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Hiroshi Sasaki
Rikkyo University, sasaki-h@rikkyo.ac.jp

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Positioning of Green Information Systems and Technology from an Ecosystem Perspective

Completed Research Paper

Hiroshi Sasaki
College of Business, Rikkyo University
3-34-1 Nishi-Ikebukuro, Toshima-Ku
Tokyo, Japan 171-8501
sasaki-h@rikkyo.ac.jp

Abstract

The aim of this paper is to define eco-focused information systems and technology (Green IS/IT) as a crossing between sustainable ecosystem (SE) and business ecosystem (BE) research. This paper examines 1,001 ecosystem studies covering sustainable, social, industrial, innovation, platform, and information technology ecosystems. Japanese newspaper entries on 833 ecosystem topics involving successful Green IS/IT implementation are also investigated. Our analysis suggests that Green IS/IT study can be positioned as an important ecosystem research agenda at the intersection of SE and BE. At present, SE and BE are studied separately, and empirical research is fragmented into subthemes.

Keywords: Green IS/IT, ecosystem, Japan, complexity, hierarchy

Introduction

Maintaining a healthy and resilient ecosystem is crucial. Executives of private, public, and non-governmental organizations have tackled the sustainability problem along three dimensions—environmental, social, and economic—when building future visions and strategies (Bonacchi and Rinaldi 2007; Dyllick and Hockerts 2002; Hart 1995; IUCN 2003; Ketola 2008; Kleine and von Hauff 2009; Malhotra et al. 2013). Interconnected strategies between pollution prevention, product stewardship, and sustainable development is needed (Hart 1995). Social responsibility and ethics should also be considered for sustainability management (Korhonen 2003). As described later, sustainable ecosystems and social ecosystems can be categorized into the same group without any confusion (hereinafter, SE for both).

In addition to corporate strategies considering SE, international cooperation on it is progressing, too. One example is proposed by the Paris Agreement, which came into force in 2016. The "Nationally Determined Contribution" action plan obligates signatories to work under a mechanism whereby their actions are evaluated by international audits every five years. Another example is the effort to attain 17 Sustainable Development Goals (SDGs) adopted by United Nations Development Programme (UNDP) in 2015, with these SDGs to be completed by 2030.

Information systems (IS) can facilitate all these strategies and action plans because IS can increase "process efficiencies and information effectiveness through technology-enabled business transformation (Elliot 2011, p.231)." Gholami et al. (2016) emphasized that "it is difficult to imagine solutions to environmental challenges without a substantial IS component (p.522)." Moreover, the IS community can help in creating a sustainable society through eco-focused information technology and systems (hereinafter, Green IS/IT) research to provide useful tools for information technology (IT) professionals (Gholami et al. 2016).

Alongside this, business supply chains are in some ways analogous with natural ecosystems. Recently, the notion of business ecosystems, such as platform ecosystems, innovation ecosystems, and IT ecosystems, has gained popularity (hereinafter, BE). With intense competition, high-tech firms are keen to develop new products or services on a new digital platform. Our previous study identified two different streams (SE and BE) in ecosystem studies (Sasaki 2017). However, as a later section describes, the two ecosystem studies (SE and BE) have not been well integrated to date. In particular, research on Green IS/IT from an ecosystems perspective is rare. The purpose of this paper is to examine the positioning of Green IS/IT at the junction of research into SE and BE.

Japan is a natural candidate for considering Green IS/IT solutions for several reasons. Firstly, Japan, like some other developed countries, faces an aging society and low birth rates. Randers (2012) states that Japan typifies a "grocline" nation, meaning that "the combination of individual growth and social decline occur together," and therefore Japan possesses "a long-term possibility to bring back to a sustainable planet because it could slim the human footprint (pp. 95-97)." Green IS/IT implementation in Japan has the potential to improve the efficiency of the labor force while coping with environmental issues, especially for labor-intensive industries such as agriculture and fishing, and services such as medical care and elderly care. The second reason is that the Great East Japan Earthquake of 2011 has led to increased attention in Japan to eco-friendly lifestyles, including in the area of creature comforts such as food, clothing, health, and welfare services. Responding to this social change, Japan's New Energy and Industrial Technology Development Organization (NEDO), established as a governmental organization in 1980, has been leading the way in implementing the concept of smart communities—urban ecosystem that use cutting-edge technologies in the areas of energy, robotics, and IT (NEDO, 2017). The third reason is the emergence of big data and Internet of Things (IoT) innovation around the globe. Sasaki (2016) analyzed 144 cases of big data and IoT solutions in Japan and found that current big data initiatives are directed toward (a) analyzing and predicting customer behavior, (b) providing useful data obtained from sensors (including energy consumption data, biometric data, and car navigation systems data) to local governments and healthcare facilities, and (c) developing new products or services. Green IS/IT implementation covers all three of these directions. In this sense, research on Green IS/IT from an ecosystem perspective is fruitful.

This paper is organized as follows. The next section examines 1,001 ecosystem studies. In the third section, a time-series of 833 Green IS/IT-related ecosystem topics in Japanese newspapers are analyzed. In the final section, the results are summarized and the issue of Green IS/IT positioning is discussed from an ecosystem perspective.

Literature review

Green IS/IT

This section provides a brief overview of Green IS/IT research. A more comprehensive review by Loeser (2013) gives definitions of Green IT and IS in a review of 78 papers:

> *"The concept of Green IT refers to measures and initiatives which decrease the negative environmental impact of manufacturing, operations, and disposal of Information Technology (IT) equipment and infrastructure.*
>
> *The concept of Green IS refers to practices which determine the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, business operations, and IS-enabled products and services."* (p.6)

Since this paper uses the term Green IT and Green IS without particular distinction, the term Green IS/IT will be used here.

Malhotra, Melville, and Watson (2013) examined 23 papers on Green IS/IT published from 2008 to 2013, classifying them into four categories, called the value space of research. They explained these categories' intents as the following:

> *"conceptualize (review papers, conceptual frameworks, etc.), analyze (case studies, ethnographic analyses, quantitative empirical analyses, hermeneutics, etc.), design oriented (design science), or impact oriented (implementation and sustainability impacts using action research, in vivo real-time approaches, etc.).*" (p.1266)

Most studies were categorized as "conceptualize" or "analyze" (Malhotra et al. 2013). Another study, by Gholami et al. (2016), reexamined the Green IS literature published from 2013 to 2016. The results indicate that there are still few papers in the "design" and "impact" categories. Similarly, Adomavicius et al. (2008) point out that the study of IT ecosystems lacks analytical tools that would provide real value to current practitioners. Considering these observations, this paper applies the above categories (excluding "design" and "impact") when operationalizing the stages of empirical research.

Ecosystem

We searched peer-reviewed documents in English (full papers, excluding proceedings) posted in the academic databases EBSCO, JSTOR, and AISeL, using the key word "ecosystem." We then limited the results to journals related to social science and excluded book reviews, editorials, and papers by anonymous authors. Taking the end of December 2017 as a cutoff, we obtained 1,001 papers. From these, we extracted 391 core documents, in which the key term "ecosystem" appeared three or more times in the main text.

Table 1 shows the journals that contain at least 20 selected papers. Journals published by the Academy of Management Journals published by Academy of Management (141 papers: Academy of Management Review, Academy of Management Journal, The Academy of Management Executive, The Academy of Management Perspectives, Academy of Management Discoveries, Academy of Management Learning & Education) appear at the top on the list. Also included are 196 papers from AISeL (which is based on the IS research community), and the three leading journals of business ethics and society—*Business & Society*, *Business Ethics Quarterly*, and *the Journal of Business Ethics* (Paul 2004).

Table 1. The list of ecosystem studies

Journal Name	Number of papers
Business Strategy and the Environment	190
Journal of Business Ethics	114
Communications of the Association for Information Systems	67
Strategic Management Journal	63
MIS Quarterly	52
Business & Society	46
Academy of Management Journal	42
Sustainable Development	35
Business & Information Systems Engineering	32
The Academy of Management Perspectives	32
Academy of Management Review	29
Interfaces	28
Annals of Operations Research	23
Academy of Management Learning & Education	22
Journal of the Association for Information Systems	20

Environmental Policy & Governance	20
International Review for Environmental Strategies	20

Hierarchies

A huge number of papers struggle with the complexity of ecosystems. As "complexity frequently takes the form of hierarchy (Simon 1962, p.468)," subsystem decomposition into a hierarchical structure is beneficial. SE studies have made the best use of hierarchies, structuring this into nature (the Earth), society, region, city, local community, and individual (Bonacchi and Rinaldi 2007; Chow and Chen 2012; Dyllick and Hockerts 2002; Ketola 2008; Kleine and von Hauff 2009; Young and Tilley 2006). The Earth can be positioned at the top of the hierarchies, as Korhonen (2003) states:

> *"the parent ecosystem relies on infinite energy source of the sun. The economic subsystem relies mainly on non-renewable and emission intensive fossil fuels. In ecological economics, this fundamental difference between nature and the economic system (Ring 1997) and the dependence of the economic subsystem on the parent ecosystem (Daly 1997) are seen as the core challenges and focus points of sustainable development research."* (p.302)

In contrast, BE focuses more heavily on disruptive innovations. Researchers have a strong interest in how the existing ecosystem will be transformed to an emerging ecosystem through competition, collaboration, and co-creation among players (Adomavicius et al. 2008; Ansari et al. 2016; Margherita 2013; Sitbon 2015; Tan et al. 2017; Tan et al. 2016). They often describe hierarchies composed of technological layers (Adomavicius et al. 2008; Xin et al. 2010), and/or supply chain structures (Adner and Kapoor 2010; Adner and Kapoor 2016). One exception is Elliot (2011), who examines the environmental sustainability of IT by assuming hierarchies composed of environment, society, government, industry and alliances, organizations, and individuals and groups within organizations. Yet the relationship between upper and lower levels of the hierarchy is not always harmonious. Rather, trade-offs, dilemmas, and conflict are possible everywhere (Beckmann et al. 2014; Cennamo and Santalo 2013; Chertow and Miyata 2011; Dyllick and Hockerts 2002; Hahn et al. 2010; Haight et al. 2000; Kearins et al. 2010; Ketola 1997; O'Shea et al. 2013; Panapanaan et al. 2016; Stubbs and Cocklin 2008; Wolff 1998). Trade-offs can be found between (a) social, ecological, and economic development (O'Shea et al. 2013); (b) economic and ecological goals (Ketola 1997); (c) the needs of different stakeholders (Dyllick and Hockerts 2002); (d) decision alternatives (Chertow and Miyata 2011; Wolff 1998); (e) affordability and profitability (Panapanaan et al. 2016); and (f) participant adoption and value appropriation (Thomas et al. 2014). Beckmann et al. (2014) argued that "business firms can transform sustainability-related trade-offs through win–win-oriented governance strategies aimed at creating value (p.20)." Theoretically, the importance of a holistic view (and avoidance of reductionism) is widely recognized in both BE (Adner and Kapoor 2016; Buckley and Prashantham 2016; Ciara 2017; Fichman et al. 2014; Pahlke and Wolf 2010; Rahimi et al. 2017), and SE (Heuer 2011; Lertzman and Vredenburg 2005; Parto 2000; Pogutz and Winn 2016; Scherrer 2009).

Common issues

Some issues are common between SE and BE. The most obvious example is sustainability itself. SE focuses on environmental sustainability, while BE focuses on business sustainability, which comes from out-innovating the competition (Moore 1999). A second example is supply chain management. Reducing the resource flow within the natural environment and forming a recycling-oriented industrial ecosystem in SE (Preuss 2005; Parto 2000) is related to cooperating with component suppliers and competitors on the same platform (Adner and Kapoor 2010) and with establishing a keystone position in the value chain (Iansiti and Levien 2004) in BE. However, environmental issues are rarely discussed in BE. A third example is how innovators deliver creative destruction. In SE, such innovators are social entrepreneurs (Belz and Binder 2017; Mair et al. 2012; Stubbs 2017; Young and Tilley 2006) and in BE they are platform leaders who can exert a strong influence on the ecosystem that produces and uses products (Gawer and Cusumano 2002). In BE, platform entrants also have a chance to overcome incumbent players by drawing on the strength of developers' indirect network effects (Zhu and Iansiti

2012). A fourth example is the industrial ecosystem. In SE, it is "a new innovation in designing interorganizational linkages. [Industrial ecosystems] consist of a network of organizations linked to each other through an ecological logic (Shrivastava 1995b, p.188)," while in BE, it is the disruptive innovation process by which a new entrant gains a competitive position in an industry, or the method by which firms work together to cocreate value that is emphasized (Ansari et al. 2016).

Thus, ecosystem studies have complex aspects with different points of discussion. This might be the primary reason why a transdisciplinary (multidisciplinary/interdisciplinary) approach is recommended in areas such as sustainable development (Cohen 2006; Hediger 1997; Hensel 2012; Stead and Stead 2000; Wakelin 1971), corporate social responsibility (CSR; Schaltegger et al. 2013), business ethics (Boiral 2009; Clifton and Amran 2011; Nga and Shamuganathan 2010; Richardson 2009; Tencati and Zsolnai 2012), and IS/IT (Agerfalk and Fitzgerald 2008; Cohen 2006; Elliot 2013; Ericson 1969; Kallinikos et al. 2013; Leonardi et al. 2016).

Quantitative analysis on 391 core papers

Our review revealed that one striking feature of ecosystem phenomena and ecosystem study is complexity. This paper attempts to visualize that complexity by applying cluster analysis and correspondence analysis.

Structure of ecosystem studies

We conducted a word cluster analysis of the abstract of the 391. Figure 1 illustrates that ecosystem studies have five clusters (62 words are embedded into the five boxes), with SE and BE clearly separated. The first branch (#1) has words that describe a business ecosystem. The other four clusters are grouped into two—divided into sustainable ecosystem and social ecosystem, and each of them has two clusters (#2 / #3, and #4 / #5). Cluster #2 has words related to sustainable ecosystem, while #4 has words that relate to social ecosystem. As for #3 and #5, #3 has words related to strategy, and #5 has words related to research. Almost all words are correctly classified, with a few exceptions. The exceptions include (a) both #3 and #5 have "strategic" and "strategy"; (b) #2 contains the word "community," which should be included in #4; and (c) #5 has "ecology," which should be included in #2. These exceptions imply that sustainable and social ecosystem studies are interrelated.

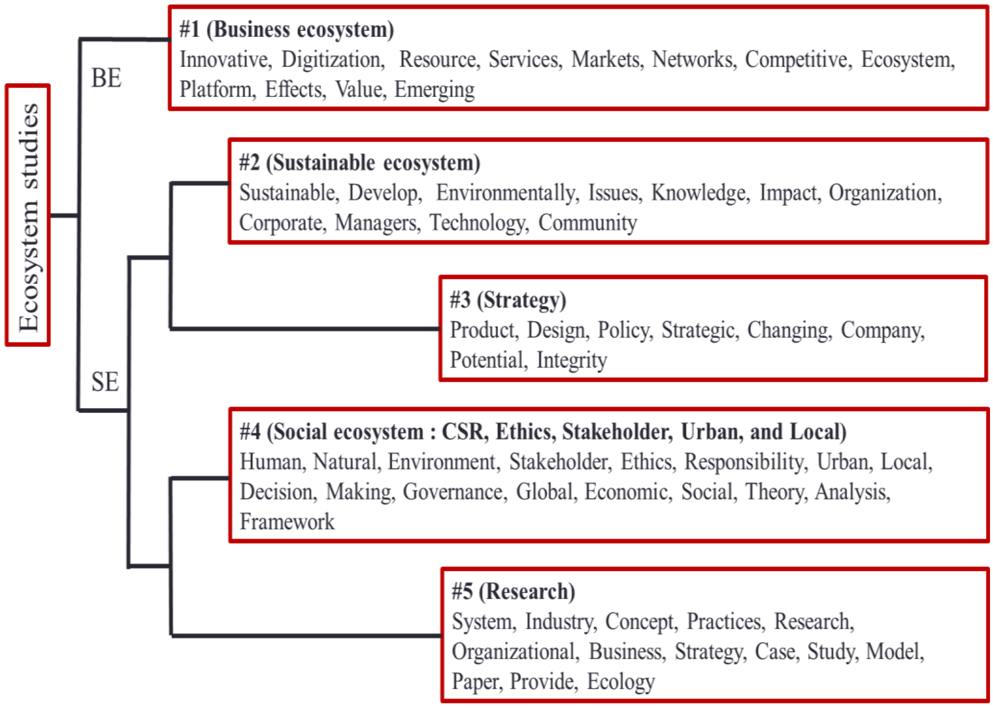

Figure 1. Word cluster analysis

Research subjects, background theories, and empirical research stages

We analyze the relationship between ecosystem research subjects, background theories, and empirical research stages. After creating cross tabulations between two of the three factors, we applied correspondence analysis in order to visualize the cross tabulations.

- Ecosystem subjects

As already mentioned, ecosystem studies have some specific subjects (subthemes) and a hierarchical structure. We identified six subjects that were referred to by over 20 papers: (a) sustainable ecosystem (51 papers; sustainable ecosystem, natural ecosystem, environmental ecosystem, insular ecosystem, forest ecosystem, aquatic ecosystem, coastal ecosystem, marine ecosystem, mangrove ecosystem); (b) social ecosystem (22 papers; social ecosystem, social-ecological system, socio-ecosystem, socio-ecological system, urban ecosystem); (c) industrial ecosystem (25 papers; industrial ecosystem, industry ecosystem); (d) innovation ecosystem (21 papers); (e) platform ecosystem (23 papers; platform ecosystem, platform-enabled ecosystem);, and (f) IT ecosystem (33 papers; ICT ecosystem, digital ecosystem, open-sourcing ecosystem, e-commerce ecosystem, WiFi ecosystem, PC ecosystem, Ethernet ecosystem, digital financial ecosystem that includes “fintech”-related topics such as mobile money, funding, and payment).

- Background theories

We also identified seven theories that were referred to by over 20 papers: (a) ethics (165 papers); (b) competitive strategy (151 papers referring to “competitive advantage”); (c) CSR (99 papers referring to CSR, corporate responsibility, social responsibility, or corporate social responsibility); (d) a resource-based view (53 papers referring to resource-based view, resource based view, or RBV); (e) systems theory (39 papers); (f) stakeholder theory (32 papers) and institutional theory (31 papers); and g) transaction cost economics (20 papers referring to transaction cost economics, transaction cost perspective, transaction cost theory, or TCE).

- Empirical research stages

We use “the value space of research” (Malhotra et al. 2013) excluding “design” and “impact” because these have rarely appeared in previous studies. We thus define the empirical research stages as the following: (a) conceptualization, (b) framework, (c) hypothesis, and either (d) qualitative analysis or (e) quantitative analysis. Note that papers in the qualitative analysis stage were identified by presence of indicative terms, such as “qualitative research”, “qualitative study”, “qualitative analysis”, “structured interview(s)”, “semi structured interview(s)”, “semi-structured interview(s)”, and “semistructured interview(s)”. Papers in the quantitative analysis stage were similarly identified by terms, such as “dependent variable(s)”, “independent variable(s)”, “statistical description”, “descriptive statistics”, “correlation” “regression”, “factor analysis”, “principal component analysis”, “cluster analysis”, “structural equation”, “SEM”(structural equation modeling), “significance level”, and “p-value”.

Figure 2 demonstrates the result of the first correspondence analysis between ecosystem subjects and background theories. The diameter of each circle reflects the number of papers (the same applies hereafter). This figure shows that ecosystem studies can be divided into three groups: (a) sustainable, social, and industrial ecosystem studies frequently citing CSR, ethics, and systems theory; (b) platform and innovation ecosystem studies citing RBV and competitive strategy; and (c) IT ecosystem study, which is located between (a) and (b), citing TCE.

Figure 3 illustrates the result of the second correspondence analysis between ecosystem subjects and empirical research stages. In this case, ecosystem studies can be classified into three groups: (a) IT ecosystem study, characterized by qualitative and quantitative analysis; (b) innovation ecosystem study, characterized by being at the hypothesis-developing stage; and (c) all other ecosystem studies still in the conceptualization and framework-building stages.

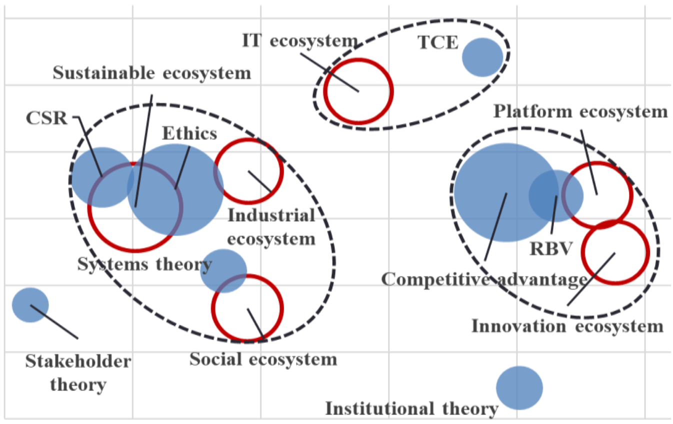

Figure 2. Ecosystem subjects and background theories

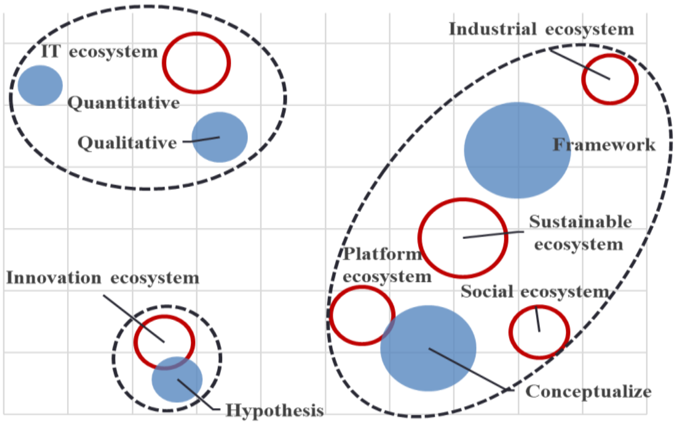

Figure 3. Ecosystem subjects and empirical research stages

Diffusion of Ecosystem in Japan

SE and BE trends within 686 articles

We searched the Nikkei newspaper (Japan's leading economic newspaper: 1990-2017) for articles containing the term "Green IT" ("グリーン IT" in Japanese) and found 77 matching articles from 2001 to 2017 (no articles were found that dated before 2001). Only 14 articles appeared after 2010. In contrast with Green IS/IT, the word "ecosystem" ("エコシステム" in Japanese) is much more popular in Japan. We found 833 articles from 1990 to 2017. Our data screening found that several articles were extracted simply because the company and/or division names contained the term "ecosystem." Excluding these articles left 686.

First, we divided them into four groups by year of publication—118 articles (before 2000), 60 articles (2000–2005), 176 articles (2006–2010), 77 articles (2011–2015), and 255 articles (2016–2017)—then specified the key words for each group by applying a complementary similarities measure. Table 2 shows the top 10 words. It is obvious that SE-related terms have been replaced by BE-related terms since 2006. The following terms relate to SE and BE.

(1) SE-related terms: environmental problem, re-use, recovery, metal, recycle, waste, and mineral

(2) BE-related terms: Apple, Google, smartphone, OS, software, terminal, PC, tablet, Microsoft, venture, investment, AI, IoT, entrepreneur, and start-up. Among these, the following are related to business ecosystem creation: venture, investment, entrepreneur, and start-up.

The key terms of Green IT (there is no Japanese term specifically for Green IS) in 77 articles were added to the table. It should be noted that, comparing (1) and (2), "Green IT" is used more narrowly, focusing on energy efficiency (e.g., energy saving and power consumption).

Table 2. SE-related terms (*) and BE-related terms (**)

	-2000	2001-2005	2006-2010	2011-2015	2016-2017	Green IT (2001-2017)
1	Development	**Recovery***	**Apple****	**Venture****	**AI****	IT
2	Nature	Chiyoda	**Google****	Ecosystem	**IoT****	Energy saving
3	Utility	Operation	**Smartphone****	Growth	Things	Green IT
4	Sales	Tokyo	**OS****	**Investment****	Ecosystem	Firm
5	Research	**Metal***	**Software****	Success	Business	Power consumption
6	Issue	**Recycle***	**Terminal****	Firm	Firm	Data center
7	**Environmental problem***	**Waste***	CEO	Necessity	**Entrepreneur ****	IT devices
8	**Re-use***	Environment	**PC****	Establishment	Service	Utility
9	Theme	**Mineral***	**Tablet****	**Smartphone****	**Start-up****	Server
10	Participate	Factory	**Microsoft****	Experience	Alliance	CO2

Second, we apply a third correspondence analysis to examine the relationships between ecosystem subjects and industries. The following terms are used for grouping.

(1) Ecosystem-related terms: sustainability (sustainability problem, re-use, recovery, metal, recycle, waste, mineral, plastic, environmental protection), investment (venture, investment, entrepreneur, start-up, venture capital [VC]), IT (smartphone, OS, software, terminal, PC, tablet, iPhone, AI, IoT, IT, ICT, big data, 8K, 5G, fintech), local (local, community, local government), platform, industry, and innovation.

(2) Industries: consumer electronics manufacturer (Sharp, Sony, Toshiba, Mitsubishi, Panasonic), automobile manufacturer (Toyota, Honda, Nissan), mobile carrier (DoCoMo, AU, Softbank), electric power, and US IT firms (Microsoft, Google, Apple, Facebook, Twitter, Silicon Valley).

As a result, close ties appeared between the following pairs: electronic power industry and sustainability; automobile industry and "industry" (as an ecosystem-related term); consumer electronics / mobile carrier industries and IT / investment / US IT firms (Figure 4).

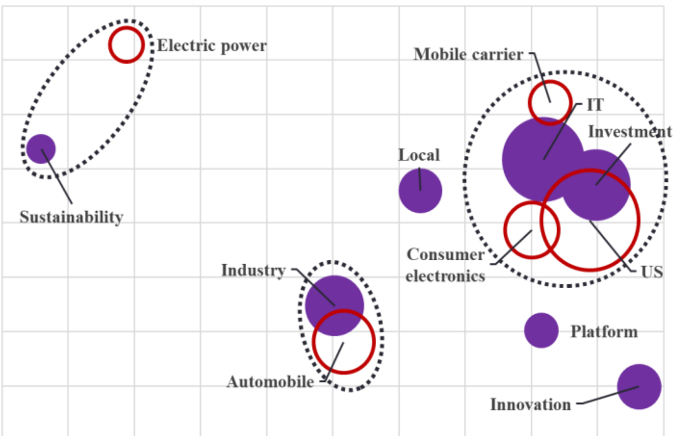

Figure 4. Relationships between ecosystem-related terms and industries

Green IS/IT in ecosystem articles

This section explores some typical examples of Green IS/IT in recent newspaper articles. The first example is from 2017 about the automobile industry. Honda, the third-largest automobile manufacturer in Japan exhibited a portable lithium ion storage battery at Information Technology International Fair (an international trade show) instead of advertising new automobiles or motorcycles. Using in-vehicle accumulators and fuel cells, electric vehicles have the potential to be store and supply energy for various purposes. Honda is trying to move toward the creation of entire ecosystem in order to expand the capabilities of electric vehicles.

The second example is about retail industry and was published in 2016. AEON, one of the top retailers in Japan, has begun efforts to improve the local living infrastructure in collaboration with institutions (financial, education, research, and medical), manufacturers, retail companies, and local community groups. These efforts are aimed at new town development in a wide range of services such as e-commerce, public transportation, and elderly and medical care. The new town planning system is called a regional ecosystem. The president of AEON said that IT digitization permits new things to be accomplished.

The third example is about the consumer electronics industry and was published in 2015. Toshiba, a famous electronics manufacturer in Japan, has been working to realize smart cities and factories around the world. According to the article, the company's semiconductor factories collect and analyze 1.6 billion pieces of data every day in order to enhance quality and accelerate the operation rate. This enables solutions to food shortages, disaster prevention, and energy problems in the future. Toshiba is attempting to cooperate with other companies to build new ecosystems.

The fourth example is about the mobile carrier industry and was published in 2017. DoCoMo, Japan’s leading mobile communications company, forecasts that so-called 5G technology will create new business opportunities. The president said that 5G is not just a technology to increase the efficiency of industries. He added that sharing digital data brings solutions for various social problems, such as aging, and that Japan has a good chance to build a testbed for creating a new 5G ecosystem.

Discussion

Given the analysis above, this section revisits the issue of how to position Green IS/IT from an ecosystem perspective.

Several lines of evidence indicate that SE and BE phenomena are interrelated, although SE and BE studies are largely separated. Cluster analysis clearly divided previous studies in social science into SE and BE categories. SE could be further grouped in sustainable ecosystem and social ecosystem topics (although some exceptions were found on a term basis; Figure 1). With respect to business practices, mentions of Green IS/IT solutions (e.g. smart grids and smart cities) have been appearing in ecosystem-related articles in the newspaper. Our analysis suggests that (a) the term ecosystem is more popular than Green IS/IT; (b) Green IS/IT used mainly in the context of energy efficiencies; and (c) the distribution of ecosystem-related topics has shifted from SE to BE since 2006 in Japan.

Table 3 summarizes the details of the literature review, newspaper analysis, and specific examples. The result of correspondence analysis is shown on the left side of the table. First, platform and innovation ecosystem studies often cite management theories (RBV and competitive strategy). Platform ecosystem stays at the conceptualization and framework-building stage, while innovation ecosystem shifts to the hypothesis-developing stage. Second, SE (sustainable, social, and industrial) often cites sociology-based theories (i.e., CSR, ethics, and systems theory). Yet they still stay at the conceptualization and framework-building stage. Third, IT ecosystem study is distinctive. It is placed between the SE group and BE group citing TCE (Figure 2), having proceeded to the quantitative and qualitative analysis stage. A possible reason for this placement might be our IT ecosystem classification. This paper defines IT ecosystems as employing technology-oriented terms (ICT, digital, open-sourcing, e-commerce, WiFi, PC, Ethernet, and digital financial ecosystem). Therefore, many of the IT ecosystem studies use both management theories and sociology-based theories in approximately equal measure, not focusing purely on either. With regard to TCE usage, we confirmed that IT ecosystem study cites this theory most frequently. However, this may exaggerate the actual situation because there are few papers referring only to TCE explicitly (3 papers in IT; 2 in industry, innovation, and platform; 1 in sustainable; 0 in social). Altogether, it is safe to say that SE and BE studies are separated, and empirical research is fragmented depending on the subjects (subthemes).

Meanwhile, newspaper analysis found several idiosyncratic linkages between specific industries and ecosystem subjects. The electric power industry is linked to sustainable ecosystem, the automobile industry (specifically new supply-chain building) links to industrial ecosystem, and consumer electronics, mobile carrier, and US IT industries are linked to IT ecosystem and investment. Because newspaper articles are intended to catch the latest and most popular topics, they are obviously biased by reader interests and cannot reflect all the ecosystem phenomena.

The right side of the table shows the specific examples mentioned. Green IS/IT solutions were extracted from the newspaper articles with the keyword "ecosystem." The table shows clearly that the six subjects are interrelated, not independent. First, concerning IT, the minimum unit to construct ecosystem is digital data—automobile-derived data (Honda), consumer-derived data (AEON), factory-derived data (Toshiba), and smartphone-derived data (DoCoMo). Second, two types of platforms are identified; one is a digital platform and the other is related to business partner networks. Each platform functions as infrastructure to promote digital innovation and business partner innovation. Schumpeter (1938) states that the essence of innovation is "new combinations." Digital innovation on the IT platform is actualized by generation of new linkages (combinations) between things, between people, and between people and things. Business partner linkages accelerates competition, collaboration, and co-creation among players. Third, an industrial ecosystem can emerge from a network of organizations that jointly seek to minimize environmental degradation (Shrivastava 1995a). At the same time, in collaboration with other industries, a wide range of services can be provided. Finally, as a consequence, environmental and social problem solutions like smart grid, homes, and cities are realized.

Complexity is recognized as an important feature of ecosystem phenomena and research (Adomavicius et al. 2008; Schaltegger et al. 2013). The following issues can arise when implementing Green IS/IT solutions: sustainability—environmental sustainability and/or business sustainability; supply chain—development of eco-friendly supply chain and/or competition and collaboration to acquire keystone position; innovators—social innovators and/or entrepreneurs; and industrial ecosystem—organizational cooperation beyond industries to avoid ecological degradation and/or to foster new business, economy or society. Thus, Green IS/IT involves various ecosystem-related issues to be discussed. However, because of the separation of SE and BE studies, these discussions have not been cohesively organized.

Table 3. Summary

<table>
<tr><th rowspan="3">Ecosystem subjects</th><th colspan="3">Correspondence analysis</th><th colspan="4">Examples</th></tr>
<tr><th rowspan="2">Background theories</th><th rowspan="2">Empirical research stages</th><th rowspan="2">Newspaper articles</th><th>Honda</th><th>AEON</th><th>Toshiba</th><th>DoCoMo</th></tr>
<tr><th>Automobile</th><th>Retail</th><th>Consumer electronics</th><th>Mobile carrier</th></tr>
<tr><td>Sustainable</td><td rowspan="3">CSR, ethics and system</td><td rowspan="3">Conceptual-ization and framework</td><td>Electric power</td><td colspan="4">Green IS/IT solutions: Smart grid</td></tr>
<tr><td>Social</td><td></td><td colspan="4">Social problem solutions: Smart home and city</td></tr>
<tr><td>Industrial (Industry)</td><td>Automobile</td><td colspan="4">Network of organizations that jointly seek to minimize environmental degradation (Shrivastava 1995a)</td></tr>
<tr><td>Innovation</td><td rowspan="2">RBV and competitive strategy</td><td>Hypothesis</td><td></td><td colspan="4">Bigdata and IoT innovation / Business partner innovation</td></tr>
<tr><td>Platform</td><td>Conceptual-ization and framework</td><td></td><td colspan="4">IT platform / Business platform</td></tr>
</table>

IT	TCE	Quantitative and Qualitative analysis	Consumer electronics, Mobile carrier, and US IT	Digital data			
				Automobile -derived data	Consumer-derived data	Factory -derived data	Smartphone -derived data

Conclusion

The aim of this paper is to show the position of Green IS/IT at the confluence of SE and BE research streams. This paper describes a comprehensive review of ecosystem study and traces business trends in Japan. The results suggest several things. First, Green IS/IT study can be positioned as an important ecosystem research agenda at the intersection of SE and BE. Second, Green IS/IT involves various ecosystem-related issues with a hierarchical structure. However, SE and BE studies are now separated and empirical research is fragmented according to which of six subjects is considered. A possible reason for the separation is due to the difference in the perspectives of researchers. Additionally, newspaper articles cannot capture all ecosystem phenomena. Taking all the above into account, proceeding through the empirical research stages by adopting a transdisciplinary approach with both SE and BE is needed.

This study makes the following contributions. First, from the theoretical side, this study examined Green IS/IT from an ecosystem perspective. Second, this study discussed the importance of combining SE and BE research streams. Third, from the practical side, it is notable that digital data has the potential to make each ecosystem digital, and IT infrastructure enables linking one ecosystem to another. Practitioners should hold the holistic view that Green IS/IT implementation is not just a single project but a part of total ecosystem creation that can keep our world healthy and resilient.

However, there are some noteworthy limitations to this study. First, word cluster analysis is used for exploration. As has been noted, some exceptions appear, though most words are classified in the expected way. We need to examine each paper carefully. Second is the accuracy of correspondence analysis mapping; the grouping of ecosystem subjects strongly affects the mapping. For example, the IT ecosystem in Figures 2 and 3 targets technology-oriented ecosystems based on the articles extracted by the term “ecosystem” (not Green IS/IT). Integration of survey data between ecosystems and Green IS/IT is necessary. Third, this study doesn't cover any examples of Green IS/IT outside of Japan. Ecosystems in different business environment and socio-cultural contexts should be investigated. Such extensions are left for future study.

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