate that the field of information, communication, media technologies for development (ICMT4D) is driven by the conviction that ICMTs can be used to foster development, improving the lives of people around the world. However, the debate about whether ICMTs are in fact, contributing to or undermining development efforts seems to be as old as the field of ICMT4D itself. Studies by references [25,26] found a wide scope of literature, showing the potential of using ICMTs to support various sustainable development areas, such as economic empowerment, e-governance, or environmental sustainability. Contrarily, some scholars have pointed out a large variety of harmful effects [27], positing that ICMTs are undeniably detrimental for sustainable development as they are linked to issues such as economic inequalities, surveillance, or environmental pollution [28,29], among others.

In this paper, we examine how information, communications, and media technologies (ICMT) impact the sustainable growth of economies. The concept of green ICMT involves minimizing the national carbon footprint and ICMT waste while optimizing sustainable energy, thereby increasing environmental wellbeing. reference [16] collected primary data to study this phenomenon. Barriers included lack of funding, inadequate managerial support, lack of interest/participation on the part of stakeholders, lack of awareness of green ICMT, inattention regarding ICMT impact on sustainability, inadequate regulations, etc. Almost 64 percent of the respondents either strongly agreed or agreed with the barriers; the other 36 percent either partially disagreed, disagreed, or strongly disagreed [16].

Today, ICMT is essential for economic development, comprising (i) access to digital resources, (ii) development of digital capabilities, and (iii) utilization of digital assets and capabilities [21]. The IT Development Index proposed by the International Telecommunications Union (ITU, in Figure 3) specifically measures the positive contributions of ICMT to development.

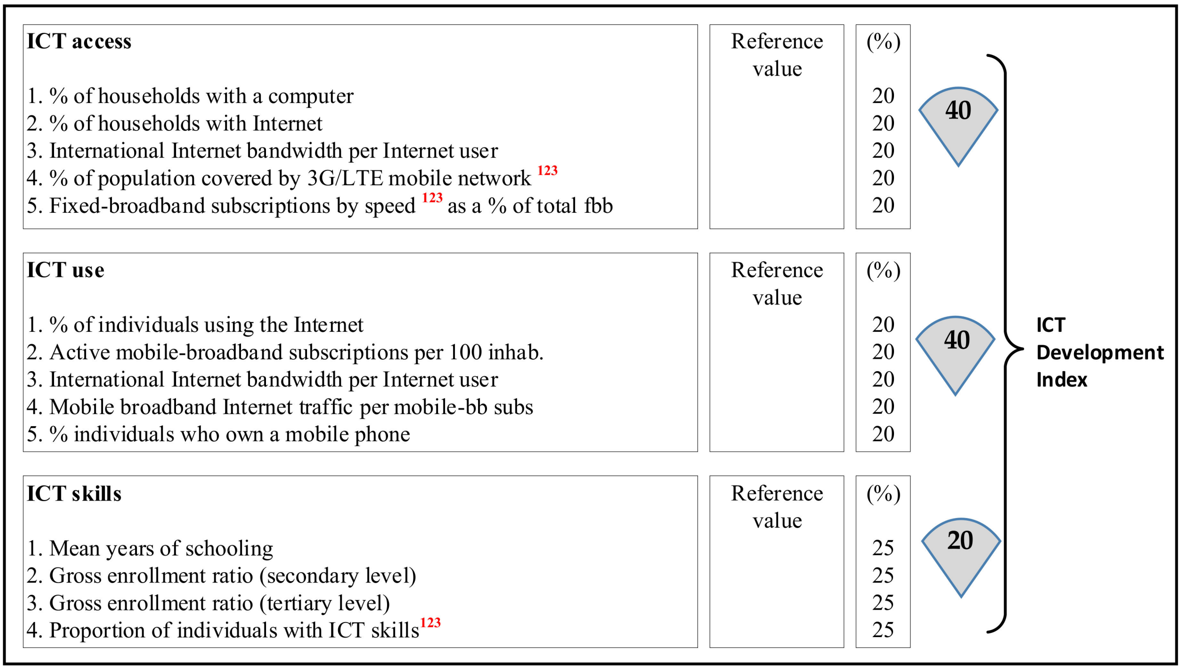

Figure 3. Composition of International Telecommunications Union (ITU)'s ICT Development Index. (Source: adapted and modified from reference [21]).

With numerous studies focused on the impact of ICMT on economic growth—the results of which have often proved to be contradictory—it can generally be assumed that ICMT induces positive economic growth, at least in most developed countries. It should be noted that an increase in economic growth does not necessarily translate to an increase in human development, as inequality or poverty, for instance, can arise even if the economy is strong. However, it should be understood that human development is necessary for ICMT/technological development. The authors of reference [30] examined the impact and influence of ICMT development on human development and economic growth in 27 European countries by acquiring data from the Eurostat database. To understand human development's impact, they used the Human Development Index, which includes income, education, and health, and the Education Index (EI). The used ICMT variables include ICMT in households, ICMT in firms, and ET. They also used 15 variables altogether, nine of which were structural and six of which pertained to policies, and found that different EU countries have achieved different levels of human development and economic progress based on their degree of ICMT development, meaning that it is essential for most developing countries to implement ICMT for human and economic progress [30].

ICMT is an important developmental tool for most countries. The UN describes ICMT as a means of achieving the UN Millennium Development Goals and Sustainable Development Goals (SDGs) as indicated earlier. Moreover, ICMT enables better education, governance, and health. The authors of reference [31] qualitatively analyzed the impact of ICMT on education and health in African and other developing countries to help stakeholders and other policymakers overcome sustainability issues. The results show that ICMT affects education in that it helps foster knowledge, creativity, self-directed learning, online group learning, and information system security; it also offers a better overall mental impact. On the other hand, reference [31] also found that continuous use of ICMT can have an overall negative impact on health, leading to a sedentary life, eye strain, body strain, and IS security issues, despite ICMT development having a positive impact on e-health systems.

Electronic governance is attributed to the efficiency of governmental performance and administration. However, the relevance of e-governance in developing countries in sub-Saharan Africa is questionable in cases where the performance of the government has proven rather inefficient and employees are poorly trained. Whether a technological transfer would have positive effects in developing countries is unclear, and it cannot be assumed that the transfer would lead to positive results without considering various other situational aspects. The study makes it clear that e-governance may lead to mishaps when contextual political and administrative factors are overlooked. This may mean that additional time-consuming effort may be necessary, but the results could lead to the efficient implementation of e-government [32].

3. Theoretical Background

This section provides a brief review of the theory and model used in the context of the study. It focuses on the debates surrounding modernization theory and the information society model from the perspective of information, communications, media technologies for development (ICMT4D). There is a range of theoretical standpoints in the ICMT4D arena relevant to ICMT4D studies (see reference [33] for an overview of ICTD frameworks). In this study, we used extant theories, models, and frameworks cf. [2,34], which have grown influential in development research and practice in ICMT4D.

3.1. ICMT4D and the Theory of Modernization

The authors of reference [1] explained that theories of modernization are based on the notion that technological knowledge, tools, and techniques developed in the developed economics should also be used to develop emerging and developing economies. They contend that aid given to developing countries must be connected to political, structural, and social changes to ensure that it leads to economic growth. The research and analysis of ICMTs conducted by Reference [35] emphasized the importance of sharing and transferring emerging technologies from the industrialized North to the less-developed South to support progress. The World Bank and the UN share the belief that if less developed regions of the world are not integrated into the information society, they will face further obstacles to their development [13].

There is little doubt that ICMTs have greatly transformed the world. First, in the global North, computerized systems have increased both the private and public sectors' efficiency. Essentially, Western development institutions such as the World Bank and the Organization for Economic Cooperation and Development have understood ICMTs as powerful tools capable of changing the world for the better [36]. However, many scholars argue that, to date, ICMT4D has not been an absolute success [13]. Development theory offers a valuable insight into how development practitioners believe they can achieve their aims and what concepts their aims are based on. Therefore, development theory is also the most natural starting point when analyzing the actions taken in ICMT4D. Even though many studies on ICMT4D exist, only a few of them discuss the meaning of development by drawing on development theory [8,23]. Moreover, even though modernization theory is assumed to be outdated, several authors have argued that ICMT4D brought about its revival in the 1990s [37].

Despite criticisms leveled at modernization theory and the doubts expressed as to how far its application has helped alleviate poverty in the global South, the theory continues to exert a considerable influence over Western foreign policy on "development" in general and deployment of ICMTs in particular. The essence of modernization theory was the dualistic opposition between the North and the South and the need for the South to "catch up" with the North. The potential of ICMTs may be significant, but its success depends on the details of implementation, as the strategy to simply transfer "best practice" from Northern to Southern countries is likely to fail. According to modernization theory, ICMTs are an essential part of modernization due to some resemblances between the theory and current assumptions in ICMT4D discourse. Given this, there is an urgent need to transfer technologies (ICMTs) to the South to ensure that it can participate in the information society.

3.2. Information Society Model

Significant advances have been made in ICMTs, resulting in rapid increases in information flows globally. Most of the new and emerging ICMTs are also asynchronous, meaning that they allow messages to be sent and received at a time convenient for the individual user rather than requiring all participants to use the system simultaneously [38,39]. It is because of such capabilities that the new ICMTs are considered better than conventional ones. These capabilities are the reason questions are raised about ICMTs' potential, how they are adopted and implemented, and the larger social questions regarding their benefits to humanity. Among other things, the technological breakthroughs with new ICMTs have led to an information society, a view supported by scholars such as in references [40,41]. These trends make it evident that ICMTs offer new opportunities to support livelihoods in this information world.

Similarly, ICMTs strengthen production and increased market coordination, which are the main processes that contribute to the energy sector's opportunities and create income for people. This affirms Castell's assertion that information—and for that, matter ICMT—is an integral part of all human activity, as all processes of our individual and collective existence are directly shaped by the new technological medium [41]. According to reference [40], "technology is the basis of increased productivity, and productivity has been the transforming fact of economic life" [40,42]. Though ICMTs have an undesirable transformative effect in most societies, references [40,42] posited that technologies are the motor of change and simultaneously unharmed by social relations, indicating that neutrality is far from a fact here. ICMTs are not neutral—their design reflects some goals of their creators and can affect the arrangements of power in society. Technologies come loaded with both intended and unintended social, political, and economic leanings. Every tool provides its users with a particular manner of seeing the world and specific ways of interacting with others. ICMTs in particular can erode the boundaries erected by geographical location and the limitations once imposed by time, making it possible to link different places and continents [42]. The author of references [41,43] considered networking critical because it enables one to access information from anywhere (space), at any time, and interact with everyone. Therefore, he postulated that the information technology revolution is distinct from the Industrial Revolution, which is, of course, the fundamental tenets of the fourth industrial revolution theory.

It is also argued in reference [41] that networking reinforces capitalist power in society, with the author asserting that "because of the convergence of historical evolution and technological change we have entered into a purely cultural pattern of social ingredients of our social organization, flows of messages, and images between networks constitute the basic thread of our social structure."

Our society depends on this structure to allow the flow of knowledge technology, which has helped shape both the business world and our society in general. Many fields have been impacted by ICMTs, including energy, governance, education, health, entertainment, and communication, among others. The impacts of ICMTs are profound. As the world develops, more technologies continue to emerge. These technologies have both positive and negative impacts, especially on emerging economies and individuals' sustainable livelihood development.

3.3. Green ICMT?

Sustainable development requires careful environmental considerations. Therefore, the environmental aspects impacted by ICMT cannot be disregarded. The authors of reference [18] investigated the connections between ICMT, economic growth, financial development, and environmental performance in developing economies, and their [18] findings were based on the mean average (augmented) estimation techniques of data from 1990 to 2015 (both the mean group and augmented mean groups), using mobile penetration and Internet usage as variables. The relationship between ICMT development and human development has received widespread scholarly attention. Many researchers agree that it is not simply advancements in technology that have improved our quality of life, as other factors are involved. A qualitative analysis shows that ICMT development could enhance developments in human life when objectives are met, and proper policies are adopted; however, the trade-offs, demand for resources, and other potential downsides must be considered in a situational context [14]. Variables, including CO2 emissions, electric power consumption, financial development, gross domestic product (GDP), urbanization, ICMT (mobile and Internet usage levels), and the moderating influence of ICMT (mobile and Internet), as well as financial development and GDP, were correlated to identify similarities. The study found that both ICMT and economic growth are big contributors to CO2 emissions. Acceleration of ICMT demands an increase in the use of resources, thereby adversely impacting environmental wellbeing. The moderating effect of ICMT and economic development also raises CO2 emissions, whereas the interaction of GDP and ICMT reduces pollution. Employing green ICMT projects to improve the energy efficiency of developing economies was suggested in reference [18].

ICMT's impact on natural ecosystems is alarming [17]. The advent of ICMT at its incipient stage was encouraging, but its quick adoption exacerbated environmental degradation. The critical consequence is climate change, caused by increased CO2 emissions, and circumventing the amount of carbon footprint caused by ICMT is a challenge that is barely discussed. Although ICMT has drastically reduced the need to physically commute to a workplace and promoted electronic means of transmission (by reducing paper-based products), thereby reducing greenhouse gas (GHG) emissions, the effect of these emissions caused by ICMT is still a concern.

Moreover, it is estimated that the carbon footprint owing to ICMT can be broken down as follows: data centers produce 18 percent, personal computers and printers produce 57 percent, and telecom infrastructure produces 25 percent. Some of the key indicators of reducing a nation's carbon footprint come from stakeholder action, IT changes, policies and rules and, most importantly, the adoption process. The authors of reference [17] conclude their study with a list of suggestions of possible ways to alleviate ICMT's share of the carbon footprint, including saving power (such as reducing energy consumption, e.g., by turning off monitor/computers when unused). These factors can only be applied on an individual level. These techniques can be suggestions to help reduce the carbon footprint, as the adoption mechanisms vary from country to country.

Agbogbloshie in Ghana is cited as the largest e-waste dumpsite in the world. The locals burn cables covered in plastic to extract the valuable copper contained in digital devices. This practice significantly pollutes the air, soil, and water. Why is the use of personal media and communication devices more detrimental to the environment than that of business and industry? This is of particular concern when considering the notion that ICMT is gaining further significance in the context of economies seeking to improve or maintain their national GDP. The authors of reference [44] point out a more dubious digital divide: "Global flows of e-waste from the Global North to the Global South continue to damage local environments and harm human health. Weak e-waste regulations and limited use of safety measures for e-waste workers in Accra, Ghana [for example], foster an exploitative environment within the industry and pose health risks for those working and living near e-waste processing sites."

The authors of reference [45] analyzed the impact of ICMT on environmental sustainability based on a set of predicted environmental indicators in 2020. There are significant chances of improving environmental impacts when certain adoption mechanisms are employed. In their study of the European Union, the indicators used to assess environmental impact included the volume of transport to GDP, modal splits of transport, energy consumption (inclusive of the weight of renewable sources), GHG emissions, and non-recycled but collected waste, among others. The result was that the effect could be anywhere between −20 to +30 percent. The authors also suggested that ICMT apps that make transportation more efficient would, in turn, cause more energy consumption and GHG emissions. To alleviate these effects, they suggested implementing e-materialization, intelligent transport systems, restriction of electricity consumption, efficiency in electric production and supply, ICMT-supported applications for energy savings, renewable energy adoption, and ICMT-supported waste management.

The trends of power consumption from 2007 to 2012 caused by the top three categories of ICMT (communications, data centers, and personal computers) were analyzed in reference [46]. Communication networks involve security and access equipment, office networks, telecom operator networks; data centers included servers, communication equipment, storage and cooling, and provisioning systems; and personal computers included Liquid Crystal Display (LCD), Cathode Ray Tube (CRT) monitors, laptops and desktops. The authors of reference [46] then estimated that consumption would be 10 percent for communication networks, 5 percent for data centers, and 4 percent for personal computers. However, the annual growth rate of ICMT caused by energy consumption is estimated to be 7 percent, excluding other ICMT-based equipment, such as smart televisions, mobile phones, set-top boxes, Google or Alexa speakers, tablets, gaming consoles, printers, scanners, remote cameras, Automated Teller Machines, etc. This suggests that ICMT-based electricity consumption grows at an alarming rate worldwide, despite switching to energy-efficient devices such as LCDs, tablets, etc.

In reference [3], the impact of the acceleration development and use of ICMT to enhance human development in 49 countries across sub-Saharan Africa from 2000 to 2012 was examined. The indicators for the analysis included income levels, legal origin, religious affiliation, governance/stability, access to maritime trading routes, national wealth, etc.; the ICMT factors assessed included mobile phones, telephones, and Internet penetration per 100 inhabitants. Certain control variables such as GDP per capita, foreign aid, private domestic credit, foreign direct investment, and remittances were also added. The findings, through correlation analysis using a Tobit model, show that the post-2015 sustainable agenda policies designed to boost ICMT development (mobile, Internet, and telephone penetration) would in turn increase overall human development.

Therefore, the dematerialization of goods promotes sustainability—that is, electronic means replacing physical–material production and consumption. However, the rebound effect of using such low-emission books, music, video streaming, etc., would increase Internet consumption, which in turn would increase energy consumption. The carbon savings gained by the development of ICMT would cause environmental issues as the demand for energy increases. Studies such as that of reference [47] investigated the promotion of e-commerce and teleshopping, potentially alleviating the impact of transportation services. However, with many transportation systems offering delivery of goods, the impact is nullified by green energy use due to distribution. It was claimed in reference [15] that it is not just the impact of ICMT driving energy demand but the wider political and economic contexts. Its research focused on Danish consumers' realization of a high increase in income and personal wealth due to profits from property prices, which increased ICMT usage. It is evident that although ICMT has a huge potential to pave the way for sustainable growth, other situational anomalies come into play, so this is not merely a result of technological change. One way to reduce consumption is to set high prices and taxes on energy and come up with inNovemberative policies that would make ICMT devices expensive, thereby ensuring they are purchased and used only when necessary.

4. CRISP-DM Methodology

In reference [48], a methodology is described as the "overall approach to a problem which could be put into practice in a research process, from the theoretical underpinning to the collection and analysis of data". The authors of reference [49] identified a methodology as the "overall approach to the entire process of the research study". We sought a data-driven approach to develop narratives (https://www.weforum.org/events/world-economic-forum-annual-meeting-2020/sessions/narrative-and-power, accessed on 30 November 2019) on the use of ICMT. The well-known industry-standard CRISP-DM methodology was chosen for the study as a whole, as it is robust and sound and will enable us to capture the entire gamut of the possible sequences in the data analytics process. Furthermore, the model is iterative, so sequences can be carried out in a different order. Rather than the traditional attitudinal opinion surveys long favored by traditional ICMT field researchers cf. [50], the CRISP-DM approach is more suited to the construction of an evidence-based narrative that disseminates good practice and lessons learned [51].

Figure 4 illustrates the major steps and process flows of CRISP-DM as deployed by an industry leader in Data Mining—International Business Machines. Table 1 explains the characteristics of each of these steps. Note that while the starting point is a business understanding of an analytic problem and the endpoint is the deployment of either an analytic model or findings in terms of rules, procedures, etc., the CRISP-DM approach is iterative and cyclic. In other words, it is ongoing and continuous.

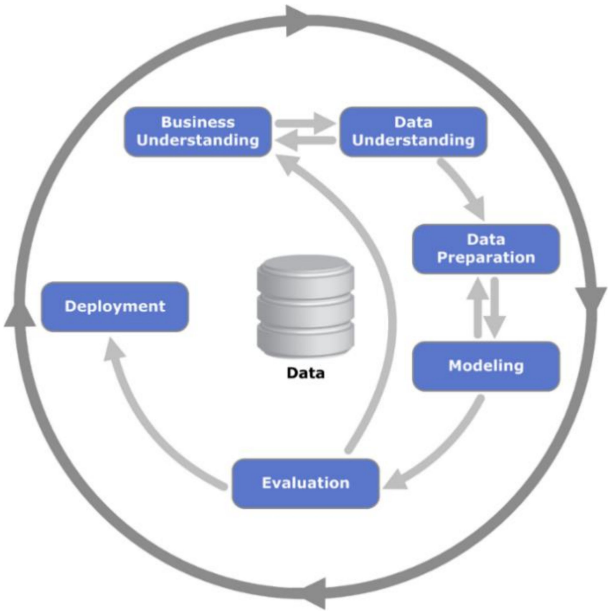

Figure 4. Cross-Industry Standard Process for Data Mining (CRISP-DM) steps. (Source: Adapted from the IBM CRISP-DM Guide: https://www.datascience-pm.com/crisp-dm-2/, accessed on 30 November 2019).

Business understanding included background information and summarization of the important terminology appurtenant to the study, as well as the elicitation of requirements, objectives, and goals of the data analytics project. Much of the data understanding and gathering focused on background details of what ICMT and SSI comprise; the way they are calculated; relevant background readings about the study; assignment of tools that may be beneficial in identifying details in the data; and the overall project plan, scope, and time constraints which should be taken into account.

Table 1. CRISP methodology delineating various functional levels.

Business Understanding	Data Understanding	Data Preparation	Modeling/Analysis	Evaluation
ICT and SSI background	Initial data collection from various sources	The rationale for the inclusion of selected variables (extracted from the background and the literature)	Variable parameter settings (IBM SPSS)	Evaluation of the generated results
Literature reviews	Data description (what each variable indicates)	The rationale for the selection of countries (to understand disparities/similarities in high- and low-income countries)	Correlation analysis	Inspiration and insights from literature
Assessment of tools	Data exploration (conducting a couple of tests from the gathered data)	Exclusion of countries that have fewer or no data points (i.e., data cleaning) and data integration	Assessment of the generated model	Recommendation and limitations
Project plan	Data quality (treating null values)	Data integration	—	Conclusion

Data understanding involved collecting data from various sources online. All of the data collected were secondary. Every variable in the study was specified to understand how the selected variable was computed and any metadata used in the calculation. Again, data gathered from various sources were explored, and missing values were addressed to ensure data quality.

The rationale for the inclusion of certain variables and selected countries was addressed in data preparation, which was carried out based on background studies and feature analyses. Unification of data from several sources was conducted to ensure coherency, and countries that had missing, noisy, or outlier data to work with were excluded from the data cleaning process. Analyses were conducted using IBM SPSS, and the findings were discussed as part of the evaluation process. Correlogram charts were generated using R Studio software. The findings were also compared to the literature review for inspiration and insight.

4.1. Data Collection

The following published sources, as tabulated below in Table 2, provided data for our analysis. They were authoritative and in the public domain.

Table 2. Model indicators and data sources.

Variable Name	Source	Website
ICT Access	International Telecommunications Union	www.itu.int (accessed on 15 January 2019).
ICT Usage	International Telecommunications Union	www.itu.int (accessed on 15 January 2019).
ICT Skills	International Telecommunications Union	www.itu.int (accessed on 15 January 2019).
ICT Development Index	International Telecommunications Union	www.itu.int (accessed on 15 January 2019).
Education	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Healthy Life	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Income Distribution	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Good Governance	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Biodiversity	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Renewable Water Resources	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Greenhouse Gases	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
Renewable Energy	Sustainable Society Index	www.ssfindex.com (accessed on 15 January 2019).
GNI per capita data used for country selection	Knoema	www.knoema.com (accessed on 15 January 2019).

The indicators tabulated below in Table 3 were collected from the sources listed in Table 2 for the selected countries, majorly the ITU's ITDI and the SSI, but also the World Bank (obtained from knoema.com).

Table 3. List of indicators and variables incorporated into the analytic model.

Indicators	Aggregate or Composite
ICMT Access	(1) Fixed telephone subscriptions per 100 inhabitants. (2) Mobile cellular telephone subscriptions per 100 inhabitants. (3) International Internet bandwidth (bit/s) per Internet user. (4) Percentage of households with a computer. (5) Percentage of households with Internet access. Weights equally proportioned (20 percent) for each of the sub-indicators.
ICMT Usage	(1) Percentage of individuals using the Internet. (2) Fixed-broadband subscriptions per 100 inhabitants. (3) Active mobile-broadband subscriptions per 100 inhabitants. Weights equally proportioned (33.33 percent) for each of the sub-indicators.
ICMT Skills	(1) Mean years of schooling. (2) Secondary gross enrolment ratio. (3) Tertiary gross enrolment ratio. Weights equally proportioned (33.33 percent) for each of the sub-indicators.
IT Development Index	The weighted average of ICMT access, usage, and skills in 2:2:1 ratio, respectively.
Education	Gross enrolment ratio (percentage).
Healthy Life Years	Life expectancy at birth in the number of healthy life years.
Income Distribution	The ratio of income of the richest 10 percent to the poorest 10 percent people in a country.
Good Governance	Sum of the six Worldwide Governance Indicators (voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption). Each indicator was graded on a scale from −2.5 to +2.5, and the accumulated range of all six indicators ranged from +15 to −15. Higher magnitude indicates better governance.
Biodiversity	10 years change in the forest area.
Renewable Water Resources	Annual water withdrawals/consumption (m^3 per capita) as a percentage of total renewable water resources.
GHGs	CO2 emissions per person per year. Countries that emit more than 10 tonnes of CO2 are scored 0, and ones below 10 tonnes are scored on a scale of 0 to 10. For instance, a rating of 5 indicates 5 tonnes of CO2.
Renewable Energy	Consumption of renewable energy as a percentage of total energy consumption.

The ratings of the ICMT development-related indicators (ICMT access, ICMT usage, and ICMT skills) were "normalized" to a scale ranging from 0 to 10 and were thereby dimensionless. The same applied to all of the indicators. ICMT access included telephone, mobile, broadband, and computer access. Each parameter was equally weighted, and the indicator comprised 40 percent of the weight in calculating the overall index. Similarly, ICMT use also included Internet, broadband, and mobile usage in the appertaining country/economy. ICMT skills were measured based on the education enrolment ratios of the country/economy. The final index was calculated using the weighted average method, giving 40 percent for ICMT usage and access and 20 percent for ICMT skills. These indicators were worth considering, as reference [17] posited that the highest proportion of the carbon footprint comes primarily from data centers, computer usage, and telecom usage.

Note that the SSI combines three dimensions (human, environmental, and economic) and 22 indicators that contribute to the wellbeing of a collective of society. Hence, education, for instance, was calculated based on the enrolment ratios of the country (as a percentage). A healthy lifestyle was computed by looking at life expectancy at birth in terms of the number of healthy life years. Income distribution was determined by calculating the ratio of income of the richest 10 percent and the poorest 10 percent of people in a country. Good governance was the cumulative value of the six worldwide governance indicators, identified as (1) voice and accountability, (2) political stability, (3) government effectiveness, (4) regulatory quality, (5) the rule of law, and (6) control of corruption. These data were obtained from the authoritative World Bank's World Development Index, and each indicator was assigned a value from −2.5 and 2.5, meaning that the overall cumulative range was between −15 to +15. Biodiversity was calculated by looking at a 10-year change in forest area and size of the protected land areas as the percentage of the total land areas of a country. Renewable water resources were determined by taking annual water withdrawals (m3 per capita) as the percentage of renewable water resources. GHG emissions were also calculated by looking at the amount of carbon dioxide emissions (in metric tonnes) per capita per year in a single country. However, it should be noted that the score for GHG was calculated as 10-x, with x being the number of tonnes. If the country emits more than 10 metric tonnes, the value was set to zero. This means that a higher score indicated less GHG emissions and vice versa. Renewable energy was assessed by looking at the percentage of renewable energy production out of total energy production. Again, the score was calculated by normalizing this value into a 10-point scale [7].

4.2. Data Cleansing and Integration

Data retrieved from various Excel/CSV files were cleansed for missing values and integrated through Excel. Statistical analyses and charts were generated using IBM SPSS. Countries were first segregated based on their gross national income per capita score. It was ensured that data collected from various sources were complete so that data imputation could be reduced.

Countries were segregated into high- and low-income (i.e., the countries were moderated based on gross national income per capita) to ascertain the behavior of ICMT development and sustainable growth in high- and low-income countries from a macro perspective. As can be seen from the list of countries, many high-income countries were part of the Organization for Economic Cooperation and Development (OECD), whilst many low-income countries were located in Africa.

When considering missing values, the SSI data were exhaustive for all countries for the years 2006, 2008, 2010, 2012, 2014, and 2016, and there were no missing values for the ICMT data of high-income countries. Thus, for reasons of availability and dependability of the required data, we included the data for the years 2002, 2007, 2008, 2010–2013, and 2015–2017. However, there were seven missing values for Burundi, six for Haiti; two for Guinea and Yemen; and one missing value each for Malawi, Myanmar, and Nepal.

5. Findings and Discussion

In high-income economies, education showed a moderate positive relationship with ICMT development. This suggests that high-income countries were well-informed and could exploit and assimilate ICMT to improve education [31]. Consequently, ICMT (for instance, Internet usage) could be used for self-directed learning with quality content, which underdeveloped economies lack access to. Furthermore, reference [3] revealed that educational development happens not only in high-income countries but also in developing countries with increased ICMT diffusion.

In regard to low-income economies, education showed some correlation with ICMT access. Educational levels could be improved with awareness, appropriate regulation, and participation. The authors of reference [16] mentioned that barriers to ICMT implementation are due to the lack of attention to sustainable measures, lack of stakeholder participation, and funding issues. These factors must be addressed on a contextual basis if they are to be improved. With some correlation in education, reference [3] further revealed advances in human development (particularly in health, income, and education) in 49 sub-Saharan countries, indicating that ICMT development could increase educational enrolment rates, a finding which applies to both developed and developing economies.

A healthy lifestyle showed a moderate relationship with overall ICMT development in high-income economies. This can be attributed to increased information access, storage, etc., and is beneficial in analyses of data conducted by universities, companies, and medical institutions, for example. Countries with a high degree of economic development are better positioned to harness such informational and communicational facilities to analyze health-based information, offering technical support and thereby increasing health and longevity. The authors of reference [30] also opined that countries with higher rates of ICMT diffusion exhibit higher magnitudes of human development (education, health, and income).

Figure 5 is output from correlation analytics using IBM SPSS and R-studio on the dataset specified in the previous section. Descriptive statistics, Pearson correlation coefficients, and correlograms for high- and low-income countries are placed side by side for ease of comparison.

High-income Countries — Descriptive Statistics

Description	Mean	SD*	N
ICT Access	8.055	0.5635	19
ICT Usage	6.212	0.7404	19
ICT Skills	8.489	0.7770	19
ICT Development Index	7.404	0.5173	19
Education	9.289	0.8854	19
Healthy Life	8.481	0.2591	19
Income Distribution	6.334	1.8800	19
Good Governance	8.063	0.5844	19
Biodiversity	6.596	1.5082	19
Renewable Water Resources	8.620	2.1684	19
Greenhouse Gases	1.868	1.2743	19
Renewable Energy	1.991	1.8424	19

Low-income Countries — Descriptive Statistics

Description	Mean	SD*	N
ICT Access	2.146	0.3968	20
ICT Usage	0.505	0.2625	20
ICT Skills	2.957	0.7709	20
ICT Development Index	1.652	0.3365	20
Education	5.482	0.9322	20
Healthy Life	5.255	0.7305	20
Income Distribution	4.086	2.0335	20
Good Governance	3.435	0.8847	20
Biodiversity	5.472	1.7418	20
Renewable Water Resources	9.155	1.9704	20
Greenhouse Gases	9.751	0.2089	20
Renewable Energy	7.648	1.9262	20

High-income Countries — Correlations

Description	ICT Access	ICT Usage	ICT Skills	ICT DI**
Education	0.122	0.423	0.822	0.541
Healthy Life	0.452	0.495	0.159	0.527
Income Distribution	0.376	0.379	0.429	0.510
Good Governance	0.527	0.693	0.515	0.781
Biodiversity	0.534	0.452	0.346	0.595
Renewable Water Resources	0.490	0.592	0.645	0.746
Greenhouse Gases	0.502	0.403	0.130	0.488
Renewable Energy	0.310	0.337	0.300	0.418

Low-income Countries — Correlations

Description	ICT Access	ICT Usage	ICT Skills	ICT DI**
Education	-0.077	0.233	0.579	0.301
Healthy Life	0.395	0.152	0.457	0.443
Income Distribution	0.257	-0.175	-0.177	-0.015
Good Governance	0.225	-0.098	-0.258	-0.043
Biodiversity	-0.022	0.256	-0.097	0.025
Renewable Water Resources	0.022	-0.137	-0.223	-0.134
Greenhouse Gases	-0.202	-0.448	-0.428	-0.431
Renewable Energy	-0.222	-0.214	-0.307	-0.312

**Std. Deviation; ** Development index*

Figure 5. Analytics of indicators for high- and low-income economies.

Healthy lifestyles were found to show a moderate correlation with ICMT development, indicating advancements in health care because ICMTs increase life spans in low-income economies. An increase in overall human development occurs due to ICMT, excluding other external factors. In reference [14], it was indicated that situational contexts, such as policies and demands, should also be considered for improvements. People living in low-income countries have the same needs as high-income countries, but their needs are less likely to be met than those of people living in high-income economies.

Income distribution was found to be moderately correlated with ICMT development—in other words, advances in technology reduce income inequality. On the other hand, countries with less inequality are more likely to possess the means for greater ICMT diffusion, access, and usage. Income levels make ICMT more affordable, as the money can be spent on a greater set of possibilities. Reducing inequality allows a larger percentage of a population to access ICMT, rather than restricting access to such technology to the upper classes. However, low-income economies do not necessarily show any correlation with increased ICMT diffusion. An explanation could be that increased ICMT development leads to enormous amounts of data being gathered, including data collected to gauge a country's genetic, species, and ecosystem diversity. High-income countries with increased ICMT development could gather data to solve problems such as the rate at which forest areas and land areas are impacted by various policies, thus indicating the existence of a relationship between ICMT development and biodiversity in high-income economies.

Good governance shows a strong positive relationship with ICMT development. ICMT acts as a conduit for the notion that political awareness reduces corruption and offers a platform for efficient economic and political development to take place by fostering governmental accountability and raising sociopolitical awareness among citizens. The authors of reference [32] asserted that when contextual policies and political and administrative factors are considered, a country can, in effect, form an efficient e-governance system, although it is unclear if governance would successfully materialize in low-income countries. In one of the studies conducted on African e-governance, they [32] also found that while disregarding various situational aspects that influence governance, defining several countries as low-income economies possibly overlooked other situational political and administrative factors preventing them from achieving good governance.

Renewable water sources are again linked to a moderate degree in ICMT development, as the latter has prompted the analyses and awareness of the water generated by the hydrological cycle. GHGs were positively correlated with ICMT development, which means that countries with more advanced technological development were able to quickly adopt sustainable energy measures rather than resorting to traditional power generation methods such as burning fossils [12]. Although developed countries emit more GHGs, the trend indicates that greater usage of ICMT will increase the value of the variable, meaning less CO2 emissions. As indicated by reference [45], there are still innumerable parameters other than renewable energy consumption that can help alleviate the magnitude of environmental impacts, including the use of ICMT to save energy, manage waste products, and responsibly consume energy [46]. Switzerland, Sweden, and Iceland showed a high development of ICMT and a reduction of GHG emissions during the period examined. Developed economies are better able to harness the advantages of adopting sustainable energy resources, and increasing ICMT development contributes to the adoption of renewable energy sources. This has a negative impact on GHG, as the more renewable energy is consumed, the more CO2 emissions are reduced. As indicated by reference [12], developed countries are more likely to adopt sustainable energy methods to alleviate environmental impacts. However, biodiversity and renewable water resources show almost no correlation with ICMT development in low-income countries.

Figures 5 and 6 also visualize the relationships between GHG, renewal energy, and ICMT development. It should be noted that high-income economies (left) reduced their GHG emissions and increased clean energy adoption due to ICMT development, while low-income countries exhibited different behaviors (right). Specifically, GHGs and renewable energy show a moderate negative correlation with overall ICMT development in low-income economies. Consumption of technology demands more energy, which means more fossil fuels being burnt, thereby increasing CO2 emissions. This hurts environmental wellbeing and causes environmental degradation, global warming, and climate change; however, it can be alleviated when countries replace traditional power generating mechanisms such as fossil fuels with sustainable energy resources. It should be noted that underdeveloped economies are at a disadvantage when it comes to adopting sustainable energy sources, meaning that improvements in ICMT can still lead to environmental degradation if energy is not properly produced.

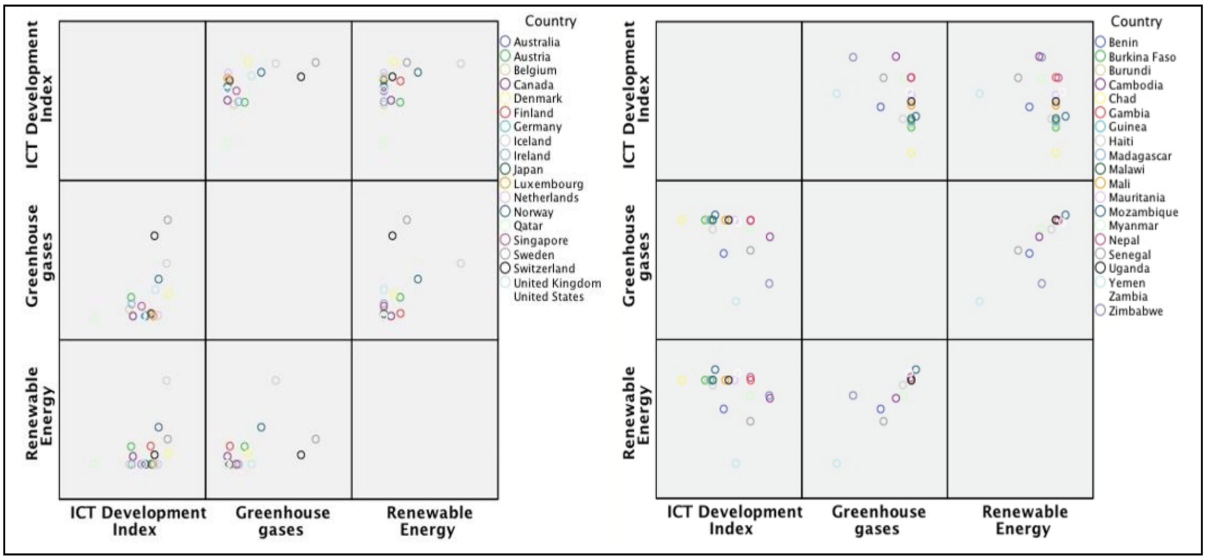

Figure 6. Matrix scatter diagrams showing relationships between greenhouse gas (GHG), renewable energy, and information, communications, and media technologies (ICMT) development in high- and low-income countries (generated using IBM SPSS Statistics).

The data showed that out of the low-income countries analyzed, Zimbabwe has the highest ICMT development and also emits the highest amount of GHG. This may not be ideal for sustainability and could instead focus more on the fundamentals or try to alleviate environmental impacts by adopting sustainable resources. It was further indicated in reference [12] that ICMT acceleration could be achieved in less developed countries through technology transfers. However, in contradistinction to high-income economies, low-income economies demonstrate the opposite behavior in terms of GHG emissions and renewable energy adoption, implying that ICMT development may not necessarily lead to increased renewable energy adoption. The authors of reference [18] promoted the idea of green ICMT adoption for developing countries to reduce environmental impacts, as both ICMT development and the need for economic growth lead to increased GHG emissions. Another option is to tax on carbon emissions/energy consumption [15], which could discourage people from frivolous usage of resources. This applies to both high-income and low-income countries striving to alleviate environmental impacts.

Backward integrating some of our findings to another interesting research study, [19] suggested that sustainability owing to ICMT diffusion is linked to information culture, ICMT management, and quality of ICMT adoption. It is also important to be responsible when it comes to striking a balance between ICMT growth and usage: irresponsible consumption could outweigh any methods that strive to foster energy efficiency [46]. Excessive utilization should be avoided because, as the authors of reference [17] claimed, too much energy is wasted on frivolous use of resources. In short, although ICMT has a positive impact on education and healthy lifestyles, the alarming rate at which resources are consumed should be taken into consideration in alleviating the effects of environmental degradation. Furthermore, reference [15] suggested implementing policies on carbon taxing and imposing heavy prices on energy-intense ICMT devices to lower the impact of energy usage.

6. Theoretical Contributions and Policy Implications

This article attempts to deliver a data-driven narrative of a macro-economic perspective of 39 economies. The micro effects driving these indicators and countries are not considered, as the results imply only the overall trends from the historic secondary data. It is understood that several situational anomalies could prevent a country from achieving sustainable growth, including influences on policy, political regulations, the geographic and demographic context of a country, the increased need for more resources, lack of awareness, and thoughtless use of resources. These anomalies also depend on the context of the country in consideration, and the factors which influence one country may not necessarily be attributed to another country. However, the overall global trend of ICMT diffusion and its effects are evident. The academic contribution of this paper is that such a nexus has been established.

We may conclude that ICMT affordances depend on the use-case context and are disparate among higher-income and lower-income economies. For instance, reference [12] suggested that underdeveloped lower-income nations could accelerate ICMT development via technological transfer, claiming that ICMT fostering nations are much more inclined to adopt renewable energy sources. However, historical data reveal that acceleration in ICMT development in low-income economies causes more GHG emissions and less usage of renewable energy, bringing other situational anomalies (poor infrastructure, weak investments in schooling, healthcare, etc.) into play. In reference [16], it is claimed that an increase in awareness, policy regulations, funding, cooperation, and participation could alleviate the negative effects that impede sustainable development. On the other hand, low-income economies could also alleviate environmental degradation by focusing more on fundamental needs than on competing for export-driven economic growth. Otherwise, developing countries with the means to implement ICMT projects should implement green ICMT methods to improve energy efficiency [18] and ICMT-supported applications that aid in saving energy and waste management [45,52]. The contribution for practice is that ICMT per se may not be green, and, hence, the onus is on policy-makers to implement green ICMT.

6.1. Research Contributions

Scholars have argued that ICMT development has a direct impact on sustainable growth and has a strong influence on the human and environmental wellbeing dimensions of the SSI [6], including education, health, income distribution, governance, biodiversity, GHG emissions, and renewable energy usage, among others. The definitions of ICMT and SSI were discussed, along with the mechanisms through which they are calculated [7]. The study was based on the industry-standard CRISP methodology for delivering a data-driven narrative on the influence of ICMT on sustainable growth. The methodology proved to be effective, as it was flexible, robust, and offered unparalleled flexibility in executing and performing the various tasks that comprise the data analytics process.

They allow the transfer of good practice and lessons learned from ICMT for sustainability policies across relatable societies or economies. However, Daniel Bell [40] himself, the originator of the terms "post-industrial society" and "the information society", was dismissive of such benchmarking, suggesting it was a clutch at relevance. "Faced with the problem of enlarging their focus from the nation states of Europe and North America in order to deal with a horde of "new nations," students of comparative politics allowed themselves to assume that there must be common political characteristics of these "underdeveloped" nations which correlated with their economic characteristics and a new subfield was born of this seduction." Hence, the less developed nations may learn from those more developed and vice-versa. Here lies the major fallacy in the premise of much of ICT for Development.

The countries included in our research were categorized by income level to identify similar or disparate behaviors relating to the effects of ICTs on sustainability. Correlation analysis revealed the disparate behavior relating to ICTs in high- and low-income economies. On the one hand, high-income economies experience positive effects, such as increased education enrolment levels and life expectancy, less income inequality, good governance, significantly larger proportions of forest and land area, increased renewable resources for energy production and, therefore, reduced GHG emissions due to increased ICT development. On the other hand, sustainable growth can involve negative behaviors when it comes to low-income economies. What brings about this difference? Based on our empirical findings, we theorize that there remain significant gaps in digital literacy (awareness), regulatory policies (comprehension), and technological capabilities (expertise) between developed and underdeveloped economies, leading to the positive and negative outcomes of ICT. Consequently, the development of literacy, governance, and capabilities are necessary prerequisites for the effective exploitation of ICT for sustainability. The authors of reference [34] referred to this as the digital literacy maturity model for development.

The findings illustrated in Figure 7 (adapted from reference [34]) corroborate those of reference [10] and illustrate a maturity model for ICMT for Development ICT and the data value pyramid. In this maturity model theory, the transformational functionalities of ICMT are contingent or dependent on the current development level of an economy (e.g., low, medium, or high on the Human Development Index). We, therefore, prescribe the following contingency theory of ICMT for sustainable development: The transformational impact of ICMT varies according to the maturity level of a given economy. The access level of ICMT contributes to the functional development of an economy or country. Usage and participation (levels 2 and 3) lead to socioeconomic participation and a resulting contribution to the development of a sustainable economy. There is a subtle difference between usage and participation—while usage is transactional, participation also involves the production of collective intelligence and social capital. Finally, at the highest level of human values, individuals and enterprises transform into sustainable economies, from the foundations enabled access, usage, and participation. In brief, sustainability is not optimized by access to and usage of ICMTs alone; it requires the participation and values of an informed and active citizenry.

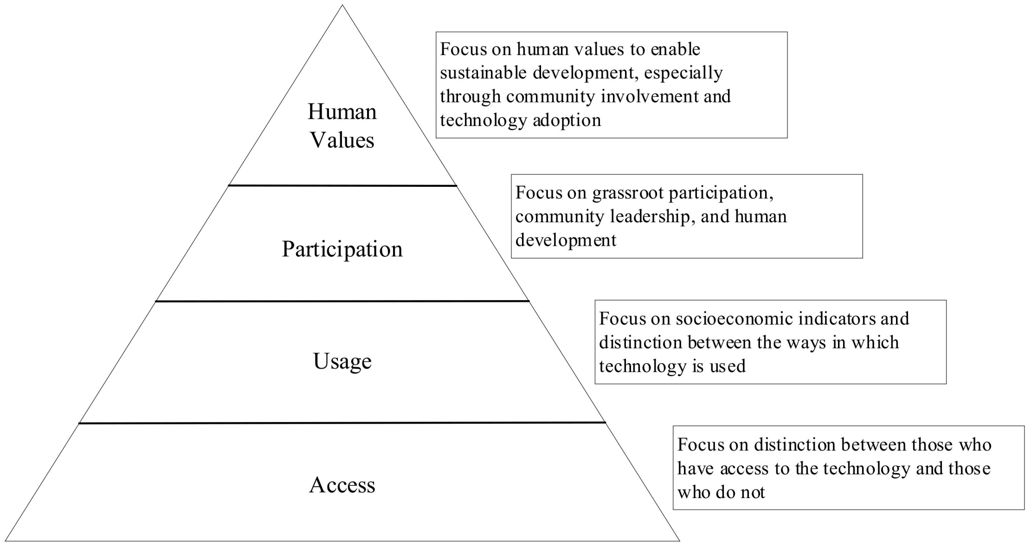

Figure 7. ICMT for sustainability pyramid (source: adapted from [34]).

Although educational enrolments and life expectancy show a moderate positive relationship with increased ICT development, there is almost no correlation when it comes to income inequality, governance, and biodiversity. The authors of reference [34] highlighted other causes, such as digital enterprise and inNovemberation. There has been an increase in GHG emissions and a decrease in the employment of sustainable energy resources with increased ICT diffusion, implying that growth in ICT development does not necessarily translate to sustainable low-income economies unless other external situational factors are taken into account. It was suggested in reference [15] that carbon taxes and increasing the prices of fossil fuel consumption could also lower a country's usage of resources and alleviate environmental impacts.

6.2. Limitations and Further Research

A major limitation of the study reported in this paper is that the data do not provide sufficient policy guidelines for benchmarking ICMT usage against the UN's 17 SDG (Sustainable Development Goals). However, our findings suggest that high-income nations are in a position to propel all of the goals by harnessing ICT to solve sustainability problems, whereas low-income countries have exhibited negative reactions to Goals 7 (clean energy) and 13 (climate action) with increased GHG emissions and decreased renewable energy production, as well as Goal 16 (governance) having no impact on ICT development. There are numerous unexplored nuances. For example, reference [10] discussed improvements in education, women's empowerment, economic productivity, and ICT access (Goals 4, 5, 8, and 9) in the context of Ecuador, indicating that public policy, accessibility, structural strategic planning, etc., are all important if one is to look for improvements. Similarly, to circumvent negative reactions to the climate-change-related goals put forth by the UN, governments of low-income economies should strive for policy improvements and strike a balance between technological growth and sustainable development to avoid further debilitation of the environment. As exemplified by the output in low-income countries, ICT growth showing a very low correlation with good governance indicates that public policy and the adoption of such policies and influences have come to be of prime importance.

Although the micro effects that prevent a country from achieving sustainable growth were not considered, it is worth noting that the overall trend suggests that ICMT diffusion has had different effects in high- and low-income economies, which indicates that responsible consumption, technology transfer, efficient green ICMT implementation [52], and policy regulations [18] are necessary if the improvement is to be achieved. In conclusion, while the author of reference [2] believed that ICMTs can be of great significance, he postulated that, despite unprecedented spread, there are still many questions to which we do not have clear answers. For example, reference [53] investigated the idea of digital resilience as a major contribution to organizational sustainability. There has been scant scholarly attention in this area and the philosophical question of ICMT for economic resilience and sustainability. Further and deeper narratives will address this gap.

As future work, we propose the development of a core body of knowledge that presents narratives on ICMT for sustainability from the perspectives of both the "North" as well as the "South". Neither group has "exclusive rights" to best practices or lessons learned. While ICMT diffusion may differ and result in different impacts, the notion of green ICMT for the purpose of sustainability is a global and common one. There are policy mechanisms that can be shared across the North-South spectrum as much as within each grouping. This article serves as a modest step in this direction.

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