Review

Ambidextrous SMEs for a Sustainable Society: A Narrative Review Considering Digitalization, Open Innovation and Green Innovation

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Ambidextrous SMEs for a Sustainable Society: A Narrative Review Considering Digitalization, Open Innovation and Green Innovation

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Abstract

In recent years, ambidexterity has been one of the major themes in business management. In particular, ambidexterity has been actively studied in small and medium-sized enterprises (SMEs), where ambidexterity is difficult to achieve due to a lack of management resources. However, there are no consistent research results on the impact of ambidexterity on corporate performance, and it is difficult to ignore their path dependency and argue that ambidexterity should be pursued in any era or situation. At the same time, studies showing that ambidexterity is related to open innovation and digitalization, and that open innovation and digitalization are related to sustainability and green innovation, suggest that ambidexterity can be used not only for corporate performance but also for achieving sustainability through green innovation. Therefore, this study aimed to clarify the relationship between ambidexterity, digitalization, open innovation, and green innovation in SMEs and conducted a narrative review of 106 relevant papers published between January 2020 and May 2025 through the literature search using major literature databases. The findings of this study suggest that SMEs' ambidexterity, coupled with digitalization, open innovation, and green innovation, may contribute to solving contemporary sustainability challenges through the mechanism that (a) resource-shortage SMEs need to rely on external resources through open innovation to achieve ambidexterity; (b) however, open innovation requires orchestration, which necessitates cost reduction through digitalization; and (c) the ambidexterity enables the simultaneous achievement of micro, short-term goals through exploitation, such as market performance that leads to firm survival, and macro, long-term goals through exploration, such as green innovation that leads to sustainability. We then pointed out that there is a lack of research integrating green innovation with ambidexterity, digitalization, and open innovation in previous studies, and argue that this needs to be clarified in future research. This expands the theory of ambidexterity beyond its traditional role as a means to improve the performance of individual companies, and into a new role as a means to resolve larger societal issues, including sustainability. This study makes a unique contribution to academia and the business community by arguing that ambidexterity should be evaluated from the perspective of whether it contributes to solving national and global issues, beyond the traditional perspective of whether it contributes to the development of SMEs.

Keywords: digitalization; green innovation; open innovation; small and medium-sized enterprises

1. Introduction

In business, ambidexterity refers to combining both incremental, efficiency-oriented innovation and radical, novelty-oriented innovation for short-term success and long-term survival [1]. In 1996, Tushman and O'Reilly proposed that organizational ambidexterity—defined as "The ability to simultaneously pursue both incremental and discontinuous innovation…from hosting multiple contradictory structures, processes, and cultures within the same firm" [2: p. 24]. The ambidexterity

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discussed in this study follows this definition. As companies face increasing global competition, the importance of ambidexterity is increasingly recognized. However, small and medium-sized enterprises (SMEs) generally have scarce resources compared to larger companies [1], are at a disadvantage in terms of managerial expertise and access to capital, talent and resources [3], and lack systems to manage exploration and exploitation [4,5], making ambidexterity more likely to lead to overinvestment beyond their capabilities [6,7]. Therefore, many researchers have argued that SMEs, especially those with limited resources and capabilities, perform better by specializing in either exploitation or exploration [8–11]. The way they specialize is explained in the context of path dependency. A study of 150 German medium-sized enterprises in the engineering industry showed that to gain competitive advantage, exploration, which creates radically new knowledge, products and services, needs to be prioritized over exploitation [9]. This result may reflect the context of the German engineering industry, which is characterized by intense competition, active research and development, and radical innovation to stay competitive [12]. Relatedly, a study of 180 emerging UK B2B technology companies showed that dependency on key customers has a significant negative impact on firm survival, including reduced motivation to develop products [13]. Similarly, a study of 150 Spanish agribusiness companies (146 of which were SMEs with fewer than 200 employees), known for their high level of competition, found that exploratory innovation has a greater impact on market and financial performance than exploitative innovation [14]. These studies provide a rationale for placing exploration, rather than exploitation, at the core of a firm's strategy in highly competitive and fast-changing industries. An overview of these studies is provided in Table 1. As these examples show, SMEs may become exploratory in competitive environments, but such conditions are not available for all SMEs, and they do not inform us whether the ambidexterity that arises from competition is desirable from a sustainability perspective.

Table 1. Analysis of the relationship between ambidextrous and performance.

Country	Subject	N	Direction	Method	Summary	Dependent variable	Independent variable	Effect size (ΔR^2)	#
Germany	Medium-sized companies in the engineering industry	150	Cross-sectional	Partial Least Square-Structural Equation Modeling (PLS-SEM)	To survive and gain competitive advantage, companies must prioritize exploration over exploitation to create radically new knowledge, products, and services.	Competitive advantage	Exploration orientation	0.350	[9]
United Kingdom	Young B2B technology company	180	Longitudinal	Multinomial logistic regression model	Dependence on key customers has a significant negative impact on a company's survival.	Corporate survival	Exploitation (dependence on a key customer)	0.040	[13]
Spain	Agribusiness SMEs	150	Cross-sectional	Partial Least Square-Structural Equation Modeling (PLS-SEM)	Innovation ambidexterity affects business performance, with exploratory innovation having a stronger impact on market and financial performance than exploitative innovation.	Financial/market performance	Exploration	0.425	[14]

Meanwhile, Jakhar et al. found that firms with a strong tradition of exploitative innovation tend to implement more short-term oriented sustainability practices in response to stakeholder pressure, whereas firms with a long-standing tradition of exploratory innovation implement more long-term sustainability practices [15]. This means that experiential inertia leads firms to rely heavily on established methods and processes, creating the trap of "path dependency" or "empiricism." Such dependence limits sensitivity to new technologies and emerging markets, ultimately hindering the development of exploratory innovation. Relatedly, a study based on case studies of green innovation

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in five multinational manufacturers concludes that the path dependency problems faced by companies hinder strategic ambidexterity, forcing them to choose between a highly uncertain and risky green strategy based only on exploration and a more conservative but non-green strategy based only on exploitation [16].

As a way to break this path dependency, some studies have focused on open innovation and digitalization. A study of 434 managers of 139 hidden champions in China showed that the synergy between value co-creation with stakeholders and digital leadership (high digital literacy leadership) strengthens the relationship between exploration and competitive advantage and weakens the relationship between exploitation and competitive advantage [17]. This suggests that open innovation and digitalization promote exploration. In addition, a recent analysis using regional data from China shows that digitalization and sustainability tend to develop in tandem [18]. This suggests that digitalization contributes to improving sustainability.

Other researchers have provided evidence that SMEs can achieve ambidexterity by integrating the conflicting demands of exploration and exploitation [5,19–21]. Of these, a study based on survey findings from five German SMEs found that "traditional" ambidexterity for exploitation and "agile" ambidexterity for exploration are feasible, and recommended context-specific ambidexterity [20]. Meanwhile, a study of 500 Russian SMEs found that exploration improves firm performance but reduces reliability, and exploitation reduces firm performance but increases reliability, during a crisis, and argued for the need to use ambidexterity differently depending on the situation [21]. Such developments in the discussion will have the effect of enriching the debate surrounding ambidexterity. At the same time, the assertion that ambidexterity is situational ironically testifies to the fact that there is no one-size-fits-all approach that works for all companies. At least, the low consistency in the relationship between ambidexterity and performance makes the recommendation of ambidexterity less persuasive. With the current accumulated research, it is no longer possible to claim that ambidexterity is the optimal strategy at any time and in any situation. Should SMEs engage in ambidexterity? If so, what makes ambidexterity possible and what are the benefits of engaging in it? This issue has not yet been adequately addressed or discussed. While long-term and macro-level issues, including global environmental issues, are widely discussed on the policy side, corporate research is dominated by discussions of short-term and micro-level issues, such as how to improve performance. As March once argued that exploitation may contribute to short-term performance and exploration to long-term performance [1], ambidexterity may be a trump card to bridge this gap and simultaneously solve different issues.

In this review, we reflect on how ambidexterity may be related to digitalization, open innovation and green innovation through the following mechanisms: (a) To achieve ambidexterity, resource-starved SMEs need to rely on external resources through open innovation; (b) However, open innovation requires orchestration, which in turn requires cost reduction through digitalization; and (c) Ambidexterity allows firms to simultaneously achieve short-term micro goals by leveraging market performance that leads to survival and long-term macro goals by exploring green innovation that leads to sustainability. We then points out that there is a lack of research integrating green innovation with ambidexterity, digitalization, and open innovation in previous studies, and argue that this needs to be clarified in future research. This study aims to provide current research findings and future directions towards addressing the research gap around ambidexterity in SMEs, namely, developing ways to simultaneously achieve higher performance and green innovation through ambidexterity via open innovation and digitalization. This expands the theory of ambidexterity beyond its traditional role as a means to improve the performance of individual companies, and into a new role as a means to resolve larger societal issues, including sustainability. For that purpose, this study aimed to clarify the relationship between ambidexterity, digitalization, green innovation, and open innovation in SMEs and conducted a narrative review of 106 relevant papers published between January 2020 and May 2025 through the literature search using major literature databases.

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2. Method

A narrative literature review on digitalization, open innovation, ambidexterity, and green innovation in SMEs was conducted following the recommendations of Green et al. [22]. A narrative review was adopted because there were few studies that systematically addressed the variables of interest in this review, and a systematic review was considered premature. The literature search in Scopus, PubMed, Web of Science, and Google Scholar databases focused on articles published between January 2020 and May 2025 and aligned with the objectives outlined in the previous section. The period from 2020 onwards was chosen in order to include literature that reflects the digitalization triggered by the COVID-19 pandemic and the recent rise in environmental awareness. The keywords used were "ambidexterity", "digitalization", "green innovation", "eco-innovation", "ecological innovation", "environmental innovation", "open innovation", and "small and medium-sized enterprises" in various combinations connected with AND and OR, as well as in combination with the words "review" or "meta-analysis". Following recent systematic reviews [23], in our analysis we treated "green innovation" as synonymous with "eco-innovation," "ecological innovation," and "environmental innovation". Nevertheless, for clarity and readability, we used "green innovation" to represent these in our review. The search was performed in the title and abstract. In other words, this review focused on digitalization, open innovation, ambidexterity, and green innovation in SMEs, as well as on these general reviews. In case multiple reviews or articles on the same topic were identified, the most recent and/or most cited ones were given priority. In addition, the reference sections of the selected papers were examined to check for possible additional research. In principle, the included studies were peer-reviewed articles written in English that matched the above keywords. However, to draw policy implications, books and government reports written in English and Japanese were added to the inclusion criteria. Japanese books and reports were chosen because Japan is distinctive in terms of path dependency. On the other hand, studies that dealt with ambidexterity but did not discuss it from the perspective of digitalization, open innovation, or green innovation, or studies that did not provide any suggestions, were excluded from this review. Similarly, studies that only dealt with digitalization, open innovation, and green innovation individually and did not address ambidexterity were excluded. However, studies that dealt with two or more of digitalization, open innovation, and green innovation were included if they provided suggestions for ambidexterity, even if they did not directly address ambidexterity. Although the review was limited to SMEs, we included empirical studies in which more than 50% of the sample included SMEs. The criterion for SMEs was less than 250 employees, as defined by the European Commission [24]. See Figure 1 for the review process of the current research. After a four-step screening process, 106 articles were selected for the review.

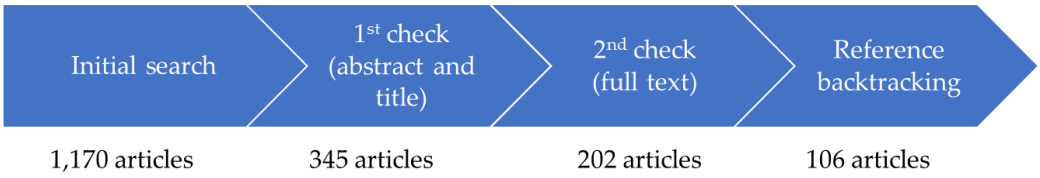

Figure 1. Review process of the current research.

3. SMEs and Ambidexterity

Compared with large enterprises, SMEs often lack adequate coordination mechanisms and resources, such as human and financial capital [25,26]. Therefore, considering the potential risks of ambidextrous innovation, SMEs often must choose between exploitative and explorative innovation [27]. Exploitation generally improves the enterprises' productivity and efficiency [28,29]. However, because successful exploitation depends on the availability of capabilities, assets, or resources that a firm can control, even if a firm uses all of its available technological and market capabilities, there are

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limits to how successfully it can exploit [30,31]. On the other hand, exploration helps enterprises adapt to changes with a long-term perspective in a rapidly changing business environment [1]. This is because exploration, which leads to the continuous discovery of new markets and technological capabilities, is very effective in helping enterprises reorganize their own knowledge base, develop new products, and achieve competitive advantages in niches [32–35].

However, most SMEs are exploitative [36]. This is because exploitation has both irrational and rational aspects. The British study mentioned above showed the paradoxical result that while dependence on key customers is risky, for surviving companies, dependence has a positive effect on the growth of their customer portfolios [13]. This suggests that SMEs that have maintained good relationships with key customers by continuing exploitation for a long time may be able to use that reputation to successfully acquire new customers. This study is highly suggestive in considering why SMEs continue to engage in exploitation that may seem irrational at first glance[1]. However, relying on a specific technology and specializing in exploitation may make it difficult to adapt to changes in the times and reduce a company's competitive advantage in an industry driven by innovation and research and development [12]. Today, due to the fragmentation, complexity, and increasing unpredictability of needs caused by the transformation of the industrial structure, it is becoming increasingly important for SMEs to break away from subcontracting structures and utilize information from a wide range of sources beyond their existing networks, as well as to engage in innovation activities that agilely connect technological seeds to new businesses [13,37]. In addition, the wave of ICT in the wake of the COVID-19 pandemic and the growing awareness of the global environment in the wake of the Sustainable Development Goals (SDGs) are forcing corporate managers to make changes, increasing the risk of sticking to traditional methods. Furthermore, from the perspective of risk diversification, i.e., portfolio investment, it is necessary to have a large number of innovation activities within the country [13,37]. In other words, even if ambidexterity is unprofitable and does not directly lead to short-term sales for a single company, it may be rational to pursue from a national or global perspective in some cases.

Moreover, even if ambidexterity is not perceived as beneficial for SMEs in the short term, it may be beneficial in the long term. When exploitation is combined with exploration, SMEs may act outside the box and innovate, not for short-term gains, but for the long term, ultimately achieving positive results [14,36]. This is because ambidexterity plays a key role in integrating the conflicting demands of exploration and exploitation [5]. Ambidextrous SMEs have the ability to manage exploitation and exploration to improve efficiency without losing the ability to develop novel ideas, products, and processes. Moreover, these SMEs can make important decisions quickly and flexibly about their financial structures, for example, to explore new and different markets through internationalization or to launch new products and brands [39,40]. Therefore, ambidextrous SMEs may have a higher resilience, such as more easily identifying opportunities to recover from crises [36]. Identifying how SMEs can achieve ambidexterity may help increase their resilience and reach solutions that are agreeable to SMEs, countries and the world from a macro or long-term perspective. Below, we

[1] For example, in Japan, large and small enterprises form a keiretsu system, and SMEs have been required to engage in process innovation and incremental innovation to quickly and accurately supply products and parts with the specifications required by large enterprises within the existing supply chain [37]. In such an environment, exploitation by utilizing existing information networks has a greater impact on corporate performance than exploration, which requires new information networks. This keiretsu system is unique to Japan in that it involves cross-shareholding, which promotes trust building and mutual information sharing between companies, reduces transaction costs (e.g., monitoring costs), and acts as a deterrent to betrayal [38]. It is thought that sourcing information from outside the keiretsu and exploring through open innovation and digitalization was costly and not very profitable for SMEs.

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provide evidence that combining ambidexterity with open innovation, digitalization and green innovation can be beneficial.

4. Ambidexterity and Open Innovation

To overcome scarcity of internal resources and become ambidextrous, SMEs need to rely more on external resources. Innovation leveraging external resources is called open innovation [41]. The objectives of open innovation often differ between large companies and SMEs: large companies adopt open innovation to take advantage of their partners' assets and capabilities, while SMEs resort to open innovation to offset scarcity of internal assets [42–45]. SMEs usually suffer from a significant shortage of financial and human capital resources, managerial and technical skills, and know-how, and therefore see networking as a way to broaden their technological capabilities [46,47]. By leveraging external collaboration, SMEs can reduce the costs associated with innovation investments and successfully adapt and reconfigure their innovation processes [46,47]. Collaboration with external organizations, which involves open innovation, is a good approach to expand the portfolio of innovation activities, increase knowledge complementarity and improve productivity, thus positively impacting SMEs' innovation capabilities [48–51]. By embracing open innovation, SMEs can benefit financially by leveraging existing capabilities, resources and structures, strengthening an already trusted network of relationships, and by reducing knowledge waste [52–54].

Open innovation may be one of the few advantages SMEs have over larger companies that they can easily adopt. In contrast to multinational enterprises that are not interested in a particular region and move around in search of the best location, SMEs are often historically tied to specific locations and local residents for multiple generations [55,56]. For example, SMEs located in BW, Bavaria and North Rhine-Westphalia, home to 70% of the world's leading German SMEs, are rooted in a specific influential local social capital context and leverage their ties to surrounding communities, companies and universities to effectively enter international markets [57]. Thus, SMEs may have an advantage in that they can conduct open innovation by leveraging their local networks. Findings from a sample of 615 SMEs in Thailand reveal a statistically significant positive relationship between open innovation implementation and ambidextrous innovation practice advances. This relationship suggests that embracing open innovation promotes ambidextrous innovation, thereby facilitating creativity and knowledge exchange with fresh perspectives [58]. Also, results based on 388 SMEs in Ghana show that a high level of openness further enhanced the impact of organizational learning ambidexterity on SMEs' innovation performance [59].

However, open innovation often involves orchestration [60]. The costs of deploying open innovation are an important consideration, especially for financially constrained SMEs [45,61]. open innovation entails the risk of losing internal assets, as well as agency and transaction costs and the costs of managing partnerships [6,62]. First, to introduce open innovation, SMEs must search for, negotiate with and manage suitable partners, which is costly and time-consuming. Failure to do so may lead to transaction costs and promote opportunistic behavior of partners. Second, SMEs implementing an open innovation strategy are concerned about the loss of relevant knowledge and assets within the company, and therefore engage in a selective disclosure strategy while protecting their internal knowledge. In addition, the information acquired from the external environment is not related to the company's core capabilities, so they need to invest time and human resources in screening and integrating relevant external assets. In addition, due to the various costs associated with the introduction of open innovation, SMEs need to seek a balance in resource allocation between traditional business projects and open innovation projects when adopting open innovation [62]. Therefore, the results of a study of 377 European SMEs by Costa et al. show that open innovation is a cost to SMEs, at least in the short term [47]. However, it is worth noting that their study revealed that digitalization can help SMEs control costs by reducing external activities and focusing their activities on their core business.

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5. Ambidexterity, Green Innovation, and Sustainability

Based on 336 valid questionnaires collected from an industrial sample of Portuguese SMEs, Cancela et al. showed that ambidexterity has a positive impact on sustainability, which in turn has a positive impact on new product success and green product innovation. Moreover, they found that green product innovation increases new product success due to the growing demand for more sustainable products and that the chain of influence between ambidexterity and further product success strengthened when customer pressure increased. The study highlights the need to actively manage exploration and exploitation investments to increase ambidexterity, especially when sustainability and green innovation are the expected outcomes [63]. Similarly, ambidexterity was shown to have a positive impact on economic, environmental and social sustainability in 300 emerging market multinationals headquartered in China [64] when it is followed by sustainability exploration practices which reflect process innovation (e.g., end-of-pipe technological solutions), product innovation (e.g., improvements or entirely new products or services), and sustainability-oriented learning (e.g., developing capabilities and competencies for sustainability-related innovation) [64]. Jakhar et al. [15] in a manufacturing facility in India with over 100 employees demonstrate that exposure to exploitative/exploratory innovative capabilities induces sustainable behaviors in the short and long term. Exploitative innovation seeks to make changes that utilize the same technology and promise benefits with very little uncertainty. These innovations can be achieved under a given infrastructure arrangement without much investment. Exploitative innovation involves improvements to existing processes and products to improve efficiency [15]. Exploratory innovation, on the other hand, delves into different technologies with significantly different and better ways to conceptualize products and processes. Exploratory innovation is uncertain but produces results in the long term. Exploratory innovation involves design improvements and cannot be achieved without introducing significant changes to the company's infrastructure and therefore requires sufficient investment. An example where exploration and exploitation coexist is a fuel cell system that includes sustainability practices based on fuel cell technology (eco-efficiency) and hybrid technology (eco-design) [15].

Table 2. Mediation test of digitalization, ambidexterity, and green innovation.

Country	Subject	N	Direction	Method	Summary	Dependent variable	Independent variable	Mediator	#
Portugal	SMEs	336	Cross-sectional	Structural equation modeling	Ambidexterity positively influences sustainability, which in turn positively influences new product success and green product innovation.	Green product innovation	Ambidexterity	Sustainability	[63]
China	Knowledge-intensive SMEs in Nanjing	289	Cross-sectional	Linear regression	Digital innovation mediates the relationship between ambidextrous learning and sustainable competitive ad-vantage.	Sustainable competitive advantage	Ambidextrous learning	Digital innovation	[64]
India	Manufacturing facilities with 100+ employees	1,471	Cross-sectional	Structural equation modeling	The exposure of manufacturing firms to exploitative/exploratory innovative capabilities induces sustainable behaviors with temporal and enduring focus.	Sustainable behavior	Stakeholder pressure	Ambidexterity	[15]

6. Ambidexterity and Digitalization

6.1. Knowledge Absorption Under Cost Constraints

To reduce the costs associated with the adoption of open and green innovation, SMEs are seeking cost-reduction strategies. One of the most important ways to achieve this is through digitalization.

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Digitalization can help SMEs with fewer resources in terms of time, money, and manpower to acquire external knowledge, thereby increasing their knowledge base [65,66].

6.2. Responding to Radical Innovation

Compared to incremental innovation, radical innovation as a higher-level innovation type involves more tacit knowledge and external heterogeneous resources, which may far exceed the firm's existing knowledge base [67,68]. In this case, digitalization provides SMEs with a valuable opportunity to filter what is available in the market and determine the cutting edge of their industry. This allows SMEs to be more proactive in implementing radical innovation. In addition, sharing dynamic information and knowledge with partners contributes to the generation of new ideas and content, which helps improve the firm's innovation performance [69–71].

6.3. Risk Reduction

In addition, SMEs with limited resources have a low risk tolerance, which creates an incentive to avoid radical innovation, which involves greater uncertainty and risk compared to incremental innovation [72,73]. Digitalization helps companies discover, identify and prevent uncertainties [74] and reduce the degree of risk [75], thus encouraging SMEs to carry out radical innovations [76].

6.4. Empirical Research

The results of related previous studies are summarized in Table 3. Results from a study of 1,474 SMEs across industries in Germany [77] and a study of 204 SME managers in Finland [78] showed that organizational ambidexterity mediates the relationship between digital orientation and growth strategies. These suggest that ambidexterity is more likely to lead to higher performance when accompanied by digitalization. However, the order of digitalization and ambidexterity may be reversed. A study of 366 small SMEs in Istanbul showed that digital transformation partially mediates the relationship between SMEs' ambidexterity and competitive advantage [79]. Similarly, a study using the 2019 World Bank Business Survey and follow-up surveys conducted in 2020 and 2021 among 8,928 companies in 21 countries indicates that organizational ambidexterity indirectly influences innovation through digital capabilities [80]. These findings suggest that organizational ambidexterity can increase a company's competitive advantage by enhancing digital capabilities. Thus, previous studies have shown that digital *orientation* may predict ambidexterity [77,78], and ambidexterity may predict digital *transformation* and digital *capability* [79,80]. This may have important implications for when and how ambidextrous organizations should adopt digitalization.

Table 3. Mediation test of digitalization, ambidexterity, and performance.

Country	Subject	N	Direction	Method	Summary	Dependent variable	Independent variable	Mediator	#
Germany	SMEs all industries	1,474	Cross-sectional	Hierarchical ordinary least square regression analysis.	Digital orientation facilitate innovation ambidexterity	Innovation ambidexterity	Digital orientation	n.a.	[77]
Finland	SMEs in rural areas of Southern Ostrobothnia	204	Cross-sectional	Ordinal regression analysis	Organizational ambidexterity mediates the relationship between digital orientation and growth strategies.	Growth strategies	Digital orientation	Organizational ambidexterity	[78]
Turkey	SMEs in Wholesale and Retail Trade Sector within the Boundaries	366	Cross-sectional	Partial Least Square-Structural Equation Modeling (PLS-SEM)	Digital transformation partially mediates the relationship between ambidexterity and competitive advantage in SMEs	Competitive Advantage	Organizational Ambidexterity	Digital Transformation	[79]

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Multi Country	of Istanbul Province World Bank Business Survey (Tracking 21 countries)	8,928Longitudinal	Partial least squares structural equation modeling	Organizational ambidexterity indirectly affects innovation through digital capabilities	Innovation	Organizational ambidexterity	Digital capabilities	[80]

7. Digitalization, Green Innovation, and Sustainability

Furthermore, the use of digital technologies can improve the sustainability of companies. Despite the fact that SMEs account for 60-70% of the world's industrial pollution, they are less environmentally conscious than larger companies [81–83]. This is reflected in their insufficient knowledge of environmental technologies and laws [84,85]. Nevertheless, SMEs often undertake green innovations, driven by stakeholder pressure and growing consumer demand to be more environmentally conscious [86]. Organizations can use digital tools to monitor resource usage in real time, optimizing processes, reducing waste and improving environmental efficiency [87,88]. For example, blockchain is used to prove that recycled raw materials are being used [89]. Digitalization can therefore improve environmental performance by facilitating the optimization of resource use and the implementation of circular economy and sustainable business models [90].

However, SMEs face unique challenges in implementing digital platforms, as they may lack the necessary resources, skills and commitment [91,92]. Therefore, human networks can be a key source of resources and facilitate SMEs' discovery of valuable opportunities [93–96]. For example, designing processes that handle production inputs consisting of used, recycled or recovered materials and transform them into customer value requires the involvement of partners, experts and customers who know about the benefits and limitations of materials in terms of the continuous circulation of materials and the reduction and elimination of waste [97–99].

8. Digitalization and Human Resources

8.1. Digitalization and Skilled Labor Force

Moreover, highly educated employees with a master's degree or higher have a complementary effect on radical innovation [100]. Highly educated employees have advanced logical thinking and decision-making abilities. Compared to less educated employees, they tend to be more interested in the long-term development of SMEs than in their short- and medium-term performance [101], they are quicker to adapt to rapid changes [102], and they are able to absorb external knowledge gained through digitalization and integrate it into their internal innovation processes [103,104]. Therefore, by promoting them to key positions for digitalization, it is possible to understand and integrate new knowledge related to digital technologies and enable transformation to develop new products, processes, or other forms of innovation. A study of 1,014 manufacturing companies in Greece (mostly small and medium-sized enterprises) showed that absorptive capacity, including human resources, mediates digital capabilities and innovation performance [105]. In addition, digitalization improves communication both inside and outside the company, giving more educated employees access to the new knowledge and resources they need to innovate at scale [106], and it also makes more educated employees more efficient and productive, giving them more time to innovate [107]. Moreover, as digitalization reduces the workload of routine tasks, highly educated employees are able to take on more non-routine tasks [108]. These non-routine tasks are conducive to radical innovation, as they can stimulate the generation of new ideas and increase divergent thinking.

8.2. Financial Constraints and Management Expertise

The ability to leverage versatile and cost-effective resources such as digital infrastructure is particularly important for SMEs with general resource constraints [109]. However, SMEs tend to face financial constraints, and financial obstacles are a serious problem when investing in innovative

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activities [110]. In particular, limited funds are one of the main challenges in implementing digitalization [111,112]. Therefore, there is a need for human resources in SMEs who are responsible for financing. By acquiring financial resources, companies can strategically invest in the innovations they need to develop competitive advantages [113]. Specifically, strategies such as having top management team members with strong financial backgrounds build good relationships with financial institutions through relationship networks, increasing access to financial resources and mitigating financial constraints are required [114,115]. A study of 1,303 listed manufacturing SMEs in China found that digitalization in SMEs promotes radical innovation more than incremental innovation, and that the employment of highly educated employees and the financial background of top management team members strengthen this relationship [76].

9. Green Innovation, Sustainability, and Open Innovation

Green innovation may facilitate open innovation. This is because following an environmentally friendly business strategy for SMEs requires collaboration with others who are interested and knowledgeable in such activities. Thus, a study of 543 SMEs in Ecuador showed that environmental protection related to nature, climate change, pollution, biodiversity, etc., and waste reduction of raw materials, water, and energy may improve innovation performance by facilitating open innovation activities such as acquiring knowledge from outside the company (customers, research institutes, external networks, universities, etc.), engaging employees in research and development activities, using patents and royalties, and synergizing and partnering with competitors [116]. On the other hand, a study of Indonesian SMEs showed that open innovation may have a positive impact on green innovation by facilitating innovation through collaboration with various stakeholders [117]. In light of the role of digitalization discussed above, digitalization may contribute to the formation of a positive feedback loop in which green innovation and open innovation enhance each other, thereby promoting the ambidexterity that accompanies contemporary green innovation and sustainability. Figure 2 shows that Green Innovation and Open Innovation have a mutually reinforcing relationship through Digitalization.

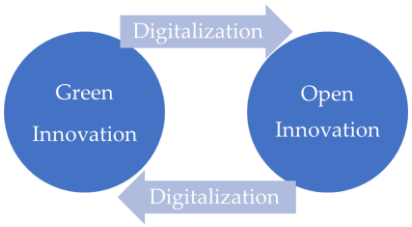

Figure 2. Mutually reinforcing relationship between green innovation and open innovation through digitalization.

10. Combination Effects

10.1. Digitalization, Open Innovation, Green Innovation, and Performance

Digitalization may improve firm performance by bringing about open and green innovation. However, the effect may not be large. A structural equation model of 684 SMEs based in Mexico showed that SMEs' technological capability significantly influences their open innovation activities, such as information gathering and deployment within the company, and process and product improvements, as well as their green innovation activities, such as designing products with energy-saving and less polluting materials [118]. This result suggests that SMEs on the path to digitalizing their processes are more likely to adopt open and green innovation and become more competitive. The effect size *f* from technological capability to open innovation was large at 0.377, and from

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technological capability to green innovation was moderate at 0.262. Meanwhile, the path from technological capability to corporate performance was not significant. Additionally, the effect of open innovation on corporate performance was small at 0.025 and that of green innovation on corporate performance was small at 0.016 [118].

10.2. Digitalization, Ambidexterity, and Performance

A meta-analysis of 113 studies using 115 independent samples and 192,188 observations over the period 1990-2021 shows that Industry 4.0 is associated with innovation ambidexterity, which in turn leads to superior firm performance, consistent with dynamic capabilities theory [119–121], which views innovation ambidexterity as a dynamic capability that can be driven by a firm's Industry 4.0 digital technologies to achieve superior performance [122]. The effect sizes of the direct effect of Industry 4.0 on innovation ambidexterity and firm performance and the correlation between innovation ambidexterity and firm performance were 0.38–0.54, which is small to medium level based on the criteria suggested by Cohen [123], according to which a coefficient size of 0.20 is small; 0.50 is medium, and 0.80 is large. The study also showed through moderation analysis that the positive impact of Industry 4.0 itself on firm performance is less than that of Industry 4.0 and innovation ambidexterity combined, that is, the combination of Industry 4.0 technology and innovation ambidexterity strategy can produce superior firm performance. This result suggests that digitalization alone is not enough to have a significant effect on performance, and that companies can generate financial and non-financial benefits by developing dynamic capabilities such as innovation ambidexterity [122].

10.3. Research Achievements and Challenges

Thus, digitalization may have a greater impact on performance when combined with open innovation or green innovation, or when combined with ambidexterity, than when it is adopted alone. However, the increased impact is small to medium, leaving room for improvement of the model. Furthermore, previous studies have yet to examine the impact of ambidexterity combined with digitalization and open innovation on green innovation, or the impact of the green innovation created by it on performance. This may be because previous studies on ambidexterity have focused on improving corporate performance, which may have led to a narrow perspective and little consideration of the idea that the pursuit of sustainability and performance improvement can be achieved simultaneously. If we expect resource-poor SMEs to contribute to solving environmental problems while surviving, we need to make a major effort to change the role assigned to ambidexterity. Alternatively, such analyses may become more relevant if there is a stronger tendency to view green innovation as an outcome that is as valuable as performance. For example, if more evidence is gathered that exploration (especially full-scale green innovation with design improvements) reduces the environmental burden of economic activity compared to specializing in exploitation, it may be possible to argue for the rationality of ambidexterity from a long-term or global perspective, even if financial performance is inferior to specializing in exploitation.

11. Discussion

11.1. When Should Digitalization Be Adopted?

This study showed that ambidexterity is related to SMEs' green innovation and sustainability for reducing environmental impact, and that the more long-term or macro perspective is taken, the greater the significance of SMEs adopting ambidexterity. Resource-poor SMEs can achieve ambidexterity through open innovation, which allows them to access external resources. However, open innovation is costly. Therefore, to achieve ambidexterity, SMEs need to promote digitalization and enable open innovation at low cost. To achieve this, support is also needed for human and financial networks that support digitalization. Under such circumstances, ambidexterity may

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contribute to the development and sustainability of SMEs. However, previous studies have not yet examined the impact of ambidexterity combined with digitalization and open innovation on green innovation, or the impact of the resulting green innovation on business performance.

The digital revolution increasingly requires SMEs to pursue technological innovation and comply with environmental sustainability goals [124]. However, SMEs remain cautious about adopting the solutions offered by digital technologies [124,125], especially the smaller they are [126]. Underdeveloped investments and capabilities in automation, lack of resources, and a perception of uncertainty are the main obstacles for SMEs to enter digital manufacturing at the same pace as larger companies [127]. However, if SMEs can develop capabilities related to digital platforms, the platforms could become a major growth driver [26]. In addition, if digitalization and open innovation are combined to facilitate ambidexterity and demonstrate that green innovation and performance increase simultaneously, digitalization may become more attractive and more adopted by SMEs than it is now.

For example, in Japan, one in four SMEs has received some kind of request from their business partners regarding decarbonization, and 70% of companies are working on decarbonization, mainly focusing on energy conservation. However, even these companies cite challenges such as a lack of human resources and know-how, the measurement and visualization of emissions, and a lack of funds to work on reduction, and their efforts toward decarbonization are insufficient [128]. This suggests that resource-poor SMEs are not fully equipped to foster green innovation. Therefore, through digitalization, there is a lot of room for SMEs to facilitate green innovation and solve sustainability-related issues by increasing the efficiency of their internal resource use and by broadening the scope of their external resource use by reducing the orchestration costs associated with open innovation.

It is difficult to say whether ambidexterity is beneficial for individual SMEs. Therefore, it may not be wise to recommend ambidexterity to disadvantaged SMEs that are on the verge of bankruptcy. However, apart from SMEs that face such imminent risks, ambidexterity is worth pursuing as a forward-looking policy. This becomes even more significant when considered not only on an individual company but also on a national and global scale. Such discussions could greatly expand the existing research stream on ambidexterity. That is, even if it is not necessarily the best for individual companies, ambidexterity may be judged as a recommended approach for SMEs when evaluated from a macro- and long-term perspective. Ambidexterity may be useful as a means for SMEs, the country, and the world to find a compromise on global challenges such as decarbonization. Therefore, further progress in digitalization and its spread to SMEs are essential, and it is considered that top priority support from national, local, and international organizations is required.

11.2. Theoretical Implications

This narrative review showed that digitalization and open innovation can promote ambidexterity in SMEs, and that ambidexterity can lead to green innovation. However, it also showed that implementing these strategies alone or in partial combination may not sufficiently improve SME performance. On the other hand, there are few studies that deal with the relationship between green innovation and ambidexterity, and it is a niche topic [129]. In particular, research has not yet confirmed the relationship between ambidexterity and green innovation achieved by combining digitalization and open innovation, and the relationship between green innovation thus achieved and performance. This is surprising, considering that sustainability has been taken up as a common challenge for humanity and ambidexterity management has become a big boom. This gap may be because researchers have only considered ambidexterity as a strategy to improve the performance of individual companies. However, today, as supply chains are being reconsidered and more economic entities are required to comply with environmental standards, there is an increasing need for SMEs to innovate from a global perspective, beyond the convenience of individual companies. Ambidexterity makes it possible to explore technologies with low environmental impact while utilizing conventional technologies. In other words, it has the potential to balance the realities of

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SMEs with the ideals for the future of the planet. Further research on green innovation and ambidexterity could enhance the growth potential of SMEs and point the way to global sustainability. This review should be used to advance this research.

11.3. Practical and Policy Implications

Based on this research, national and local governments should use their budgets to promote open innovation and digitalization in SMEs. Furthermore, to curb the excessive costs of open innovation, the government should create opportunities for collaboration between companies, or between companies and specialized institutions such as universities, and promote the development of infrastructure for digitalization. Specifically, subsidies targeted at the introduction of digital platforms by SMEs, tax incentives for green R&D collaboration, subsidies to promote the hiring of highly educated personnel for core positions, and the promotion of knowledge exchange programs between universities and SMEs are recommended. These will lead to open innovation and digitalization, and innovation in line with sustainability and the trends of the times will help SMEs gain global trust and secure profits. Figure 3 is a proposal for a new framework based on this review, and Table 4 summarizes past research and prospects for future research.

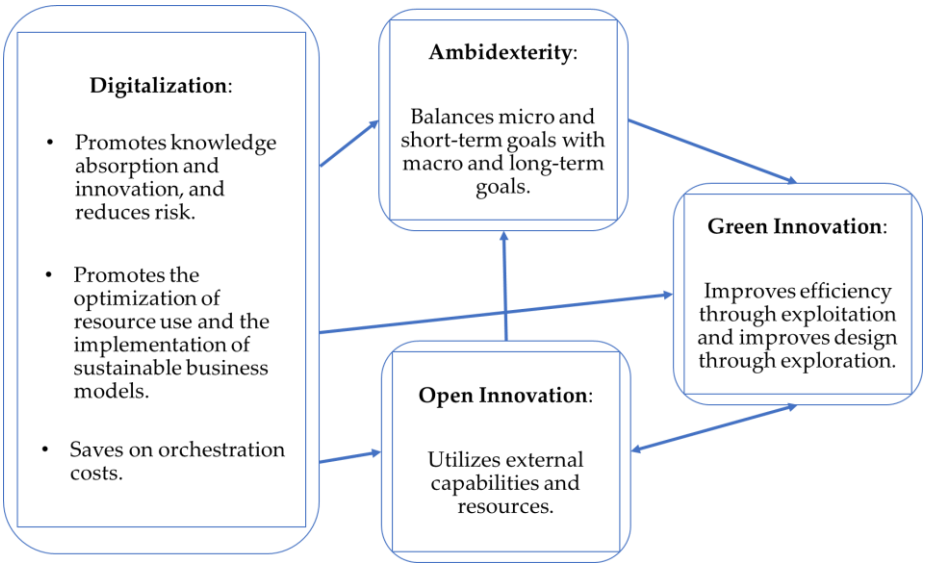

Figure 3. Proposal of a new framework based on this review.

Table 4. Review of research to date and outlook for future research.

Variable	What previous research has revealed so far	What future research should address
Digitalization	It enhances the competitive advantage of SMEs by combining with organizational ambidexterity to enable knowledge absorption under cost constraints, respond to radical innovation, and reduce risks. Furthermore, it contributes to open innovation, as well as green innovation and sustainability by facilitating orchestration cost savings and resource utilization optimization.	The main obstacles to digitalization among SMEs are a lack of financial and human resources, as well as a lack of understanding about the convenience of digitalization. It is necessary to consider how the government can provide specific support to overcome these obstacles.
Open Innovation	Leveraging external capabilities and resources compensates for shortfalls in internal assets and enables ambidexterity.	It is necessary to clarify strategies for reducing costs associated with orchestration, including digitalization.

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Green Innovation	It is promoted by ambidexterity and has a mutually enhancing relationship with open innovation.	There is a need to understand the effects on performance when combined with digitalization, open innovation, and ambidexterity.
Ambidexterity	Although it has been primarily employed in relation to performance, recent research has shown its potential to be driven by digitalization and open innovation, thus stimulating green innovation.	A new framework is needed that positions ambidexterity not just as a micro- or short-term goal of the development of individual companies, but also as part of a strategy for achieving macro- or long-term goals for the sustainability of the planet.

12. Limitations and Future Research Directions

This study has three limitations. First, this is a narrative review and may have missed findings that could have been found using other methods, such as a systematic review. Second, limiting the review to English and Japanese literature may have led to important literature written in other languages being overlooked. Finally, some of the findings of this review, such as the lack of research on the relationship between ambidexterity and green innovation, may have been found by using search terms other than ambidexterity. Future research may be able to confirm or extend the findings of this review through a more comprehensive review using more diverse methods.

13. Conclusions

This review examines the relationship between ambidexterity, digitalization, open innovation, and green innovation. Digitalization and open innovation may enable SMEs to overcome resource scarcity issues and achieve ambidexterity. However, the impact of combining digitalization with open innovation and green innovation, and digitalization with ambidexterity on business performance is not large. Furthermore, the impact of combining digitalization with open innovation and ambidexterity on green innovation, or the resulting impact of green innovation on business performance, has not yet been examined. This is surprising given the current situation of increasing interest in the global environment, but it may be because researchers have viewed ambidexterity as a means to improve SMEs' short-term business performance. Given the long-term domestic and global challenge of sustainability, ambidexterity efforts, which are likely to be related to green innovation, should be promoted to more SMEs. Thus, giving ambidexterity a larger role may make it a more valuable research topic and increase its policy significance. Based on the results of this study, future research should refine and develop an analytical model that combines digitalization, open innovation, ambidexterity, and green innovation, and conduct research aimed at achieving both corporate survival and sustainability. In addition, the government should promote the digitalization of SMEs and provide the necessary human and financial support to enable SMEs to promote open innovation, ambidexterity, and green innovation efforts while keeping costs down.

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