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Multiple Conjunctural Impact on Digital Social Innovation: Focusing on the OECD Countries

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Received: 14 August 2019; Accepted: 3 September 2019; Published: 6 September 2019

Abstract: This study aims to explore the influencing factors of multidisciplinary digital social innovation (DSI) in the OECD (Organization for Economic Cooperation and Development) member countries in light of the socio-technical system transition theory. It sets up the eight variables of the four areas that comprise the DSI, and then identifies the causal conditions (arrangements) based on the empirical findings through the fuzzy-set multi-conjunctural analysis. In short, it concludes that, if OECD member countries have high level of democracy and e-participation, high GDP and business-friendly environment, high social expenditure, and high level of ICT (Information and Communication Technology) development and patent applications, they are highly likely to achieve a sufficient level of digital social innovation. This study underlines that the result of combined arrangement explains that the DSI can be more properly characterized by the multi-level and structured approach of the socio-technical system transition that goes beyond the fragmentary approach of existing innovation theories and the current related academic field. Moreover, this study reveals that the social factors (including the social capital variable) that have attracted attention from previous studies may have little effect on the DSI. In essence, it suggests that citizen interaction and social change can be newly formed through technological innovation in a multi-dimensional way, and that more in-depth discussion regarding the new context of 'digital citizen' might be required.

Keywords: digital social innovation; socio-technical system transition; fuzzy-set multiple conjunctural analysis; OECD countries

1. Introduction

Today, the Internet and mobile phone influence various aspects of our lives. With only a few clicks, one can find the information required and can disseminate information with an unspecified number of the general public. Additionally, individuals build networks with others through SNS (social network service) and by communicating and exchanging ideas, sometimes even creating a new identity of their own. The development of the Information and Communication Technology (ICT) most importantly accomplishes a change of communication form to enable communication that transcends time and space.

The forthcoming new digital technologies and communication platforms of the 'Fourth Industrial Revolution' (or called Digital Transformation) era (the Fourth Industrial Revolution can be defined as an era of technology convergence in which the boundary between physical space, digital space and biological space is diluted based on the digital revolution (Third Industrial Revolution), such as IT technology), will not deliver much more drastic changes than hitherto accomplished changes to our living and consciousness, economy and culture, but also to the national policy decision-making.

In the transitional trend, this study highlights Digital Social Innovation (DSI) that is defined as a form of social and cooperative innovation where innovators, activists, and organizations utilize digital technology in order to produce ideas and deliver solutions for demanded social needs at a rate that is thought to be unimaginable before the Internet Renaissance [1,2]. In particular, the DSI can be regarded as the collective results of digital governance that refers to the new mechanism that administrates market and society that are based on convergence of digital technology, in which people, the state, and firms form new relations by utilizing the ICT, and decide and manage the future of the communities [3–5].

The DSI is an attempt of guaranteeing citizen participation in policy-making and its execution process by utilizing digital technology, such as crowd-sourcing (engaging consumers in production and service processes and share profits with the participants) and online petitions. A series of process of the DSI, which enhances democracy of the policy per se as well as policy formulation process through active engagement of the citizens, has effects on rendering 'throughput legitimacy' (including the condition and efficacy of governance, as well as the process and method of participation) to be strengthened [6,7]. Moreover, it is seen that the DSI encompasses the following six sectors (categories): 'Collaborative Economy', 'New Ways of Making', 'Open Democracy', 'Open Access', 'Awareness Network', and 'Funding, Acceleration and Incubation' [1,8].

Meanwhile, as digital social innovation (DSI) is of a social innovation, it requires taking an approach from the aspect of the socio-technical system transition [9]. As the previous discussions of digital social innovation have focused on utilizing digital technologies that have been used in industry to solve social challenges, they have only been expanded in short term and local views [4,10]. However, this study underlines that the introduction of the perspective of the socio-technical system transition is required in order to fundamentally solve social problems by making use of digital technology. This is not brought to sufficient attention from previous studies. Unlike researches in some related academic fields, this study tries to reveal the fact that the DSI can be more properly constituted by the multi-lateral and holistic approach of the socio-technical system transition that goes beyond the top-down and fragmentary approach of existing innovation researches. This study aims to determine how certain factors that comprise the results of DSI (digital social innovation) are composed in a combined way while considering the contexts of the socio-technical system transition and the digital governance. Particularly, it sets up the following research questions:

1. Which of the causal variables—democracy and e-participation (in politics); GDP and business environment (in economy); social capital and social expenditure (in society); and, ICT development and patent applications (in technology)—that have been set for the outcome condition of the DESI (Digital Economic and Social Index), are significant through the necessary condition verification?
2. Which of the causal sets/arrangements for the outcome condition of the DESI explain the high combined causal relationship with digital social innovation?

Subsequently, it delivers the findings of the causal sets of digital social innovation, while using the fuzzy-set multiple conjunctural analysis (STATA (Software for Statistics and Data Science) version 12.0 used) that can analyze and explain the collective contexts (arrangements) for this research, rather than the results between individual variables and of linear relationship that the existing qualitative methods highlight. For this study, thirty-four OECD countries (valid data out of all thirty-six OECD member countries, excluding Netherlands and Lithuania, where the data are not available) were included as the cases by extracting the relevant and recent data (eight variables) on the six categories of DSI, as described above.

This paper consists of four sections: in Section 2, it discusses the theoretical background of socio-technical system transition, digital governance, and digital social innovation. In Section 3, it clarifies the rationale for using the method of the fuzzy-set analysis and organizes the measurement frameworks, including the variable composition of outcome and causal sets. In Section 4, it provides the findings of fussy-set multiple conjunctural analysis, including the necessary and sufficient conditions, and also the implications and conclusions.

2. Literature Review

2.1. Socio-Technical System Transition, Digital Governance, and Digital Social Innovation

Modern days have witnessed an increasing interest in 'Socio-Technical System Transition', which regards the observation of transition, transition of system, system innovation, and transition of sustainability [11]. This has been theorized by a structured approach to problems of society, including economic polarization, unemployment, and environmental and energy challenges by which society is influenced in a constant time span and cannot be immediately resolved [12]. This approach can serve a very appropriate understanding because a number of important social challenges in countries, regardless of the development status, are caused by structural limitations of the socio-technical system [11,13].

The socio-technical system transition theory argues for the transition to a socio-technical system, where new technologies, infrastructure, actions, and markets in order to encounter social challenges [14–16]. In general, the innovation-research in the field of science and technology is micro-level approaches to analyze the successful diffusion factors and obstacles of specific technologies from the emerging technology perspective. However, socio-technical system transition research focus on the role of policy for the change of social function on a macroscopic level [13,17].

In particular, the transition management theory (developed, centered on discussions in the Dutch academic world since early 2000s; focusing on the practical methodology) of the socio-technological transition theories, notes how to govern a society system by combining the merits of incrementalism that is based on open and participatory approaches and the advantages of long-term planning [14,18,19]. Namely, it recognizes and notes the need for a new governance approach to the effective management of complex and long-term transition processes [17].

This study underlines that governance can be seen as the mechanism in the ruling system that solves problems through adjustments and discussions, while it guarantees the participation of various actors, such as the state, firms, and people [17,20,21]. In this perspective, digital governance implies a mechanism in which decision-making and communication of an organization or a group is achieved by decentralized and horizontal participation of the various actors through the ICT [22]. Digital governance, which is called 'the operation mechanism of the era', can realize future vision of the state, people, and firms that ICT conceives [23].

As the collective results of digital governance, Digital Social Innovation (DSI), overcoming one-dimensional flaws where the technological progress of the 'fourth industrial revolution' simply and physically supports social system, has its particular significance of presenting chemical bonding that accomplishes enhanced governance transparency and efficiency through discussions with citizens. Conclusively, the DSI can contribute to the development of democracy, as the quality and effectiveness of governance become dramatically improved by it [24,25]. In other words, currently experimented in various forms has developmental elements for democracy and it plays an important role in increasing the efficacy of citizen participation in modern society with inherent diverse values [1,8].

In fact, the transition of the social domain through digital social innovation is possible due to an 'open, shared, cooperative social system based on open source-based digital technology'. Digital technology changes the methods of human interactions and social relationships [26]. The formation of social relations based on digital technology and openness, sharing, and cooperation becomes social capital needed to solve problems in the fields of health, environment, energy, housing, and welfare, and to promote sustainable transformation [27].

To be specific, the European Union, which places citizens (users) in the center of innovation, has adopted and is practicing a new innovation strategy called "Open Innovation 2.0", which emphasizes building an innovation ecosystem in which the users can be actively engaged [1,8]. "Open Innovation 2.0" has been evolved from the triple helix model of innovation with existing industries, research institutes, and government in the center into quadruple helix model of innovation that includes the citizens, and it is pursuing innovations through open external linkages among them [8,24].

In this transition of social innovation, the European Union considers digital technology as an important tool of the innovation, which suggests education, R&D, and digital social building as the three major strategies through "Strategy 2020". The activities of DSI in Europe are taking place in various fields with civil society at the center. As illustrated in Figure 1 below, there are 2286 ongoing projects by 2012 digital social innovators (groups) in total (as of end of 2017) [24].

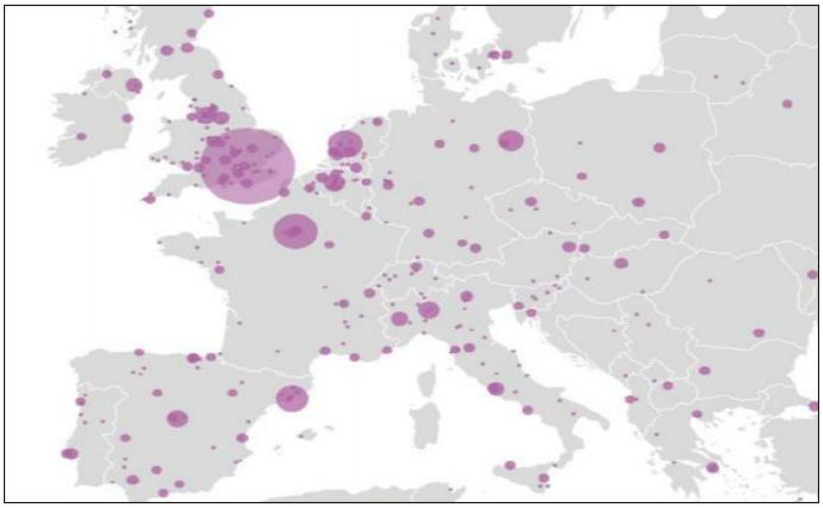

Figure 1. The Status of Implementation of Digital Social Innovation in the European Union (EU).

2.2. Multi-Level Perspectives of Socio-Technical System Transition and DSI Categories

The Socio-Technical System Transition (STST) consists of three dimensions, 'landscape' (macro-level), 'socio-technical regimes' (maso-level), and 'niches' (micro-level) [15,16]. 'Landscape' refers to macro trends (such as digital transformation and climate change) that occur over a long period of time; 'socio-technical regimes' means conditions, systems, and norms in which social functions are performed; and, 'niches' refer to a small space and practical experiment in which STST takes place [14,17]. Through the multi-layered approach, STST presents a framework for linking macro-level changes with new innovations at the micro-level to develop a discussion that integrates structured and action-oriented approaches [16,19]. Although digital social innovations (DSI) that pursue social innovation by utilizing digital technology have started from a short-term perspective, most of them can be interpreted as the transition management (governance) and the transition experiment (niche experiment) that tacitly refers to a sustainable society [13,18,20].

In particular, as shown in Figure 2, below, this study embraces the multi-level perspectives of STST by setting the digital transformation at the macro-level (landscape), the four sectors (politics, economy, society, and technology) of the socio-technical regime at the maso-level, and the six categories of digital social innovation (DSI) at the micro-level. According to various research from the European Union, the DSI can be characterized by the six categories: 'Collaborative Economy', 'New Ways of Making', 'Open Democracy', 'Open Access', 'Awareness Network', and 'Funding, Acceleration and Incubation'. The six main categories of DSI, which actively collaborate, are rooted in the context of the socio-technology transition and the digital governance [8,28].

First, in the 'Open Democracy' field, it has become possible for individuals to participate more easily and quickly in political process through digital technology, overcoming the problems of traditional representative democracy. For example, in the case of 'Liquid Feedback', as developed in Germany, decision-making principle by collective intelligence through a platform of free software for political opinion formation and decision-makings has been being practiced [1,8]. In addition, 'My Society' in the United Kingdom, which is an example of participation mechanism through information disclosure and online petition based on the digital platform, and 'Decide Madrid' in Spain, an internet platform enables citizens to directly participate in the municipal process of finance, legislation, and administration.

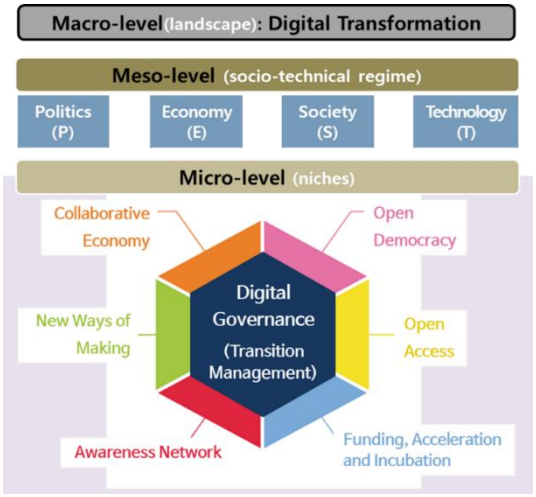

Figure 2. Multi-level Perspectives of socio-technical system transition (STST) and digital social innovation (DSI) Categories.

Second, in the field of 'Collaborative Economy', digital technology has made the ways people in the past shared their property and talents more affordable, broader, and more versatile [1]. This is called 'shared economy' or 'collaborative consumption economy'. Uber', a shared taxi service, and Airbnb's rapid growth in shared accommodation service provide worldwide examples of this digital social innovation [29]. In addition, there are well-known examples of 'Yerdle' in United States, a service that shares used goods, like a flea market, and 'Eatwith' cases, where a landlord prepares food and invites people to their home. Third, the development of digital technologies in the field of the 'New Ways of Making' has enabled people to create and build hardware and software much easier and in a wide variety [1,8]. Technical means that offer free creation and craft activities to ordinary individuals, such as open-source software, three-dimensional (3D) printer, laser cutting, and so on, are available, through which various social innovation activities are actively being carried out [30]. As a result, currently, there is a rapidly increasing number of 'makers', people who design and build the goods they need for daily life, creating 'Maker Movement' as a global trend [31].

Fourth, in the field of the 'Awareness (information dissemination) Network', network platforms that can collect, analyze, and share vast amounts of information by themselves are being utilized. By directly collecting or sharing environmental data, public data, and corporate data in a clearly organized way, it induces changes in responses and actions to the cases of emergency [1]. Typical examples of this are as follows: 'Open Spending', where information related to the public finance expenditure of the world is disclosed in pursuit of information liberal democracy, and 'Smart Citizen' cases, where citizens and scientists work together to solve environmental problems and measure environmental conditions in individual areas and share information [32]. Fifth, in the field of 'Open Access', with goals of open hardware infrastructure, internet contents accessible to anyone, and the maintenance of open licenses and sources, institutes, such as the World Wide Web Consortium (W3C), are pursuing an open approach by operating organizations, including 'P2P foundation' and 'IoT Council' [32]. 'Linux' and 'Github' are certain of the more typical platforms [33].

Finally, the category of 'Funding, Acceleration and Incubation' focuses on accelerating, incubation, and funding for the growth of the related businesses in different stages (particularly for early start-up companies) [1,8]. It shows the aspect that the main intermediate support organizations execute the funding and acceleration, while government undertakes accelerating system building, fundraising, and training of relevant personnel for corporate growth [29]. 'Crowd-funding' has been globally expanding, such as receiving small sponsorships or collecting funds from an unspecified number of people through Internet and SNS (social network service) [5]. In recent years, 'crowd-sourcing',

which is a way to engage consumers or the public in production and service processes to create better products and services and share profits with the participants, is also actively proceeding.

3. Materials and Methods

This research examines thirty-four OECD countries through comparative analysis by utilizing fuzzy-set multi-conjunctural analysis. The fussy-set analysis method consists of the fussy-set multiple conjunctural analysis and the fussy-set ideal type analysis [34,35] (the fuzzy-set analysis is a methodology developed from qualitative comparative analysis). Without setting limits within the existing traditional two membership scores, 1 or 0, fuzzy set analysis, which permits various fuzzy membership scores ranging between 0 and 1, not only represents the partial membership but also the differences in degree [34,36].

Moreover, in the causal relationship of causes and consequences (effects) performed in the conventional quantitative analysis, a certain outcome (consequences) seems to be not clearly identified with a certain cause. In other words, it was difficult to distinguish between a correlation and a causal relationship [34,37]. However, it is an important advantage to be able to overcome such problems through the fussy-set multiple conjunctural analysis that defines the relationship between cause and outcome as a necessary condition or/and a sufficient condition. In addition, it can be a powerful tool in analyzing causal complexity in medium case studies [37].

In fact, this study underlines the fact that we can clearly analyze the combinations of causal variables (conditions) for small to medium-sized (usually 15 to 50) cases through the fussy-set multiple conjunctural analysis. The fussy-set multiple conjunctural analysis is able to analyze the combination of causal conditions when compared to the existing qualitative methods, without an assumption of the independence between variables and the linear relationship. As a result, through the fussy-set multiple conjunctural analysis, this study has the strength of analyzing causal relationship by integrating not only the unilineal effects by certain variables, but also multiple causal conditions [38–40].

As shown in Table 1, below, this study with fussy-set multiple analysis presumes the Digital Economy and Social Index (DESI, published by the European Commission) as the outcome set. The DESI (and Intl.-DESI) is a composite index, exploring how the digital economy (economic activity conducted through digital technologies and innovations) can benefit all of society [41,42]. It summarizes the relevant indicators on the digital performance and digital competitiveness of Europe and major countries around the world [41,43]. The DESI (and Intl.-DESI) is composed of five principal policy areas with overall thirty-four indicators, as follows: 'connectivity' (including fixed broadband and mobile broadband), 'human capital' (including basic skills and internet use), 'use of internet service' (including citizens' use of content), 'integration of digital technology' (including business digitization and e-commerce), and 'digital public services' (including e-Government and e-Health) [44].

Table 1. The Variable Framework of Outcome and Causal Sets.

Variables (34 OECD Countries)				References (year)
Outcome Set	**Digital Economy and Social Index (DESI)**			European Commission (2016) [1]
	Areas	**DSI Category** *	**Variables**	
Causal Set	**Politics** (P)	①	(1) Democracy Index (2) E-participation Index	The Economist (2018) [45] United Nations (2018) [46]
	Economy (E)	② ③ ④	(3) GDP (4) Business Environment (Legatum Prosperity Index)	OECD (2016) (https://data.oecd.org/gdp/gross-domestic-product-gdp.htm) Legatum Institute (2018) [47]
	Society (S)	⑤ ⑥	(5) Social Capital (Legatum Prosperity Index) (6) Social Expenditure	Legatum Institute (2018) [47] OECD (2017) (http://stats.oecd.org/Index.aspx?datasetcode=SOCX_AGG#)
	Technology (T)		(7) ICT Dev. Index (IDI) (8) Patent applications	ITU (Intl. Telecommunication Union) (2017) [48] WIPO (World Intellectual Property Organization) (2018) [49]

* ① Open Democracy, ② Collaborative Economy, ③ New Ways of Making, ④ Funding/Acceleration/ Incubation, ⑤ Open Access, ⑥ Awareness Network.

For the causal sets, the eight variables were selected, respectively, based on the four areas ('Politics', 'Economy', 'Society', and 'Technology'). As Table 1 shows, this study tried to set up the four-stranded areas of the system of socio-technology transition with each of the eight main categories of DSI (digital social innovation) being rooted and activated. Particularly, the area of technology is characterized by a cross-cutting one, in which all of the six categories (variable (1)~(6)) of DSI can be rooted.

The first P (politics) area is characterized by both 'democracy index' and 'e-participation index'. The democracy index was produced by the Economist, having over 70 years' experience, which consists of the five categories: 'electoral process and pluralism', 'civil liberties', 'the functioning of government', 'political participation', and 'political culture' [45]. The e-participation index was developed from United Nations as additional index to the UN E-Government survey with 'e-information' with public information and access to it, 'e-consultation' to engage people in public policies and services, 'e-decision making' for policy options, and co-production through co-design with the citizens [46].

The second E (economy) area is composed of 'GDP' and 'business environment'. The variable of GDP underlines the size of economy (USD, constant prices, from OECD statistics), and the business environment represents the quality of economy. In particular, the latter variable as one of 'Legatum Prosperity Index', as developed from the Legatum Institute, measures a country's entrepreneurial environment, its business infrastructure, barriers to innovation, and labor market flexibility [47]. Those variables that are aligned in the DSI categories are 'Collaborative Economy', 'New Ways of Making', and 'Funding/Acceleration/Incubation', reviewed in Section 2.2.

The third S (society) area consists of the both variables of 'social capital' and 'social expenditure'. As the social capital represents social networks between people and different groups, and also the level of trust, it can be a substantial catalyst in social innovation that utilizes the power of the citizen, who is a party to social problems [3,50]. The variable of social capital as one of 'Legatum Prosperity Index' measures the strength of personal trust (relationships), social network support, and social norms [47]. The variable of social expenditure stands for net social expenditure, including public social welfare expenditure, mandatory private social expenditure, voluntary private social expenditure, and tax benefits; excluding tax burden (from OECD statistics).

The final T (technology) area includes both variables of 'ICT Development Index' (IDI) and 'patent applications'. IDI from the International Telecommunication Union (ITU) has 'ICT readiness', which is accessed by the quality, level, and access to ICTs and network infrastructure, 'ICT use' assessed by the intensity level of ICTs in a given society, and 'ICT impact' implied in the results of ICT use [48]. The 'patent application' variable represents the context that patents are an integral part of global technology innovation and an important intangible asset that accounts for most of the enterprise value, and also that the intellectual property that encompasses patents plays a role of a pioneer of breakthrough of technology innovation and of breakwater of technology protection [49].

This study focuses on the cases of thirty-four OECD countries out of all thirty-six member countries, in which the above eight variables (the most recent) data in the four areas (described in Table 1 above) are available. It attempted to collect the most recent data that may best show the characteristics of the eight variables.

4. Findings and Results

This study develops the analysis model that consists of the outcome set of the DESI (Digital Economy and Society Index) of thirty-four OECD countries, and of the causal set of the eight variables in the four categories. All of the variables are marked in uppercase, as shown below. Lower case indicates the complement of the set (d, p, g, b, s, e, i, r).

Model: DESI = **D** (Democracy Index) + **P** (E-participation Index) + **G** (GDP) + **B** (Business Environment) + **S** (Social Capital) + **E** (Social Expenditure) + **I** (ICT Development Index) + **R** (Intellectual Property).

In this study, the Y-consistency and N-consistency test ("settest (yvv yvn") was conducted to look at the necessary conditions (if the outcome set is a subset of the causal set, the fuzzy membership score

of the causal set is higher than the fuzzy membership score of outcome set). The concept of consistency indicates to what extent the relationship between causal conditions (sets) and outcome conditions (sets) is significant and influential. It shows whether empirical connections, such as 'significance', may or may not be worthy of the researcher's attention, and, in particular, is a measure of how well the researcher's theoretical arguments can be supported. In the case of the necessary condition and the sufficient condition, the value criteria, 0.65~0.8 is generally used.

As shown in Table 2, the seven variables (D(0.909), P(0.826), G(0.967), B(0.841), E(0.812.), I(0.927), and R(0.968) were satisfied with the principles of the necessary conditions ('Y-cons > 0.8' (benchmark proportion, 'almost always') and 'Y-cons > N-cons'), and the one variable (S(0.746)) was found to agree with 'Y-cons > 0.65' (benchmark, 'usually').

Table 2. Y and N Consistency of the Necessary Condition for Digital Economy and Social Index (DESI) (Outcome).

Variables	Verification Criteria		
	Y-cons > 0.8 & Y-cons > N-cons		Test Result ($p < 0.1$)
	Y-con	N-con	
D	0.909	0.444	0.000 (pass)
P	0.826	0.452	0.005 (pass)
G	0.967	0.108	0.000 (pass)
B	0.841	0.489	0.002 (pass)
S	0.746	0.584	0.075 (pass)
E	0.812	0.547	0.013 (pass)
I	0.927	0.455	0.000 (pass)
R	0.968	0.124	0.000 (pass)

As shown in Table 3 (the truth table of the causal set for the outcome set), below, there are seven sets (of the total 256 sets) that satisfy the condition of the existence of cases and the significance level, $p < 0.05$. They are also above Y-consistency 0.80 (benchmark proportion, 'almost always'). In other words, according to this criterion, a total of seven arrangements (sets) indicating a high outcome upper case set are identified ('Y' = DESI (Digital Economy and Society Index). Among the seven sets (arrangements), there are three sets with more than two case countries (best fit), respectively.

Table 3. Truth Table.

Arrangement	Causal Set								Outcome Set	Case Num.	Best Fit	Y-Cons.
	D	P	G	B	S	E	I	R	Y			
	Dem	Par	GDP	Bus	Soc	Exp	IDI	IR				
DPGBSEIR	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**6**	**AUS, DEN, NZL, NOR, SWE, UK**	**0.963**
DPGBsEIR	1	1	1	1	0	1	1	1	1	2	NZL, ISR	0.938
DPGBSEiR	1	1	1	1	1	1	0	1	1	1	FIN	0.935
DpGBSEIR	1	0	1	1	1	1	1	1	1	2	AUT, SUI	0.930
DpGBsEIR	1	0	1	1	0	1	1	1	1	1	ISL	0.918
dPGBSeIR	0	1	1	1	1	0	1	1	1	1	FRA	0.914
DPGbsEIR	1	1	1	0	0	1	1	1	1	1	LUX	0.887

For example, the first arrangement is 'DPGBSEIR' (high democracy (D), high e-participation (P), high GDP (G), high business environment (B), high social capital (S), high social expenditure (E), high ICT development (S), and high patent applications (R)), the best fits of which (cases) are AUS, DEN, GER, NOR, and SWE (Y-cons. 0.963).

The second is 'DPGBsEIR' (high democracy (D), high e-participation (P), high GDP (G), high business environment (B), low social capital (s), high social expenditure (E), high ICT development (S), and high patent applications (R)), the best fits of which (cases) are NZL, ISR (Y-cons. 0.938).

Additionally, the arrangement of 'DpGBSEIR' (high democracy (D), low e-participation (p), high GDP (G), high business environment (B), high social capital (S), high social expenditure (E), high ICT development (S), and high patent applications (R)) has the two case countries: AUT, SUI (Y-cons. 0.930).

This study carried out the verification of both Y-consistency and N-consistency in order to examine the sufficient condition (the fuzzy (membership) score of the outcome set > the fuzzy score of the causal set). This paper follows the usual criteria: the benchmark as 0.80 and the significance level of 0.01 ($p < 0.01$). As described in Table 4 below, in short, both sets were identified, satisfying the Y-consistency and N-consistency validation of the 'sufficient condition' for the outcome set (DESI), and also include the best fits (a total of eight country cases).

Table 4. Y and N Consistency of the Sufficient Condition for DESI (Outcome).

	Verification Criteria						Case Num.	Best Fit
	Benchmark ≥ 0.80, $p < 0.01$			Y-con ≥ N-con, $p < 0.01$				
	Y-con	F	P	N-con	F	P		
DPGBSEIR	0.963	52.53	0.000	0.605	13.48	0.001	6	AUS, DEN, CAN, NOR, SWE, UK
DPGBsEIR	0.938	23.94	0.000	0.723	7.90	0.009	2	NZL, ISR

As a result, the five causal sets, DPGBSEIR, and DPGBsEIR were found as the significant arrangements. Through the 'reduction process' (minimum configuration reduction sets that pass both Y and N consistency tests), the arrangements are reduced as the one causal set: D × P × G × B × E × I × R. The solution consistency of the causal set of the sufficient condition is 0.947 and the total coverage (explanatory range, strength) is 0.659 (see Table 5). The result of solution consistency, 0.947, means that the empirical connections ('significance') are very worthy (in comparison with 0.65~0.8 generally used). Additionally, the total coverage that explains the importance of empirical relevance and verifies how the cases that were included in the study can be explained by the theories (assumptions) of this study, are significantly high (explanatory range 0.659).

Table 5. The Causal Set of the Sufficient Condition for DESI (Outcome).

Set	Raw Coverage	Unique Coverage	Solution Cons.
D × P × G × B × E × I × R	0.659	0.659	0.947
Total Coverage = 0.659, Solution Consistency = 0.947			

DESI = **D** × **P** × **G** × **B** × **E** × **I** × **R** = (*Democracy Index* × *E-participation Index* × *GDP* × *Business Environment* × *Social Expenditure* × *ICT Dev. Index* × *Patent Applications*).

To summarize, the causal set of the sufficient condition explains, as follows. Among the OECD member countries, if ones have high level of democracy and e-participation, high GDP and business environment, high social expenditure, and high level of ICT development and patent applications, they are highly likely to achieve a sufficient level of digital social innovation.

As shown in Figure 3, below, the analysis of each case can be more concretely illustrated through the scatter plot that places the fuzzy score of the outcome set, DESI (Digital Economy and Society Index), on the X axis, and the fuzzy score of the causal set of the sufficient condition ('DPGBEIR') on the Y axis. As a result, except for a small number of cases, most of the cases are located at the upper left corner of the diagonal line, showing high consistency. It shows that the typical scatter plot of sufficient condition of the fuzzy-set. The countries that best describe the causal set of the sufficient conditions are the UK, Sweden, and Australia, which are located in the right edge of the diagonal.

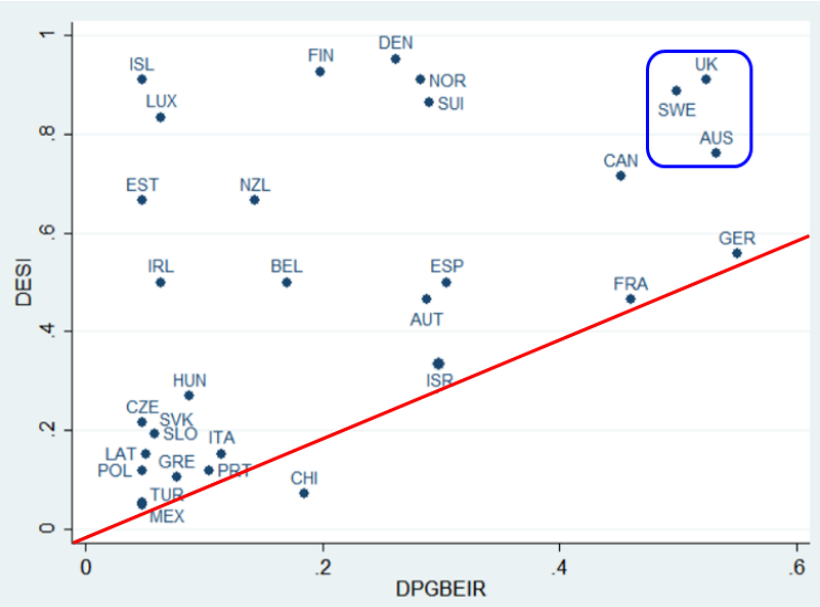

Figure 3. Scatter Plot of the Outcome Set and the Sufficient Condition.

5. Discussion and Conclusions

This study reviewed the influencing factors of multidisciplinary digital social innovation (DSI) beyond the existing top-down and static approaches of the innovation system theory through the socio-technical system transition theory. Essentially, it concludes that the seven factors in the four areas (politics, economy, society, and technology) of OECD countries—the political maturity, the active e-participation, the large scale of economy (market), the high quality of business environment, the large size of social expenditure, the high development level of ICT, and the multi-faced technology and intellectual property innovation—have a very significant impact on the DSI in a combined way. The OECD countries with high levels of the seven factors in the four areas, reflecting on the contexts of the socio-technical system transition (STST) and the digital governance, can be seen to be more effectively completing the DSI. In particular, the result of combined arrangement explains that the DSI can be more properly characterized by the multi-level (particularly meso- and micro-levels of STST) and structured approach of STST that goes beyond the fragmentary approach of existing innovation theory.

Meanwhile, there comes a suggestion from a slightly different perspective that in the combination sets satisfying the sufficient condition, the seven variables of all eight ones show the high bonding conditions, which indicates a significance of the socio-technological transition, while the S (social capital) variable is excluded from the combination for the sufficient condition. In fact, as described in Table 2 previously, this paper notes that the consistency value of the social capital (S) variable (0.746) is lower than that of the other seven variables. Additionally, the social expenditure (E) variable, which is another variable of the social domain, the result of the consistency value (0.812) is the second lowest one, followed by the social capital variable. Moreover, the statistical significance level of the both variables (S, E) in the social domain are relatively lower than the other six variables in the other three domains (politics, economy, and technology); the p-values of S and E are 0.075 and 0.013, respectively, on the other hand, the rest six variables satisfy the criteria, p-value < 0.01.

This study argues that these results suggest that the existing social factors are relatively ineffective in comparison with other domains' ones (politics, economy, and technology) in the DSI that promotes social problem solving through technological innovation. In particular, it can be seen that social capital—referring to the ability of individuals to mobilize the resources of others through social relations—as a result of accumulation in the existing systems may have little effect on the DSI. On the other hand, as the DSI evolves, it shows the possibility that social capital might be able to be constituted in other dimensions by becoming a new aggregation in the 'fourth industrial revolution' (digital

transformation) era [26]. As a result, this study assumes that these results describe an emerging aspect of the mutual structure of social change through the innovative development of new technologies. For example, the emergence and popularization of new technologies change the shape and form of people's lives, which in turn changes people's thinking, transforms into a new community of people with the corresponding way of thinking, and subsequently again requires a new technology. It may make the overall structure a full circulation.

In this context, as compared to the citizens and citizenship in the existing societies, the discussions about 'digital citizen' and 'digital citizenship' in the new era of the fourth industrial revolution will need to be considered more multi-dimensionally. In the digital (information) society, where the massive amount of information that corresponds to various topics and interests can be circulated quickly and at low cost to almost everyone, the mindset and behavior of citizens will be greatly transformed. This will ultimately lead to the search for new possibilities for the DSI through digital citizens who are actively engaged in social interaction in online/offline by using various new technologies in the digital world with interconnected rights, responsibilities, and opportunities for life. In line with it, Dufva and Dufva [27] argue the conception of 'digi-grasping' that can empower people to outline the relationship with the digital world, and also understand the choices and motivations behind current digital structures and create new structures.

In the meantime, this study has limitations in that it could not reveal (further) implications of the result cases (of OECD countries), including the best fit countries of the arrangement of causal set; UK, Sweden, and Australia, which are located on the right edge of the diagonal of the scatter plot, as illustrated in Figure 3. In addition, while the results of this paper, based on the relevant key data (eight variables) from 34 of 36 OECD countries, are sufficient to be generalized, among non-OECD countries, there is also the possibility of different results from this study. Therefore, the limitations of the study can be supplemented by subsequent studies to provide more concrete implications. It is also required for further studies to apply the analytical framework of this study to non-OECD countries.

Author Contributions: T.H., the first and the corresponding author designed the very structure of the article and completed the writing-up under the cooperation with the co-author. J.H.K., as the co-author contributed in completing the writing-up and revising the article.

Funding: This research was funded by Moon Soul Graduate School of Future Strategy, Korea Advanced Institute of Science & Technology (KAIST).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. European Commission. *Growing a Digital Social Innovation Ecosystem for Europe*; European Union: Brussels, Belgium, 2015.
2. Nesta. *Digital Social Innovation: What It Is and What We Are Doing*; Nesta: London, UK, 2014.
3. Conceição, P.; Gibson, D.; Heitor, M.; Sirilli, G. Beyond the Digital Economy: A Perspective on Innovation for the Learning Society. *Technol. Forecast. Soc. Chang.* **2001**, *67*, 115–142. [CrossRef]
4. Milakovich, M.E. *Digital Governance: New Technologies for Improving Public Service and Participation*; Routledge: New York, NY, USA, 2011.
5. Nylén, D.; Holmström, J. Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Bus. Horiz.* **2015**, *58*, 57–67.
6. Cho, H.; Lee, S.; Lew, S. Legitimacy of Digital Social Innovation and Democracy: Case of Online Petition and Public Problem Solution Project. *Informatiz. Policy* **2016**, *23*, 54–72.
7. Schmidt, V. Democracy and Legitimacy in the European Union Revisited: Input, Output and 'Throughput'. *Political Stud.* **2013**, *61*, 2–22. [CrossRef]
8. European Commission. *Digital Social Innovation for Europe*; European Union: Brussels, Belgium, 2016.
9. Markard, J.; Raven, R.; Truffer, B. Sustainability Transitions: An Emerging Field of Research and its Prospects. *Res. Policy* **2012**, *41*, 955–967. [CrossRef]

10. Westergren, U.H.; Holmström, J. Exploring preconditions for open innovation: Value networks in industrial firms. *Inf. Organ.* **2012**, *22*, 209–226. [CrossRef]
11. Markard, J.; Truffer, B. Technological Innovation Systems and the Multi-Level Perspective: Towards an Integrated Framework. *Res. Policy* **2008**, *37*, 596–615. [CrossRef]
12. Kemp, R.; Loorbach, D.; Rotmans, J. Transition Management as a Model for Managing Processes of Co-evolution for Sustainable Development. *Int. J. Sustain. Dev. World Ecol.* **2007**, *14*, 78–91. [CrossRef]
13. Kemp, R.; Avelino, F.; Bressers, N. Transition Management as a Model for Sustainable Mobility. *Eur. Transp.* **2011**, *47*, 25–46.
14. Rotmans, J.; Kemp, R.; van Asselt, M. More Evolution than Revolution: Transition Management in Public Policy. *Foresight* **2001**, *3*, 15–31. [CrossRef]
15. Geels, F. Technological Transitions as Evolutionary Reconfiguration Processes: A multi-level perspective and a case-study. *Res. Policy* **2002**, *31*, 1257–1274. [CrossRef]
16. Geels, F. From Sectoral Systems of Innovation to Socio-technical Systems Insights about Dynamics and Change from Sociology and Institutional theory. *Res. Policy* **2004**, *33*, 897–920. [CrossRef]
17. Loorbach, D. Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance* **2010**, *23*, 161–183. [CrossRef]
18. Kemp, R.; Rotmans, J.; Loorbach, D. Assessing the Dutch Energy Transition Policy: How Does it Deal with Dilemmas of Managing Transitions? *J. Environ. Policy Plan.* **2007**, *9*, 315–331. [CrossRef]
19. Song, W. The transition of socio-technical system and policy integration: The case of Netherlands 'Energy Transition'. *Innov. Stud.* **2009**, *4*, 49–69.
20. Loorbach, D. *Transition Management: New Mode of Governance for Sustainable Development*; International Books: Utrecht, The Netherlands, 2007.
21. Klijn, E.H.; Skelcher, C. Democracy and governance networks: Compatible or not? *Public Adm.* **2007**, *85*, 587–608. [CrossRef]
22. Torres, L.; Pina, V.; Acerete, B. E-Governance Developments in European Union Cities: Reshaping Government's Relationship with Citizens. *Governance* **2006**, *19*, 277–302. [CrossRef]
23. Kadar, M.; Moise, A.; Colomba, C. Innovation Management in the Globalized Digital Society. *Procedia Soc. Behav. Sci.* **2014**, *143*, 1083–1089. [CrossRef]
24. European Commission. *What Next for Digital Social Innovation*; European Union: Brussels, Belgium, 2017.
25. European Commission. *A Theoretical Framework for the DSI Index*; European Union: Brussels, Belgium, 2019.
26. Haxeltine, A.; Avelino, F.; Wittmayer, J.; Kemp, R.; Weaver, P.; Backhaus, J.; O'Riordan, T. Transformative Social Innovation: A Sustainability Transitions Perspective on Social Innovation. In Proceedings of the NESTA Conference Social Frontiers: The Next Edge of Social Science Research, London, UK, 14–15 November 2013.
27. Dufva, T.; Dufva, D. Grasping the future of the digital society. *Futures* **2019**, *107*, 17–28. [CrossRef]
28. European Commission. *Digital Social Innovation*; European Union: Brussels, Belgium, 2014.
29. Aitamurto, T. *Crowdsourcing for Democracy: A New Era in Policy-Making*; Parliament of Finland: Helsinki, Finland, 2012.
30. Brynjolfsson, E.; McAfee, A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*; W. W. Norton & Company: New York, NY, USA, 2014.
31. Berry, D.M. *Critical Theory and the Digital*; A&C Black: London, UK, 2014.
32. STEPI. *A Study on Strategies to Promote Digital Social Innovation*; STEPI: Sejong, Korea, 2016.
33. KAIST RISTI. *Digital Social Innovation and Living Lab*; Korea Advanced Institute of Science and Technology (KAIST): Daejeon, Korea, 2016.
34. Ragin, C.C. *Fuzzy-Set Social Science*; University of Chicago Press: Chicago, IL, USA, 2000.
35. Ragin, C.C. *Redesigning Social Inquiry Fuzzy Sets and Beyond*; University of Chicago Press: Chicago, IL, USA, 2008.
36. Kvist, J. Welfare reform in the Nordic countries in the 1990s: Using fuzzy-set theory to assess conformity to ideal types. *J. Eur. Soc. Policy* **1999**, *9*, 231–252. [CrossRef]
37. Choi, Y. Social science method: Fuzzy ideal center of analysis and factor analysis. *J. Gov. Stud.* **2009**, *15*, 307–337.
38. Rihoux, B. Qualitative Comparative Analysis (QCA) and Related Systematic Comparative Methods: Recent Advance and Remaining Challenges for Social Science Research. *Int. Sociol.* **2006**, *21*, 679–706. [CrossRef]

39. Katz, H.; Helmut, K.A.; Marcus, M.L. Fuzzy set approaches to the study of global civil society. *Glob. Civ. Soc.* **2006**, *7*, 186–196.
40. Schneider, C.Q.; Rohlfing, I. Case studies nested in fuzzy-set QCA on sufficiency: Formalizing case selection and causal inference. *Sociol. Methods Res.* **2016**, *45*, 526–568. [CrossRef]
41. Dentsu Aegis Network. *Digital Society Index 2018: Framing the Future*; Dentsu Aegis Network: London, UK, 2018.
42. European Commission. *Mapping Digital Social Innovation: Migration and Integration*; European Union: Brussels, Belgium, 2018.
43. European Commission. *International Digital Economy and Society Index 2018*; European Commission: Brussels, Belgium, 2018.
44. European Commission. *Digital Economy and Society Index 2018: Methodological Note*; European Commission: Brussels, Belgium, 2018.
45. The Economist. *Democracy Index 2018: Political Participation, Protest and Democracy*; The Economist: London, UK, 2018.
46. United Nations. *E-Government Survey 2018*; United Nations: New York, NY, USA, 2018.
47. Legatum Institute. *The Legatum Prosperity Index 2018*; Legatum Institute: London, UK, 2018.
48. ITU. *Measuring the Information Society Report 2017*; ITU: Geneva, Switzerland, 2017.
49. WIPO. *World Intellectual Property Indicators 2018*; WIPO: Geneva, Switzerland, 2018.
50. Tapscott, D.; Agnew, D. Governance in the Digital Economy: The Importance of Human Development. *Financ. Dev.* **1999**, *36*, 34–37.