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THE CONFIGURATIONAL IMPACT OF DIGITAL TRANSFORMATION ON SUSTAINABILITY: A COUNTRY-LEVEL PERSPECTIVE

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THE CONFIGURATIONAL IMPACT OF DIGITAL TRANSFORMATION ON SUSTAINABILITY: A COUNRY-LEVEL PERSPECTIVE

Research paper

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Abstract

This study focuses on the important national issue of sustainable development, and by incorporating the conditions for digital transformation reveals the necessary and sufficient relationships that lead to a high or low level of national sustainability. In order to deepen our knowledge of the prerequisites for the desirable outcome (i.e. higher levels of sustainability), we proposed a configurational model combining the available national data on digitalization dimensions. To empirically analyse related data for 134 countries, we used Fuzzy-set Qualitative Comparative Analysis and Necessary Condition Analysis. Our findings suggest multiple asymmetric configurations that justify the high and low levels of the Sustainability Global Index Score as well as the significance of digitalization for achieving sustainable development goals. The NCA and fsQCA solutions provide novel insights into varying sustainability levels across countries, and how 10 dimensions of digital transformation readiness contribute to this. The results also highlight the role of skills and business usage as core conditions for sustainability solutions. This research theoretically enhances our perception of asymmetric interactions between national digital transformation and sustainability and can serve a pragmatic role in steering sustainability strategies and national digital transformation.

Keywords: Digital Transformation, Sustainable Development Goals, National Development; FsQCA, NCA.

1 Introduction

The concept of sustainability contends that the national wealth of nations should be maintained for future generations, while countries seek to meet the demands of their current generation (Balkyte *et al.*, 2010). The associated challenges have contributed to an international mobilization to develop a set of broadly applicable sustainable development goals to address national problems, including disease, poverty and degradation to the environment. To this end, the United Nations introduced 17 Sustainable Development Goals (SDGs). Despite numerous international initiatives in developed and developing countries, few United Nations member states have achieved the SDGs (Seele and Lock, 2017). In this regard, earlier studies focused on the game-changing promise of national digital transformation and digital technologies for sustainability (Seele and Lock, 2017; Sachs *et al.*, 2019). Digital technologies have transformed the relationships of humans with each other and their natural environment such as enhancing the transparency and accountability of sustainable governance (Boyd and Crawford, 2012). It is argued that digital transformation can help reduce the negative environmental effects of humans and promote sustainability (Hampton *et al.*, 2013). In this study, we consider digital transformation at the national level and by digital transformation, we mean "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies* " (Vial, 2019, p 1.).

Despite recent research illustrating the importance of using digital technologies and encouraging digital transformation to fulfil the SDGs, there are concerns about the effects of digital transformation on sustainability (Seele and Lock, 2017). Most countries promote digitalization projects within their national boundaries to facilitate their social and economic development (Hanna, 2016). In order to evaluate progress towards national digital transformation, it is therefore important to establish comparative and reliable statistics on digital technologies (Milenkovic *et al.*, 2016). The Networked Readiness Index (NRI) was an international response to this need by assessing the ability of countries to leverage ICTs and digital technologies to improve competitiveness and well-being (Sachs *et al.*, 2019). The key purpose behind the development of the index is to illuminate ICT performance drivers and the value of ICT diffusion and usage for national well-being and prosperity. The index provides a methodological framework that defines the factors that allow countries to fully benefit from ICT developments (Baller *et al.*, 2016).

We included the NRI developed by the World Economic Forum to assess national readiness for digital transformation. The index is one of the international approaches to measuring emerging national disruptions caused by digital technologies (Baller, Dutta and Lanvin, 2016). The NRI measures 1) the overall national environment for technology use and creation, 2) networked readiness in terms of ICT skills, affordability, and infrastructure, 3) technology adoption and usage, and 4) digital economy and e-society. The index aims to answer two major questions: 1) what level of ICT access and use is achieved within a country. 2) What is the impact of digital technologies once a country accessed and used the ICT (Baller *et al*., 2016).

The goal of this paper is to examine the combinatorial effects of the national digital transformation in order to achieve the 17 sustainable development goals. We have integrated the complexity theory and configuration modelling techniques of fuzzy set qualitative comparative analysis (fsQCA) and Necessary Condition Analysis (NCA) to provide a broader knowledge of the complex relationships between digital transformation readiness and sustainability. Accordingly, the current research attempts to address the following key question: under what configurations of digital transformation readiness factors have countries led to high or low rates of sustainable development? In this paper, we are developing a model reflecting the 10 pillars of the NRI as a measure of countries' readiness for digital transformation.

From a theoretical perspective, this study extends current knowledge of sustainability and digital transformation by examining how national readiness for digital transformation helps explain the sustainability rate of a country. The study proposes the configurational effects between digital transformation readiness (conditions) and different levels of sustainability (outcomes) by demonstrating the asymmetry in the condition-outcome relationship and the combination of national digital transformation readiness that is necessary and/or sufficient to achieve sustainability.

From a methodological point of view, this paper expands the literature on complexity theory by combining the theory with fsQCA and NCA configuration modelling techniques. The objective is to illuminate the complex and asymmetric interactions between the causal factors of digital transformation preparedness and their impact on high or low levels of sustainable development across countries. It is argued that although the configuration analysis provides valuable insight, it is still almost unrecognized in the IS community (Liu *et al.*, 2017). Configuration Theory simulates complex relationships between variables and considers a phenomenon to be clusters of interrelated elements (El Sawy *et al.*, 2010).

In the next part of the paper, we will examine the theoretical background and the conceptual model of the study and then explain the methodology and the results of the analysis. This paper finishes with the discussion and the conclusion sections.

2 Theoretical background and conceptual model

2.1 Digital Transformation and Sustainability

Digital technologies have created new waves of national transformations and have disrupted traditional thinking on economic and social issues such as prosperity and well-being (Tapscott, 1996). Some scholars consider digital technologies as the driving force of competitiveness and welfare (Breene, 2016). Similarly, previous IS works urge nations to establish digitalization to improve the well-being and sustainability of their societies (Grover *et al.*, 2019). Such reports state that the use of technological advances is one of the major prerequisites for sustainability (Thore and Tarverdyan, 2016). Likewise, some scholars argue that digital transformation through the use of digital technologies can be a powerful tool for promoting sustainability (Seele, 2016; Maffei *et al*., 2019) and supporting SDGs (Sachs *et al.*, 2019). For instance, in one study the authors claim that ICT has potential in urban China by promoting e-participation and citizen mobilization (He *et al.*, 2017). Other reports also mention the positive impacts of ICT on social sustainability, for example in reducing corruption (Bhattacherjee and Shrivastava, 2018) or increasing happiness (Gelot *et al*., 2015)

Prior research confirms that the relationships of variables in phenomena like sustainability (Balkytė and Peleckis, 2010; Park and Saraf, 2016; Vial, 2019) and digital transformation (Majchrzak *et al*., 2016) are not linear. The researchers also encouraged the development of new methodological approaches to model the asymmetrical relations of complex phenomena (Zhang *et al*., 2012). As presented in Table 1, most earlier studies focus on the linear and symmetrical interactions between ICT and digital technologies. Previous studies also developed diverse and sometimes conflicting findings (See Table 1).

On the other hand, most of the preceding studies incorporated one or more of the NRI indicators. For instance, studies by (Yunis *et al*., 2012) focused on ICT usage, readiness, and environment; concluding that there is a stronger relationship between ICT and global competitiveness in high readiness countries than in low readiness countries. In another study, the authors measured factors such as ICT readiness and concluded that an inverted U-shaped relationship exists between ICT and CO2 emissions (Higón *et al*., 2017).

2.2 Complexity theory and configurational modelling

The complexity theory attempts to quantify the nonlinearity and variability of connections and feedback loops in complex networks leading to persistent changes in the system (Grobman, 2006). Multiple IS literature research integrated complexity theory with fsQCA to investigate the non-linearity of phenomena such as mobile learning adoption (Pappas *et al.*, 2017), personalized e-commerce (Pappas *et al.*, 2019), or the adoption of e-government services (Kourouthanassis *et al.*, 2016). We could not find any relevant study in the IS literature that integrates fsQCA with NCA to analyse the dynamic interaction between digital transformation and sustainability. Some of the IS scholars challenged the prejudice of traditional regression or correlation approaches because these strategies presume the interaction between variables is symmetrical and linear (El Sawy *et al.*, 2010; Liu *et al.*, 2017) and cannot model the complexity of complicated combinations. Asymmetric interaction between a measurer and the result variable means that a measurer may be unnecessary but is a requirement for the result variable to occur (Woodside, 2013), and the presence or the absence of one or more additional variables will affect the impact of a variable on the outcome (El Sawy *et al.*, 2010). Asymmetric modelling introduces different recipes for combining variables, which is called the configuration of variables (Liu *et al.*, 2017).

Overall, our research offers a novel way of thinking about modelling and analysing a complex phenomenon, particularly regarding digitalization and sustainability interconnected and non-linear relationships. The methods we used in this study allow us to go beyond the traditional linear model by using a conjectural and asymmetrical approach, resulting in different theory structures and practical solutions. The neo-configuration approach therefore opens up a new direction and framework for both theorizing and empirical study.

Source	**Variables**	**Methodology**	**Findings**
This study	*political and regulatory environment, business and innovation environment, infrastructure and digital content, affordability, skills, individual usage, business usage, government usage, economic impacts and social impacts, as conditional factors, and sustainable development goals as outcome.*	*Asymmetrical modelling (combining complexity theory, fsQCA, and NCA)*	*Please visit the result section*
(Matei and Savulescu, 2012)	Networked readiness, global competitiveness and ICT sector share in national economies	Symmetrical modelling Correlation analysis	There is a significant relationship between ICT and development of a sustainable knowledge economy.
(Yunis *et al.*, 2012)	ICT usage, readiness, and environment and global competitiveness	Structural equation modelling (SEM)	ICT has a significant relationship with the global competitiveness of countries, while there is a stronger relationship in high readiness countries than in low readiness countries.
(Gouvea *et al.*, 2018)	environmental sustainability, ICT, and human development	Ordinary least squares regression	ICT and human development has a positive and significant effect on environmental sustainability
(Pradhan *et al.*, 2019)	ICT diffusion, innovation diffusion, venture capital investment, and economic growth	vector error-correction model	In the long run, there is a significant relationship between venture capital investment, ICT diffusion, and innovation diffusion with economic growth in Europe.
(Apaydin *et al.*, 2018)	hyperconnectivity and socio-economic sustainability	canonical correlation analysis	Affordability of technologies and high individual ICT usage in the emerging countries did not impact socio-

Source	Variables	Methodology	Findings
			economic sustainability.
(Jetzek *et al.*, 2019)	Open Government data and sustainable value	SEM	Open data, digital governance and digital infrastructure in a country have a positive effect on the country's level of sustainable value.
(Dima *et al.*, 2018)	Global Competitiveness Index (GCI), research and development expenditure, percentage of population with tertiary education, lifelong learning, GDP per capita, and debt to equity	Pearson coefficient and panel-data regression models	Both innovation and education are crucial determinants of EU competitiveness and economic convergence.
(Park *et al.*, 2018)	Internet use, financial development, economic growth, and trade openness and carbon dioxide (CO2) emissions	Pooled mean group (PMG) estimator	Internet use has lowered the environmental quality in EU countries.
(Lee *et al.*, 2018)	ICT use and e-government development (telecommunication infrastructure, online service, e-participation) and government corruption	A three-step analysis of the mediating effects and a Sobel test (empirical analysis)	A significant relationship between e-government user levels, governance, government regulation, and government corruption
(Higón *et al.*, 2017)	ICT readiness, ICT use, ICT intensity, GDP, Government effectiveness, rule of law, number of passenger car, population density, oil, Kyoto ratification, education, industry share and CO2 emissions	Linear OLS regression	An inverted U-shaped relationship between ICT and CO2 emissions

Table 1 Examples of previous studies exploring the interaction of ICT and sustainability across countries

2.2.1 Configurational model of this study

To understand the complex relationship between digital transformation readiness in national level (as the causal conditions) and sustainable development goal (as the outcome of interest), we incorporated fsQCA and NCA to develop the configurational model. Therefore, this paper represents the asymmetrical relationships between NRI sub-indexes including environment, readiness, usage, and impact configurations to realize the investigated outcome (sustainable development) (Figure 1).

We considered the World Economic Forum's 10 major pillars as conditional variables, and integrated the SDGs into our configuration model as the existing index for measuring sustainable development. Since NRI pillars are different dimensions of digital transformation preparedness, we considered them to be the conditions for our configuration model that could predict high and low levels of sustainable development. Table 2 represents NRI Sub indexes, pillars and the focus of related variables in each pillar.

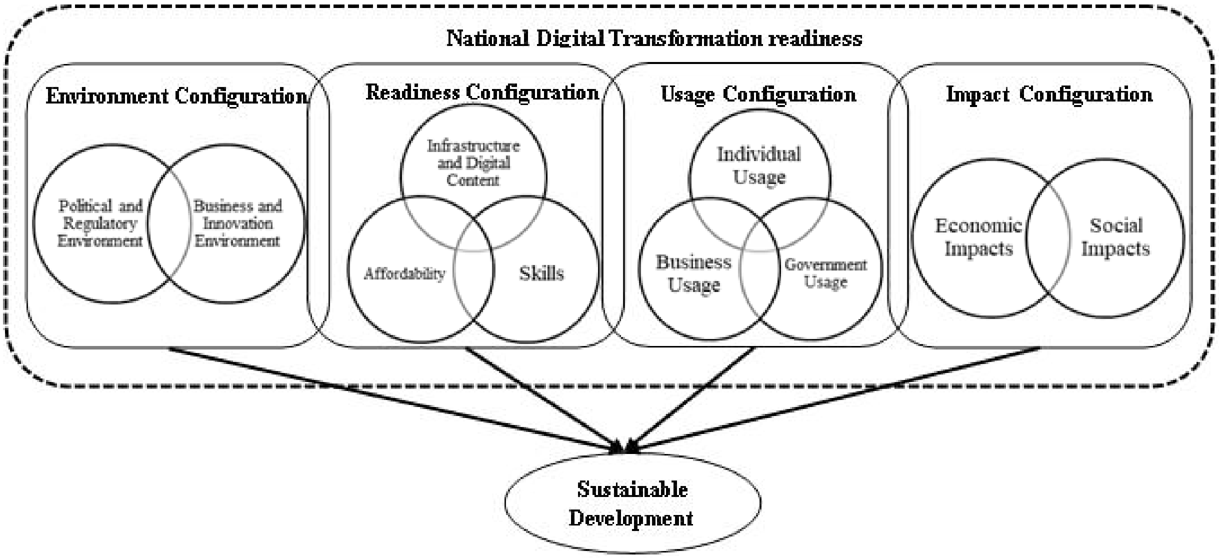

Figure 1 The proposed configurational model of the study and its variables

NRI Sub Index	*Pillars*	*Focus*
Environment	Political and regulatory environment (PRE)	The national legal framework facilitating ICT penetration and a safe development of business activities
	Business and innovation environment (BIE)	The business framework conditions to boost entrepreneurship in the field of ICT
Readiness	Infrastructure and digital content (IDC)	The development of ICT infrastructure and the availability of digital content
	Affordability (Af)	The cost of accessing ICT
	Skills (Sk)	The educational ability of a society to make an effective use of ICT
Usage	Individual usage (IU)	The ICT penetration and diffusion at the individual level
	Business usage (BU)	The firm's technology absorption and innovation capacity
	Government usage (GU)	The ICT policies and online government services
Impact	Economic impacts (EI)	The effect of ICT on economy shift towards more knowledge intensive activities
	Social impacts (SI)	The ICT impact on education and society, e-participation and government efficiency in ICT exploitation.

Table 2 Conditional variables representing national digitalization readiness and their main focus

3 Research Methodology and Data

FsQCA and NCA as configurational analysis techniques were used in this study to examine how the cumulative impact of systematically interdependent digitalization factors as opposed to isolated attributes shape sustainability. FsQCA concentrates on the 'middle ground' between variable-oriented quantitative methods and case-oriented qualitative methods (Ragin, 2009) and apprehends the three main features of causal complexity, including conjunction, equifinality, and asymmetry (Misangyi *et al.*, 2017). Conjunction implies that conditional variables may not have an isolated impact on outcomes, but rather combine into multiple clusters that produce the outcome. Equifinality means that more than one combination of conditional variables can lead to an outcome. Asymmetry means that the recipes for the occurrence of an outcome are not necessarily the same for its absence, and therefore each outcome group requires separate theoretical and empirical consideration (Greckhamer, 2016). In our research, we used fsQCA to analyse the conditions (digital transformation factors) underlying the phenomenon of interest (sustainability) given its strength in handling complex multidimensional interactions.

In addition, we used NCA to explore the order in which the conditional factors lead to varying degrees of outcome (Dul, 2016). NCA soundly complements the results of fsQCA and, as a novel statistical method, identifies the variables that are necessary but not guaranteed for the achievement of the outcome. Supplementing fsQCA with NCA provides solutions that are more accurate or complete and can deliver actionable knowledge that has very powerful policy implications (Ragin, 2009). The analysis was carried out using fsQCA 3.0 and R 3.6.1 software with NCA package version 3.0.1(Dul 2018).

3.1 Data pre-processing

We used data from the NRI dataset, sourced from WEF (Baller *et al.*, 2016) to measure digital transformation readiness. We used the Sustainable Development Report dataset to obtain the Sustainability Global Index Score (SGIS) (Sachs *et al.*, 2019). The FsQCA analysis begins by carefully converting data into measures of set membership based on empirical and/or theoretical knowledge, a process known as *calibration* (Misangyi et al., 2017). We applied the direct method of calibration to transform the measures into set memberships (e.g. Beynon et al., 2016; Greckhamer, 2016).

In computing the cut-off point for crossover, full and non-membership of the outcome variable, we followed Wang et al. (2019). For more than 134 countries, the national SGIS average (67.5, crossover point anchor) and the standard deviation (9.37) were calculated (with data available for all included variables). Then the cut-off points for full membership (mean plus one standard deviation) and non-membership (mean minus one standard deviation) were calculated.

For calibrating conditional variables, we followed Beynon et al. (2016) and used Probability Density Function (PDF) to compute the membership thresholds (Greckhamer *et al.*, 2018). The assessment process for the qualitative anchors was based on the calculation of the respective 5th percentile (lower-threshold), 95th percentile (upper-threshold) and 50th percentile (crossover point) values (Beynon, Jones and Pickernell, 2016).

4 Analysis Results

Qualitative methods of comparative analysis such as fsQCA try to determine commonalities through two types of analysis: necessity and sufficiency analysis (Rihoux and Ragin, 2009). Accordingly, we first conducted a necessity analysis of all condition variables, and after that, a sufficient analysis was carried out using Ragin's (2009) truth table algorithm to find out that casual relationships consistently led to the outcome of interest.

4.1 Necessity Analysis Results

Preventing guaranteed failure and increasing the likelihood of success are key components of" necessary but not sufficient" (Dul, 2016) logic of necessity analysis. A' necessary' condition is defined as a condition that must be present in order for an outcome to occur, but its presence does not guarantee that an event occurs (Ragin, 2009). We conducted a Necessary Condition Analysis to identify the specific level of digitization factors that are essential for different levels of sustainability (Dul, 2016). The NCA method quantifies the qualitative statement of" X is necessary for Y" and moves on to a more specific relationship:" a specific level of X is necessary for a specific level of Y.' (Dul, 2018). By drawing a ceiling line, the NCA separates the “empty space” and the “full space” of the data set and highlights what level of condition (*x*-axis) is necessary for what level of outcome (*y*-axis). A condition is more necessary when the empty space above the ceiling line is wider; therefore, a higher constraint is imposed on the outcome (Vis and Dul, 2016).

Visual inspection of NCA plots (Figure 2) demonstrates that the criticality of digitalization conditions for achieving sustainability is quantitatively different. In addition, to answer the question, to what extent the condition is a bottleneck for achieving the outcome, NCA defines the "effect size" as the size of the constraint that the necessary condition puts on the outcome. Dul (2016) proposed a general guideline for the magnitude of an effect size (d) ($0<d<0.1$ "small effect", $0.1\leq d<0.3$ "medium effect", $0.3\leq d<0.5$ "large effect", and $d\geq 0.5$ "very large effect). The results show that skills (0.39), affordability (0.32), IU (0.3), BIE (0.27), and IDC (0.27) have wider empty spaces above the ceiling lines and larger effect sizes; therefore, they are more essential for realizing the sustainability.

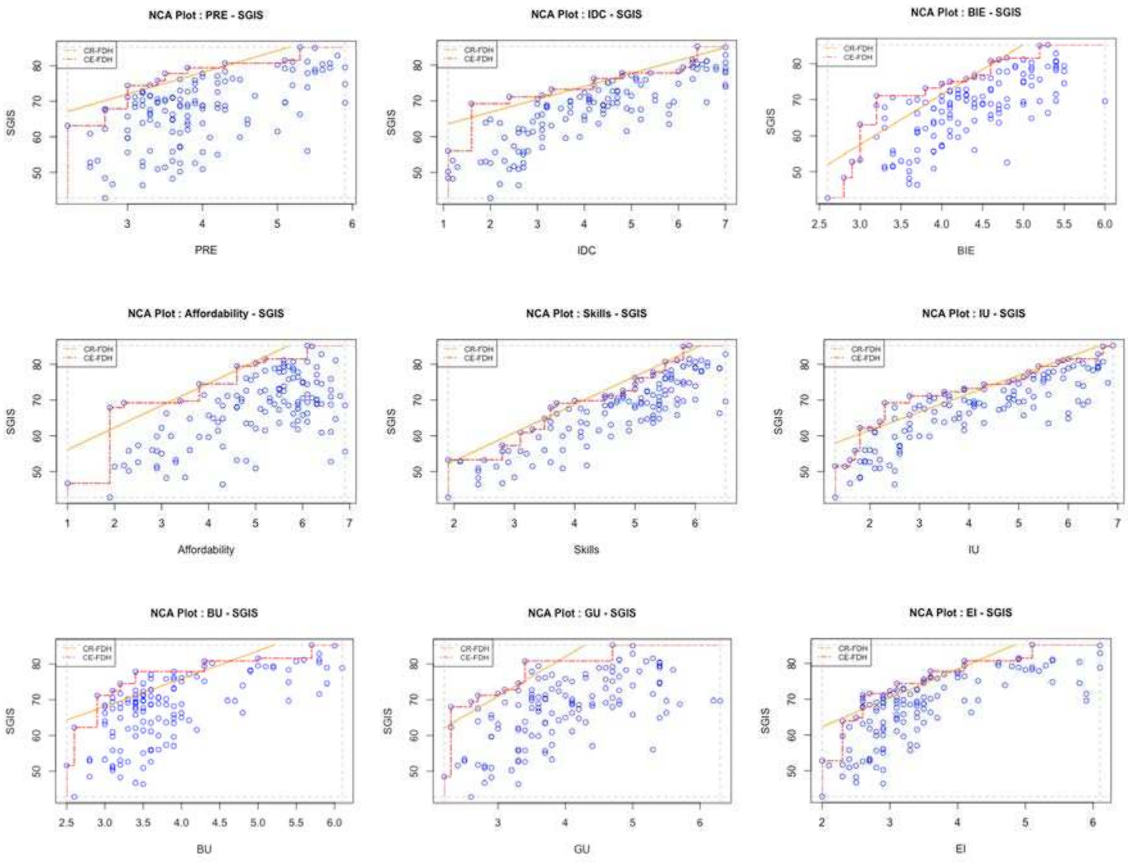

Figure 2 NCA plots of NRI pillars

***Note:** PRE: Political and regulatory environment, BIE: Business and innovation environment, IDC: Infrastructure and digital content, IU: Individual usage, BU: Business usage, GU: Government usage, EI: Economic impact.*

Bottleneck Table (BT) (Table 3) is used in the NCA for a multivariate analysis to examine the level of combination of conditions necessary for the various levels of the desired outcome (Dul, 2018). In BT, conditions and outcome are presented as a percentage of the range from the lowest to the highest observed values. The BT is used to identify the order in which the digitalization conditions are necessary to achieve sustainability. Since NN stands for not necessary, BT results indicate that very low levels of SGIS (up to 30%) can be realized without the need for digitalization endeavours. From the level of

30% onwards, the existence of digitalization factors is important, which means that in this set of cases, reaching a certain level of SGIS can only be achieved if certain conditions for digitalization have been met. The presence of a supportive business and innovation environment and qualitative skills are necessary conditions at a level of 30%. At the next level (40%), affordability, Individual usage, and infrastructure and digital contents also become critical. At the level of 50%, only political and regulatory environment, and business usage are not necessary. After this level, all NRI pillars must be present. The results of BT point out that the digitalization factors are critically different for different degrees of sustainability. For instance, NRI conditions are not critical in the low range of SGIS (< 30 per cent). Only at the 30% level, some preliminary skills, a low business and an innovation environment are prerequisites. From the 60% level of SGIS, the BT proposes that the full presence of NRI pillars is required, and countries must have a higher readiness for digital transformation to reach a higher level of sustainability.

SGIS	**PRE**	**BIE**	**IDC**	**Af**	**Sk**	**IU**	**BU**	**GU**	**EI**	**SI**
0	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN
30	NN	7.5	NN	NN	9.2	NN	NN	NN	NN	NN
40	NN	16.5	2.1	10	20.9	6.3	NN	NN	NN	7.4
50	NN	25.5	14.1	21.6	32.6	21.1	NN	4.3	5.1	18.1
60	5	34.5	21.9	33.2	44.3	35.9	14.4	13.6	18	28.7
70	23.8	43.4	41.8	44.9	55.9	50.8	29.7	23	30.8	39.4
80	42.5	52.4	61.6	56.5	67.6	65.6	44.9	32.3	43.6	50
90	61.2	61.4	81.4	68.1	79.3	80.4	60.1	41.6	56.5	60.7
100	80	70.4	96.8	79.8	91	95.3	75.3	51	69.3	71.3

Table 3 BT for multivariate examining of necessary conditions in each level of sustainability

Note: *NN: Not necessary, PRE: Political and regulatory environment, BIE: Business and innovation environment, IDC: Infrastructure and digital content, Af: Affordability, Sk: Skills, IU: Individual usage, BU: Business usage, GU: Government usage, EI: Economic impact, SI: Social impact.*

4.2 Sufficiency Analysis Results

Relations can be subjected to fuzzy truth table analysis after necessity examination to produce solutions regarding conditions and outcome configurations. The Truth Table is a key tool for determining the configuration of the condition leading to an outcome of interest. After calibrating data, we ran the truth table algorithm by applying a consistency benchmark of ≥ 0.8 and a minimum acceptable frequency of cases for solutions of 2 to identify the recipes consistently linked to the outcome. The Truth Table Analysis identifies the possible relationship between the combination of the condition variables and the outcome (Wang et al. 2019).

In Tables 4 and 5, we present the results of fsQCA sufficiency analysis using (Ragin, 2009; Fiss, 2011) notation. Using the Quine-McCluskey algorithm as a minimisation procedure for truth-table results, fsQCA presents three sets of consistent and sufficient configuration paths (i.e. complex, parsimonious and intermediate) for high and low SGIS levels.The complex configurational paths include all possible combinations of conditions without employing any simplifying assumption regarding logical remainders (i.e., combinations without cases in the study sample). Due to the large number of combinations in a complex solution, their interpretation is difficult and even impractical, and therefore experts recommend using simplifying assumptions to produce parsimonious and intermediate solutions. (Ragin, 2009; Pappas et al., 2019). The parsimonious solutions are based on simplifying assumptions and present the most important conditions that must be included in all configurations. In developing intermediate solutions, researchers apply simplifying assumptions that are consistent with empirical evidence and existing theoretical knowledge concerning single conditions that constitute logical remainders (Greckhamer, 2016).

Following Greckhamer (2016), we used a combination of parsimonious and intermediate solutions. For each configuration results in the outcome, we differentiated between core conditions which have strong relationships with the outcome (occur in both the parsimonious and the intermediate solution), and the complementary conditions that indicate a weak link to the outcome (only part of intermediate solutions but not parsimonious ones) (Pappas et al., 2016). Distinguishing the core and the complementary conditions allowed us to uncover the effects of the condition(s) in each solution and to improve understanding of the configurations of the digitalisation lead to high and low sustainability (Mattke et al., 2018). The solution tables also include coverage and consistency values for each configuration and the overall solution. Consistency reflects the degree to which cases sharing the configuration of the conditions agree to display the outcome, while coverage measures how much the configuration ' accounts for' the outcome and thus determines its empiric relevance (Ragin, 2008). The formula for the calculation of consistency is $(X_i \leq Y_i) = \sum(\min(X_i, Y_i))/\sum(X_i)$, and the coverage assessment formula is $(X_i \leq Y_i) = \sum(\min(X_i, Y_i))/\sum(Y_i)$ (Ragin, 2009). The results show an overall solution coverage of 0.75 at a high SGIS level and 0.71 at a low SGIS level, both suggesting that five high-level and four low-level solutions can cover a substantial proportion of the outcome. The overall consistency of solutions indicates that 88% of high SGIS and 87% of low-level SGIS cases can be reliably described in the resulting configurations.

Conditional variables	*Solutions*				
	S1H	S2H	S3H	S4H	S5H
Political & regulatory environment	●	●	⊗	⊗	⊗
Business & innovation environment	●	●	⊗	⊗	●
Infrastructure & digital content	●	●	⊗	●	●
Affordability	●		●	●	●
Skills	⬤	⬤	⬤	⬤	⬤
Individual usage	●	●	⊗	●	●
Business usage	●	●	⊗	⊗	⊗
Government usage		●	⊗	⊗	●
Economic impacts	●	●	⊗	⊗	●
Social impacts	●	●	⊗	⊗	●
Consistency	0.98	0.95	0.80	0.98	0.98
Raw coverage	0.52	0.59	0.28	0.27	0.27
Unique coverage	0.01	0.08	0.05	0.02	0.02
Overall Solution consistency	**0.88**				
Overall Solution Coverage	**0.75**				

Table 4 Configurations for high SGIS. Black circles (•) indicate the presence of a condition, and (⊗) circles represent the absence of a condition; big circles = core conditions; small circles = complementary conditions; Blank spaces indicate ‘don't care’.

Conditional variables	*Solutions*			
	S1L	S2L	S3L	S4L
Political & regulatory environment		⊗	⊗	⊗
Business & innovation environment	⊗	⊗	⊗	●
Infrastructure & digital content	⊗	⊗	●	●
Affordability	⊗		●	●
Skills	⨂	⨂	⨂	⨂
Individual usage	⊗	⊗	●	●
Business Usage	⨂	⨂	⨂	⨂
Government usage	⊗	⊗	⊗	●
Economic impacts	⊗	⊗	⊗	●
Social impacts	⊗	⊗	⊗	●
Consistency	0.96	0.94	0.86	0.82
Raw coverage	0.52	0.59	0.25	0.27
Unique coverage	0.05	0.07	0.01	0.06
Overall Solution consistency	**0.87**			
Overall Solution Coverage	**0.71**			

Table 5 Configurations for low SGIS. Black circles (•) indicate the presence of a condition, and (⊗) circles represent the absence of a condition; big circles = core conditions; small circles = complementary conditions; Blank spaces indicate 'don't care'.

The presence of skills has been identified as a key condition in all solutions for high sustainability (see Table 4). The first solution (S1H) proposes the presence of skills; along with other NRI pillars as complementary conditions for reaching a high level of SGIS, (government usage is a "don't care" condition). The majority of cases in this configuration are ideal cases such as Denmark, Sweden, Finland, France, or Austria, with very good technological readiness. Solution S2H is identical to the S1H and indicates that countries with similar conditions to the previous group but with a "don't care" condition of affordability can achieve a high level of sustainable competitiveness by using digital technologies in government and providing online services to citizens. This configuration includes countries such as Singapore, New Zealand, Canada, Iceland, Japan and Belgium. S3H solutions have achieved a high level of sustainability through highly skilled populations and the affordability of digital technology to citizens and businesses. Ukraine, the Kyrgyz Republic, Bahrain, and Sri Lanka are the countries of this class. The S4H (Serbia, Trinidad and Tobago, and Mongolia) path highlights that in the absence of PRE, BIE, BU, GU, EI, and SI, it is possible to improve sustainability where there are four other conditions. Solution S5H, including Montenegro and Armenia, illustrates that cases without effective ICT laws and robust regulatory environments or weak use of ICT in the business domain can achieve moderate sustainability by increasing readiness in the other eight pillars, in particular by improving the quality of ICT skills and education.

With regard to the condition configurations that led to a low level of sustainability, Table 5 highlights four recipes that are consistently linked to a low level of SGIS. Solutions S1L and S2L are similar and very likely to happen in low sustainable cases. The only difference is that PLE in the S1L solution and affordability in the second solution are 'don't care conditions'. Countries with the lowest levels of sustainability such as Chad, Congo, Nigeria, Liberia, Haiti, Niger, and Afghanistan are among the cases in these two groups. The absence of skills and business usage as core conditions and the absence of the rest of the conditions as complementary conditions make sustainability weak in these countries. The S3L solution points out that countries such as Pakistan, India, the UAE and Cambodia, despite having good conditions in IDC, affordability and individual use, have low SGIS skills because of poor conditions in skills and business usage (core conditions) and the absence of the other five factors (complimentary conditions). Finally, the S4L solution (in countries like Saudi Arabia, Kuwait, or Turkmenistan) demonstrates that, with the absence of skills and business usage as core reasons and lack of supportive political and regulatory environment, even with the presence of other digitalization pillars, countries would achieve a low level of SGIS. Overall, the significant impacts of lack of quality skills and the lack of business usage, as core conditions, are indisputable in all low sustainability solutions.

5 Discussion

Digitalization and sustainability are two key concerns on the national development agenda. While existing literature has explored the relationship between digitalization and sustainability (Apaydin *et al*., 2018; Jetzek *et al.*, 2019), an important gap in sustainability literature remains to be understood as to how different factors of digital transformation influence sustainable development goals (Higón *et al*., 2017; Pradhan *et al.*, 2019). To fill this gap, we have developed a model representing interdependent configurations of key digitalization preparedness factors to explore how sustainability can be achieved through the interactions of these factors. Using quantitative data, this paper adds to the digital transformation and sustainability literature by developing a configurational solutions comprising digital transformation factors lead to sustainability. Our study results show that a high level of SGIS can be achieved through the superior capability of countries to leverage digital technologies for increased competitiveness and well-being. On the contrary, the results show that a delay in the growth of digitalization capability will lead to a low level of sustainability that is eminent in the least developed countries.

The NCA results show that digital transformation factors are not crucial to a low level of SGIS, yet their roles are more crucial to a moderate and high level of sustainability. When countries with low level of SGIS, decide to upgrade their sustainability to higher levels, they need to improve their *affordability, Individual usage, infrastructure and digital contents* besides *business and innovation environment* and *digital skills*. In order to increase their sustainability to the highest level, countries with mid-range SGIS require a large amount of investment to enhance their readiness for digital transformation, in particular by improving their *political and regulatory environment and business usage*.

The results of the FsQCA identify multiple configurations that explain the high and low SGIS levels and emphasize the importance of digitalization in achieving sustainable development objectives. To illustrate the configurational nature of the impact of digitalization on sustainability, some solutions (S1H, S2H, S1L, and S2L) support the conventional logic, which believes that all digitalization factors should be present to achieve high levels of sustainability, whereas some configurations underline different new paths to the outcome. For example, S3H, S4H and S5H solutions together with the results of the bottleneck table show that a country with less digital readiness can still achieve sustainability by improving certain combinations of digitalization factors. In all the sufficient solutions at the high and low levels of SGIS, the skills condition is a key one, confirming the results of previous studies (Dima et al., 2018; Pradhan et al., 2019). This finding emphasizes the importance of increasing digital literacy in today's digital economy. In today's increasingly data-driven world, the development of digital education and training programs and the enhancement of digital skills are key factors determining the pace of sustainability growth. Nevertheless, recent academic and global studies show that the gap in access to skilled workers between successful countries and others is rapidly widening (e.g. World Economic Forum, 2018; James, 2020). Fourth Industrial Revolution, rapid advances in artificial intelligence, robotics and other emerging technologies along with other socio-economic and demographic factors are transforming many industries, resulting in significant changes to labor markets (Milano, 2019). The World Economic Forum states that by 2022, although 75 million jobs may be displaced by a shift in the division of labour between humans and machines, more than 133 million new roles may emerge due to the adaptations of the new division of labour between humans, machines and algorithms (World Economic Forum, 2018).

Another core condition identified in the configurations for low SGIS level is the absence of business usage factor. While the new digital economy is taking place, many businesses particularly in less sustainable economies, are acting passively or unable to move in line with this pace and are adopting digital technologies to capture their part in sustainability landscape. In recent years, the digital revolution, including big data, artificial intelligence, Internet of Things, and virtual and augmented reality, has entered public discourse in many countries (TWI2050, 2019). However, an increasing number of innovative digital products and services are mainly developed and provided by a relatively small number of companies (Baller *et al*., 2016). Businesses need to adopt and integrate digital technologies into their primary operations to absorb the capacities of digital solutions, and to enable them to drive business innovation.

The recipes explored by fsQCA and NCA in this study propose that countries ought to apply various improvements in their digitalization efforts to reach a proper level of sustainability. For instance, when a country has a low SGIS level, to reach a moderate level of sustainable development, better affordability, improvements in infrastructures, and better individual access to the Internet and mobile services can make significant progress. Analysis of the findings also shows that significant development of digitization is important in the most advanced cases of sustainable competitiveness (80 per cent SGIS and higher). Achieving this level and beyond needs further advances in policy and regulatory frameworks, better governance and major improvements in government use of ICT for the provision of online services and the development of e-participation.

6 Conclusion

In contrast to the most recent studies on digitalization and sustainability, which simply explored the direct effects of symmetrical modelling / thinking, the present study developed and examined complex configurational solutions to shed light on the association between digitalization and sustainability. Using quantitative data from 134 countries and drawing on the theory of complexity, this study adds to the literature on sustainability by developing a model representing the pillars of digital transformation as interdependent conditions for exploring how the combination of these factors would achieve sustainable development goals. Our research is one of the first endeavours in the IS literature that combines the NCA and fsQCA methods to examine the complex interrelationships between model variables. By utilizing the ceiling lines and the bottleneck table, NCA has enabled us to examine the various levels of constraints imposed by digital transformation factors at different levels of sustainability. Additionally, the fsQCA truth table, consistency and coverage scores allowed us to rigorously analyse cases to find sufficient configurations due to the analytical strength of the set theory. Collectively, these methods provide a deeper understanding of how complex combinations of digital transformation factors affect sustainability and how asymmetric relationships exist between them. The revealed solutions offer different sustainability prescriptions; however, results indicate that some variables are more important at some SGIS levels. For instance, if a country has low levels of SGIS, policymakers should take initiatives for developing infrastructures, increasing affordability, and exceptionally enhancing digital literacy. The results also underline the critical role of ICT's digital skills and business use in achieving sustainable development goals.

The present study attempted to examine the impacts of the pillars of readiness for digital transformation on sustainability using available data from 134 countries. Future studies can extend the analysis to include more countries, and consider variables in each pillar. The casual relationships of digitalization variables with different 17 sustainable development goals can also be explored by additional studies. Finally, longitudinal study can help to deepen our knowledge of the impacts of digitalization factors on sustainability. It would be also a valuable research avenue to test the robustness of the results by replicating the analysis model into new datasets.

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