Journal of Cleaner Production 455 (2024) 142265

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

The effect of industrial solution services (ISS) on innovation performance: The moderating role of sustainable development goals (SDGs)

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ARTICLE INFO

Handling editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Servitization
Industrial solution services
Patent innovation
SDG index
OECD

ABSTRACT

This article analyzes the innovation performance antecedents of manufacturing firms that implement servitization-based industrial offerings in OECD countries. These servitized offerings can be conducted either digitally (remotely) and/or physically (on-site), and provide a comprehensive solution for industrial settings. Specifically, this article proposes that firms adopting Industrial Solution Services (ISS) in their different forms, namely Digital ISS, Operational ISS and Green ISS, exhibit higher innovation performance. In order to test this assumption, a linear regression model is used to investigate the effect of the different firms' ISS strategies - Digital, Operational and Green - which are moderated by the Sustainable Development Goal (SDG) Index in the country where the manufacturers operate. The results provide evidence that adopting Digital ISS can lead to higher innovation performance when SDGs are not taken into account. Conversely, Operational and Green ISS strategies are conducive to superior innovation performance in firms operating in countries with higher degrees of SDG accomplishment. These findings have significant theoretical and managerial implications regarding the advantages of ISS strategies for promoting innovation outcomes, particularly in alignment with nationwide SDG objectives.

1. Introduction

Although manufacturing has been, and still is, the key engine for wealth generation and societal wellbeing (Koren et al., 2018), achieving sustainable industrial production has been globally recognized as a crucial challenge due to the escalating depletion of finite resources and rapid destruction of the natural environment (Kraus et al., 2020; Pang and Zhang, 2019). In this respect, manufacturing sectors account for a significant portion of the world's extraction and consumption of resources, which is projected to double by 2050 (Nedelciu et al., 2020). Such a complex global scenario has therefore pressed the need for innovative production methods that minimize the environmental impact of production and products (Severo et al., 2017). To address these concerns, manufacturing firms have turned their production systems toward new approaches to minimize the negative externalities of industrial activities, such as Green manufacturing (Kannan et al., 2022), Lean manufacturing (Mathiyazhagan et al., 2022), Sustainable manufacturing (Ching et al., 2022), and Smart manufacturing (Kannan et al., 2023). This tendency has not only moved firms toward cleaner production processes but also toward digitalized and interconnected production systems that enable the development of both product and service into a single integrated solution (Rabetino et al., 2017; Aquilante and Vendrell-Herrero, 2021; Kohtamäki et al., 2021). In particular, in manufacturing settings, the shift toward providing product and service bundles in the form of an integrated solution has been termed servitization (Vandermerwe and Rada, 1988; Vendrell-Herrero et al., 2017; Rabetino et al., 2018).

Servitization in manufacturing integrates service offerings throughout the entire product lifespan, facilitating the dematerialization and subsequent de-commoditization of the offerings themselves (Kohtamäki et al., 2024). This, in turn, has implications with regard to reducing resource use and other associated environmental impacts -from cradle to grave (cf. Brax and Visintin, 2017; Bustinza et al., 2021). In this vein, servitization strategies enable the reshaping of a product's lifecycle by redefining operational patterns through product innovation, refurbishment, the use of recycled materials, and various strategies to extend product utility throughout the entire product lifespan (e.g., Schiavone et al., 2022; Vendrell-Herrero et al., 2022). These features empower firms to adapt and transform their operations - by adopting servitization - in order to promote innovation and comply with environmental

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https://doi.org/10.1016/j.jclepro.2024.142265
Received 6 November 2023; Received in revised form 4 April 2024; Accepted 15 April 2024
Available online 19 April 2024
0959-6526/

regulations (Opazo-Basáez et al., 2018; Bustinza et al., 2024).

Accordingly, servitization reassesses innovation in industrial ecosystems via the provision of Industrial Solution Services (ISS), that is, industrial service propositions aimed at supporting manufacturing production and production-related business functions (Bonamigo et al., 2020; Kohtamäki et al., 2022). In particular, these services can be classified into Digital, Operational and Green ISS depending on their scope; digital customer support, product operation and functioning, and environmental impact, respectively. In this regard, recent literature establishes that Digital ISS enable manufacturing firms to dynamically align configurations of business model components with customer needs (Lee et al., 2022), whereas Operational ISS allow firms to optimize product operation and maintenance performance (Abhilash and Chakradhar, 2021). Finally, it has been reported that Green ISS contribute to the simultaneous advancement of industrial environmental conservation and economic growth (Queiroz et al., 2022).

Even though existing research suggests that firms engaged in servitization are inherently innovative and possess great capability to develop and incorporate innovations in order to revamp their product-service offerings (Qi et al., 2020; Lafuente et al., 2022), there is still lack of understanding regarding their capacity to yield innovation outcomes. Hence, further investigation is needed to identify the factors that can support or hinder their innovation outcomes. This is particularly significant in light of the global implementation of Sustainable Development Goals (SDGs), which set growth benchmarks for manufacturing on a global scale (Smith et al., 2018; Ronzon and Sanjuán, 2020). In short, SDGs provide industrial firms with a framework to align their operations with global sustainability goals, enhance their sustainability performance, and contribute to a more sustainable future (D'Adamo et al., 2022; Zhao et al., 2022). As a result, it is suggested herein that this global normative framework could not only impact a firm's sustainability performance but also its ability to innovate internally.

Drawing on the servitization (Vandermerwe and Rada, 1988) and natural resource-based view of the firm (Hart, 1995) as the theoretical lens, the primary objective of this study is to shed light on innovation outcomes, with regard to the patent productivity of servitized firms, so as to reveal how Industrial Solution Services (ISS), in terms of Digital, Operational and Green ISS, may influence innovation performance in industrial settings (Martín-Peña et al., 2023). The secondary objective is to assess the potential impact of SDGs on the innovation outcomes of servitized firms. To this end, this study analyzes the effect of the country's SDG Index score on the relationship between ISS and patent productivity in Organization for Economic Co-operation and Development (OECD) member countries in order to unravel whether a country's SDG degree of accomplishment may, in effect, influence the innovation outcomes of firms (Azmat et al., 2023). These two objectives are supported by empirical evidence obtained from a sample of 1144 large manufacturing firms operating in 25 OECD countries. These firms were selected on the basis of their primary NAICS codes 31–33 and secondary code 54. Data for the study was collected from the SDG Index and Orbis IP databases for year 2022.

Overall, this study makes several important contributions to the literature. First, it substantiates that adopting ISS is positively associated with innovation performance. In this regard, the study suggests that implementing Digital ISS benefits innovation outcomes in industrial firms where the SDG normative framework is absent. Second, the study reveals that SDGs negatively affect innovation performance. This indicates that the SDG framework (i.e., laws, regulations and policies) in itself exerts a negative influence on firms' capability to innovate. Finally, the study argues that for countries with higher degrees of SDG accomplishment, Operational and Green ISS favor (have a positive influence on) innovation performance in relation to patent productivity results.

The article is structured as follows: Introduction (above); Section 2 presents the theoretical background; Section 3 sets out the hypotheses development; Section 4 presents the context, variables and method; Section 5 shows the results; and Section 6 discusses the conclusions, and their implications and limitations.

2. Theoretical background

2.1. Digital, Operational and Green industrial solution services (ISS)

The connection between sustainability and manufacturing processes has become one of the central debates at national and international level in both industrialized and developing countries (Lisowski et al., 2023). In response to this, manufacturing firms have become more aware of the environmental impact and importance of adopting more sustainable practices, such as industrial servitized solutions to meet the growing demand for environmental sustainability whilst maintaining industry competitiveness (Opazo-Basáez et al., 2018; Fernando et al., 2019; Hermundsdottir and Aspelund, 2021). In manufacturing contexts, these types of services are specifically known as Industrial Solution Services (hereinafter ISS) (Bonamigo et al., 2020; Kohtamäki et al., 2022). These services are servitization-based offerings aimed at supporting firms' industrial activities by accompanying (i.e., monitoring and controlling) physical products throughout their entire lifespan (cf. Brax and Visintin, 2017; Bustinza et al., 2021). Thus, ISS adoption provides firms with the possibility to gain access to valuable information throughout the course of a product's lifetime (from service providers), which is then focused on consistently enhancing the quality of the service offering in terms of product adaptability, operability and environmental performance (Bustinza et al., 2021). Depending on their scope and functionality, ISS can be classified into Digital ISS, Operational ISS and Green ISS. A more detailed description of each ISS type is given below.

Digital ISS refers to an utterly digital-enabled service offering aimed at providing highly personalized value propositions through seamless relations between providers and customers (Lafuente et al., 2022; Lee et al., 2022). In essence, Digital ISS involves continuous real-time monitoring and collection of actionable product data so as to gain insights for the rapid (re)configuration of product characteristics according to unique customer usage patterns, needs, functional constraints and design parameters (Katoozian and Zanjani, 2022; Opazo-Basáez et al., 2022). By transforming product data (usage inputs) into digital data (i.e., virtual-physical convergence), Digital ISS helps detect and forecast consumer requirements in a precise manner, such as material type, material properties, product dimension and weight, technical specifications, and so forth (Hinchy et al., 2020; Kohtamäki et al., 2021). Thus, Digital ISS offers customers support and supervision, and enhances digital product models, opening up possibilities for firms to ensure optimal decision making, and dynamically align their business model components with customer needs throughout a product's lifespan (Rabetino et al., 2015; Papazoglou et al., 2020). Renowned examples of Digital ISS include, among others, digital twin services (Tao et al., 2022), digital prototyping services (Holmström et al., 2017), digital product memory/biography services (Gebhardt et al., 2022) and digital product modeling services (Nunes et al., 2017).

Meanwhile, Operational ISS entails a service proposition focused on ensuring the proper functioning and maintenance of the firm's products (Vendrell-Herrero et al., 2021a). Unlike Digital ISS, Operational ISS can be performed digitally and physically, providing firms with both proactive/preventive and reactive/responsive capabilities (Bustinza et al., 2022). Therefore, on the digital side, Operational ISS enables firms to monitor the continuous operation of products digitally in real time throughout their entire lifespan, ensuring optimal functionality according to established requirements (Vendrell-Herrero et al., 2021b). This allows customers to visualize, evaluate and optimize product performance throughout its functional life. On the other hand, on the physical side, these services also offer on-site reactive or corrective maintenance actions to rectify possible errors or malfunctions that may affect the product's correct operation (e.g., degradation, defects, damage and/or equipment/product failure). By applying these two provisions, firms can optimize product performance and minimize potential production process disruptions (Huikkola et al., 2022; Opazo-Basáez et al., 2023). Examples of these services include monitoring and failure prediction services (Abhilash and Chakradhar, 2021), predictive maintenance services (Behzad et al., 2019), assembly/disassembly services (Krishnakumari et al., 2021), repair and overhaul services (Ladj et al., 2021), and so forth.

Green ISS entails a service type focused on minimizing the negative effects of products on the natural environment (e.g., pollution, waste, resource degradation, greenhouse gas emissions, etc.) (Opazo-Basáez et al., 2024). Similar to Operational ISS, Green ISS can be conducted both digitally and physically, providing firms with monitoring, diagnosis and evaluation capabilities to address negative impacts resulting from product operation (Contini et al., 2023). Hence, on the digital side, Green ISS enables real-time assessment (e.g., visualization and interaction) of product performance in relation to sustainability objectives set by the organization (Beltrami et al., 2021; Queiroz et al., 2022). This allows firms to ensure that their products operate in accordance with established regulations and policies on climate change and sustainability (Javaid et al., 2022). On the other hand, on the physical side, Green ISS facilitates the on-site revitalization or mitigation of adverse environmental effects arising from product performance (e.g., soil erosion, spills and leaks, toxic emissions) by setting the best remediation, treatment and disposal routes (i.e., waste management practices) in order to protect the environment (Tripathy et al., 2023). As a result, Green ISS enables firms to align their operations with sustainable practices, and identify and rectify potential issues and deviations in a timely manner (Bag et al., 2021; Javaid et al., 2022). Some examples of these services include wastewater management services (Khurshid and Deng, 2021), air pollution control services (Ahn and Yoon, 2020), soil remediation services and waste management services (Aznar-Sánchez et al., 2019), to name a few.

While each ISS type possesses a clear orientation (i.e., customer, product and/or environmentally-focused), the possibility is not ruled out that firms can jointly analyze and exploit digital ISS information in order to assess potential interrelations between the different ISS types.[1] Nonetheless, the main objective of this description is not to elaborate on this possibility, but to illustrate ISS to further disclose its effect on the innovation outcomes of firms. With this objective in mind, Table 1 summarizes the main attributes of the different ISS types.

2.2. Sustainable development goals (SDGs) and the SDG index (SDG-I)

In the 2015 United Nations (UN) General Assembly, international leaders acknowledged the need to transition the world toward a more sustainable development trajectory (Walsh et al., 2020). To address this matter, the United Nations 2030 Agenda [2] (United Nations, 2015) put forward a set of universally-applicable objectives (i.e., applying to all nations), officially known as the Sustainable Development Goals (SDGs), comprising a total of 17 targets and 169 sub-targets, and an expanding set of 231 global indicators (Malay, 2021; Bose and Khan, 2022). In essence, this universal, integrated and transformative framework encompasses three critical dimensions with international validity such as economic development, social inclusivity and environmental sustainability (Gyimah et al., 2023; Lisowski et al., 2023). Formally officialized worldwide on January 1, 2016, the SDGs stand out as one of the most significant international agreements as they provide an effective roadmap for countries, organizations, businesses and institutions to align with the imperative of climate change action and sustainable development goals on a local, national and global scale for the next decade (Smith et al., 2018; Ronzon and Sanjuán, 2020).

While a consensus has emerged that all countries must undertake major commitments to achieve the SDGs by 2030 (Walsh et al., 2020), ensuring the actual achievement of these objectives is crucial in order to monitor progress of the 2030 Agenda. This helps national leaders determine the course of action for their country, identify areas where improvements are needed, and highlight areas of expertise where knowledge can be shared between nations (Diaz-Sarachaga et al., 2018; Tóthová and Heglasová, 2022). In this respect, it is important to point out that much of the existing literature reflects on the importance of establishing effective valuation methods and indicators to monitor the progress of these objectives over time (e.g., see D'Adamo et al., 2022; Zhao et al., 2022), thus enabling comparisons between countries so as to rank and benchmark their relative performances in specific areas (Asadikia et al., 2021; Hametner, 2022). This is not only a critical aspect in order to raise public awareness and encourage discussion, but also to improve accountability and transparency, and facilitate in-depth analysis offering updates on the development of improved policies aimed at SDG attainment (Asadikia et al., 2021; Lisowski et al., 2023).

To accomplish this, the Bertelsmann Stiftung in conjunction with the United Nations Sustainable Development Solutions Network (SDSN) released the Sustainable Development Goal Index (herein the SDG-I) in 2016 (Biggeri et al., 2019; Jabbari et al., 2020; Sachs et al., 2021). In short, the SDG-I refers to a system of indicators developed by the UN aimed at tracking and comparing the progress over time of all 193 UN member states with regard to achieving the 2030 Agenda goals (Lafortune et al., 2018). By using publicly available data from the World Bank, World Health Organization (WHO) and other international organizations, the Index score indicates the country's position on a scale from 0 (worst possible performance) to 100 (optimum performance) to show how countries are performing in the SDGs.[3] Accordingly, the SDG-I enables the measurement of corporate development across nations (i.e., for all nations – developed, developing and least developed), as regards universal challenges, by establishing a clear and common normative framework (i.e., a consistent set of indicators) that is applicable to all participants in order to achieve the defined common goals (Ronzon and Sanjuán, 2020; Olwig, 2021; Tóthová and Heglasová, 2022). Although the SDG-I has not been free from criticism in terms of methodology and scope (cf. Wang et al., 2018; Biggeri et al., 2019; Jabbari et al., 2020), its present implementation is a valuable tool, if not the most, in the quest to establish globally sustainable development practices in different areas such as poverty, healthcare, access to education, gender equality, clean water and sanitation, sustainable energy and economic development. (Biggeri et al., 2019; Sachs et al., 2021; Bose and Khan, 2022).

[1] The rationale behind this formulation is rooted in Organizational Information Processing Theory (Kroh et al., 2018). Therefore, it is argued that while a firm makes use of various data sources such as those from different business units (marketing, finance, human resource management, administration, technology, etc.), data collected from these diverse sources can be used to enhance the functions of individual business units, or can be used jointly to support company-wide decision making.

[2] The 2030 UN Agenda for Sustainable Development, also referred to as "Transforming our World: the 2030 Agenda for Sustainable Development," is a resolution (A/RES/70/1) adopted by the General Assembly on September 25, 2015 by 193 member states. It offers a detailed roadmap for all nations to achieve economic prosperity, social inclusivity, environmental sustainability and effective governance by the year 2030.Further information available at https://sdgs.un.org/2030agenda.

[3] The Sustainable Development Report (formerly the SDG Index & Dashboards) is a global assessment of countries' progress toward achieving the Sustainable Development Goals. It is a complement to the official SDG indicators and voluntary national reviews. Further information available at https://dashboards.sdgindex.org/rankings.

Table 1
Principal ISS orientations and features.

Industrial Solution Services type (ISS)	ISS description	ISS objective	Provision method(s)	Prominent examples
Digital ISS (Customer/ user-focused)	To improve customer/user experience by providing highly personalized value propositions via seamless provider-customer/ user relations.	To transform product data into digital data, facilitating precise detection and forecasting of consumer requirements, while enabling firms to align their business model with customer needs throughout the product lifespan.	Digital means.	*Digital twin services, digital prototyping services, digital memory/ biography services and digital modeling services.*
Operational ISS (Product-focused)	To monitor the continuous real-time operation of products digitally throughout their lifespan, ensuring that they function optimally according to established requirements.	To ensure the continuous and optimal functioning of products, providing both proactive and reactive maintenance to minimize disruptions and optimize product performance throughout their lifespan.	Digital and physical means.	*Monitoring and failure prediction services, predictive maintenance services, assembly/disassembly services and repair and overhaul services.*
Green ISS (Compliance-focused)	To help firms comply with climate change and sustainability regulations, aligning operations with sustainable practices, and promptly addressing potential environmental issues.	To minimize the negative environmental impact of products, whether by digitally monitoring their performance in relation to sustainability objectives or by on-site mitigation of adverse effects.	Digital and physical means.	*Waste water management services, air pollution control services, soil remediation and waste management services.*

3. Hypotheses development

3.1. ISS and innovation performance

Innovation performance focuses on assessing the effectiveness of innovation processes and benefits derived from implementing new technologies, systems, solutions and/or equipment in industrial settings (Hong et al., 2019). Hence, it centers on the capability of firms to transform innovative resources into innovation outcomes (Hou et al., 2021). In this vein, previous studies suggest that adopting digitally-enabled resources (i.e., products/services) encourages the growth and acquisition of new skills, competences and knowledge, all of which significantly enhances the innovation capacity and market success of firms (Wen et al., 2022; Radicic and Petković, 2023). So, by embracing digitally-enabled resources (e.g., ISS), firms can improve their decision-making effectiveness by acquiring valuable information that can help them identify novel solutions and ideas, rapidly detect market trends and enhance new technology applications, all of which directly stimulates the development of new innovations (Niebel et al., 2019; Opazo-Basáez et al., 2022). Moreover, a vast amount of research on innovation management provides evidence on the relevance of collaboration and digital interconnection in supplier-customer relations (i.e., sharing knowledge across organizational boundaries via integrated digital platforms) in order to access critical knowledge aimed at improving products and production processes, and thus increase a firm's likelihood of innovating (Hong et al., 2019; Andersen, 2021; Sarbu, 2022; Xie et al., 2023). Based on these considerations, it is argued here that each individual ISS type provides firms with a set of capabilities/resources (e.g., real-time monitoring and control, optimization and corrective functions, etc.) that not only enables and speeds up supplier-customer sharing on critical product information, but also facilitates the discovery of critical patterns in terms of product *functioning, operativity and greenness*. In turn, this enables firms to gain crucial expertise (deepen and broaden their knowledge) for new innovation ventures, thus enhancing their innovation capacity. The following hypotheses are therefore postulated.

H1a. Digital ISS is positively associated with innovation performance.

H1b. Operational ISS is positively associated with innovation performance.

H1c. Green ISS is positively associated with innovation performance.

3.2. SDGs, SDG-I, ISS and innovation performance

SDGs serve as a global framework for monitoring and regulating progress toward the 2030 Agenda at international/national level (Walsh et al., 2020; Malay, 2021). They therefore provide a frame of reference for firms and their development strategies that guides them to comply with sustainability regulations. This is mostly to uphold their legitimacy and competitiveness within their industry, and the fact that society will largely depend on their adherence to such regulations (Bowen et al., 2017; Bose and Khan, 2022). However, the impact of normative frameworks varies depending on the country's economic development, institutional capacity and its infrastructure, as meeting these recommended objectives requires specific resources, agreements, assistance and policies (Rosati and Faria, 2019). It is important to note that targets can be interconnected within the SDG framework, and achieving one target may affect the ability to reach another (trade-offs), so it is not always possible to achieve win-win situations (Bowen et al., 2017; Biggeri et al., 2019). In this context, SDGs may influence decision-making processes in firms when it comes to implementing new processes and technologies for development and competitiveness. As such, firms are likely to prioritize technologies that have a positive impact on their stakeholders and society because their choices will be influenced by the goal of achieving sustainability objectives (Al-Emran and Griffy-Brown, 2023; Elgin et al., 2023). Considering the above, it is argued here that the normative framework instituted by SDGs (via the SDG-I) has the capacity to put significant constraints on the actions of firms with regards to adopting technology, and their performance in terms of innovation (Asokan et al., 2022). This is primarily because firms, in their pursuit to comply with the prescribed regulations, have the opportunity to embrace digitally-enabled resources (e.g., ISS) that align with the attainment of sustainable objectives (Parmentola et al., 2022). Adopting these digitally-enabled resources thus facilitates the advancement of subsequent sustainable innovations, thereby affording firms enhanced competitiveness in accordance with their sustainable aspirations. The following hypothesis is therefore postulated.

H2. The SDG-I moderates the relationship between ISS and innovation performance.

Fig. 1 illustrates the proposed research framework and relationships between the hypotheses.

4. Method

4.1. Context

This study analyzes servitized manufacturers belonging to OECD countries included in the 2022 SDG-I. The data for servitized manufacturers was gathered from ORBIS database, which includes information on activity sector, balances, etc. A complementary database, ORBIS IP, provided the necessary information on patent productivity. A sample of

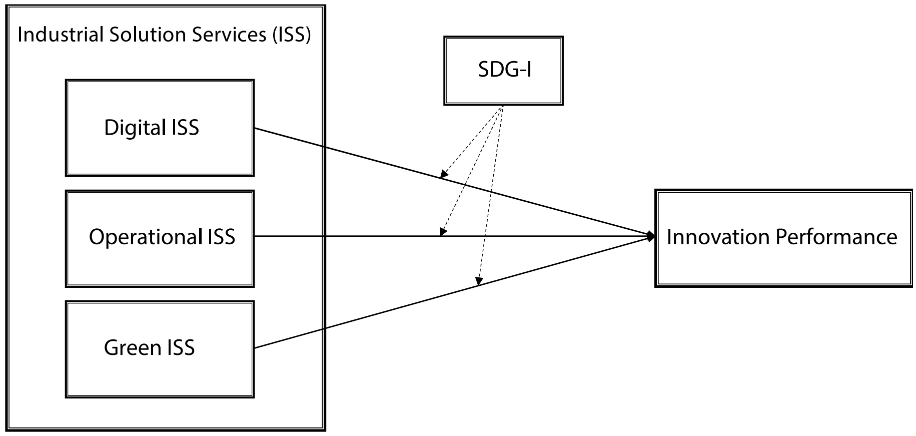

Fig. 1. Proposed framework for ISS, innovation performance and the SDG-I.

573 large firms[4] from OECD countries with more than $50 million turnover up to 2021 was selected from both databases. As for the SDG-I score for each country, the countries reached values ranging from 74.5 over 100 for the USA to 86.5 for Finland. Manufacturers were classified according to the North American Industry Classification System (NAICS) codes 31–33 for manufacturing firms. Economic activities classified as services were taken from Gomes et al. (2019), Opazo-Basáez et al. (2018), Vendrell-Herrero et al. (2023) and Wong and He (2005), where code 54 refers to Professional, Scientific and Technical Services (conceptualized here as Industrial Solution Services - ISS); codes 518-19 to ICT and related services (Digital ISS); code 811 to Repair and Maintenance services (Operational ISS); and code 562 to Waste Management services (Green ISS).

Servitized manufacturers were classified as those having manufacturing NAICS codes as a primary activity code and service NAICS code as a secondary activity. Based on this rationale, the main focus of analysis was on the servitized manufacturers adopting the different ISS types across the product lifecycle, categorizing firms into: a) Digital ISS for firms adopting digital services, b) Operational ISS for firms implementing operational services such as repair and maintenance, and c) Green ISS for firms integrating remediation and disposal services. The sample included 1144 firms employing different servitization strategies - and the study objective was to analyze those adopting ISS into their operations (154 Digital ISS, 146 Operational ISS and 202 Green ISS firms embraced an ISS type from a total of 1144 servitized manufacturers). Table 2 provides a sample description. The total sample was balanced by grouping countries into four different SDG-I rankings: countries with an SDG-I score below 74.5 includes the USA; up to 79 Australia, Canada, Chile and Italy; up to 80.5 Japan, the Netherlands and the Czech Republic; and up to 86.5 the UK, Germany and Finland. The most representative countries across the four sampled groups are the USA (288 firms), Italy (72), Japan (136), and Germany (115).

4.2. Variables

The conceptual model developed for this study is based on three key constructs, namely.

ISS, Innovation Performance and the SDG-I. A detailed description is given below on how these constructs have been operationalized.

The independent variable is Industrial Solution Services (ISS). This variable is established based on the categorization described above, which includes Digital ISS for firms offering digital services, Operational ISS for firms offering operational services, and Green ISS for firms offering remediation and disposal services. The servitized manufacturers in this variable are therefore categorized according to the ISS embraced (Digital ISS, Operational ISS or Green ISS). These three categories can be measured using dummy variables, taking 1 as the value if the firms offer digital ISS, operational ISS or green ISS, and 0 otherwise. In this sample, 154 firms are categorized as Digital ISS, 146 as Operational ISS and 202 as Green ISS. Overall, the subsample of ISS servitized manufacturers contains 502 firms offering one of the three strategies out of a total sample of 1144 firms. The remaining servitized manufacturers follow unstructured, service-led product lifecycle strategies.

The dependent variable is innovation performance, which was measured using patent productivity (cf. Sun et al., 2022). To this end, patent productivity is selected as the ratio between number of patents and number of employees (Liu et al., 2023; Meliciani, 2000). This

[4] The study used the OECD business size classification to categorize firms, which is based on the number of employees in a firm. The analysis specifically concentrates on firms classified as large, with 250 or more employees. Additional information can be found at the following website: https://data.oecd.org/entrepreneur/enterprises-by-business-size.htm.

Table 2
OECD countries and SDG-I groups.

	Digital ISS	Oper. ISS	Green ISS	Full sample
SDG-I, countries below 75: USA	30	2	10	288
SDG-I, countries up to 79: Australia, Greece, Canada, Chile, Italy, Slovak Rep., Hungary	72	88	138	288
SDG-I, countries up to 80.5: Portugal, Japan, Belgium, Netherlands, Spain, Slovenia, Czech Rep.	40	34	36	298
SDG-I, countries below 87: Poland, UK, Ireland, France, Germany, Austria, Norway, Sweeden, Denmark, Finland	12	22	18	268
	154	146	202	502/ 1144

*NAICS codes considered: 31, 32, 33, 518-9, 54, 562, 811.
*Oper. ISS: Operational ISS.

Table 3
Descriptive analysis and correlations between variables.

Variables	1	2	3	4
1. *Digital ISS*	1			
2. *Operational ISS*	0.205	1		
3. *Green ISS*	0.230	0.246	1	
4. *Innovation Performance*	0.613**	0.409*	4.214*	1
Mean Innovation Performance		0.345	Standard deviation	0.276

Note: ***p < 0.001, **p < 0.01, *p < 0.05.

variable is a continuous variable where all firms in the sample possess at least one patent. Table 3 shows the descriptive statistics and correlations for the selected variables.

The moderating variable is the Sustainable Development Goal Index (SDG-I). This index can be interpreted as the percentage of achievement in the 17 SDGs adopted by global leaders at the UN General Assembly in 2015 (Biggeri et al., 2019; Sachs et al., 2021). It takes values from 0 to 100, the score being the distance in percentage needing to be completed in order to achieve the SDGs. This measurement has previously been applied to benchmark the sustainable development performance of OECD countries (Lamichhane et al., 2021) as this organization is continuously tracking the SDG effort made by its members.

Control variables: This study includes control variables at firm, industry and country level to describe the patenting activity of firms more accurately. First, a firm's turnover is a continuous variable that is selected as an alternative control variable for firm size (Barkham, 1994). Patent productivity is shown to be related to the influence of firm size (Andries and Faems, 2013). Second, a control variable at firm level is included which is commonly used in the literature, firm age (Vendrell-Herrero et al., 2021a). Activity codes are also considered as a dummy variable at industry level and as a specific variable for each individual country.

4.3. Method

An ordinary least squares (OLS) regression was used to estimate the direct effect of the different ISS on innovation performance (H1a-H1b-H1c), and the moderation effect of the SDG-I on this relationship (H2).

Direct effect. To investigate the effect of ISS on innovation performance, models based on Equation (1) were estimated, where $INNPERF_i$ is equal to patents per employee, $DIISS_i$ (NAICS-54/518-19, Digital ISS), $OPISS_i$ (NAICS-54/811, Operational ISS) and $GRISS_i$ (NAICS-54/56, Green ISS) are the treatment variables (i.e., servitized manufacturers offering ISS), $TURN_i$ is a continuous control variable measuring firm turnover, $AGEi$ is a continuous control variable for firm age, ϑ_s are the industry dummies, ϑ_c are the country dummies, and ε_i is the robust standard error term. In this model, H1a, H1b and H1c are supported if β_1, β_2, and β_3 are positive.

$$INNPERF_i = \beta_0 + \beta_1 DIISS_i + \beta_2 OPISS_i + \beta_3 GRISS_i + \beta_4 TURN_i + \beta_5 AGE_i + \vartheta_s + \vartheta_c + \varepsilon_i \tag{1}$$

Moderation via a three-way interaction effect. To incorporate the SDG-I (H2) moderation effect, an extended model was assessed, considering the *SDG-I* scores as the moderating variable. In this model, H2 is supported if β_7, β_8 and β_9 are positive and higher than β_1, β_2 and β_3, respectively. This model tests the moderating role of the degree of SDG achievement in the relationship between the ISS types analyzed and innovation performance (see Equation (2)).

$$INNPERF_i = \beta_0 + \beta_1 DIISS_i + \beta_2 OPISS_i + \beta_3 GRISS_i + \beta_4 TURN_i + \beta_5 AGE_i + \beta_6 SDG_c + \beta_7 DIISS_i * SDG_c + \beta_8 OPISS_i * SDG_c + \beta_9 GRISS_i * SDG_c + \vartheta_s + \vartheta_c + \varepsilon_i \tag{2}$$

5. Results

The results from OLS estimation after running equation (1) are shown in Table 4, considering the control variables explained in the previous section. Column (1) shows that Digital ISS - in terms of turnover, age, industry and country - is significantly related to innovation performance ($\beta_1 = 0.57$; $p-value < 0.05$), while column (2) for Operational ISS and column (3) for Green ISS strategies are positively but not significantly related to innovation performance ($\beta_2 = 0.22$; $p-value = 0.13$ and $\beta_3 = 0.36$; $p-value = 0.11$, respectively). Similar results are displayed in Column (4), where all the variables are incorporated into the model. Column (5) shows the Variance Inflation Factor (VIF). These results support H1a but do not substantively support H1b and H1c. Ceteris paribus, and according to OLS estimation, increases of 1% in Digital ISS strategies would produce an increase of 0.68% in the innovation performance of firms.

Table 4
OLS model with control variables.

	(1) Innovation performance	(2) Innovation performance	(3) Innovation performance	(4) ISS set in Innovation Performance
Digital ISS	0.571** (2.743) *VIF: 2.112*			0.519** (1.865) *VIF: 1.910*
Operational ISS		0.224 (1.615) *VIF: 1.926*		0.195 (1.462) *VIF: 2.108*
Green ISS			0.361 (2.159) *VIF: 2.134*	0.284 (1.939) *VIF: 1.910*
Firm turnover	−1.882*** (-4.564)	−1.867*** (-4.806)	−1.831*** (-4.445)	−1.811*** (-4.730)
Firm age	−0.055** (-2.881)	−0.045** (-2.589)	−0.044** (-2.761)	−0.044** (-2.127)
Constant	0.997*** (20.846)	1.033*** (21.424)	1.255*** (21.898)	1.349*** (20.891)
Observations	1144(154)	1144(146)	1144(202)	1144(502)
R-squared	0.241	0.119	0.121	0.281
Industry dummies	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes

P-values in *italics*. ***p < 0.01, **p < 0.05, *p < 0.1.

Hypothesis 2 states that SDGs, via the SDG-I, have a moderating effect on the relationship between ISS strategies and innovation performance. The results show that the SDG-I has a negative effect on innovation performance ($\beta\_SDG\text{-}I_1 = -0.30$; *p-value*<0.05, $\beta\_SDG\text{-}I_2 = -0.32$; *p-value*<0.05 and $\beta\_SDG\text{-}I_3 = -0.30$; *p-value*<0.05, respectively) - as seen in columns 1 to 3 in Table 5. Therefore, higher SDG-I scores seem to lead to a decline in innovation performance. When considering the interactive effect of ISS strategies and the SDG-I, the results show that the SDG-I positively and significantly moderates the relationship between Operational and Green ISS ($\beta\_(OPE*SDG\text{-}I) = 1.32$; *p-value*<0.10, and $\beta\_(GREEN*SDG\text{-}I) = 0.63$; *p-value*<0.05, columns (2) and (3), respectively). Moreover, these interactive parameters are higher than the parameters for Operational ISS and Green ISS (testing for no differences between parameters, $F = 0.879$; *p-value* $= 0.349$, and $F = 0.333$; *p-value* $= 0.564$). These results partially support H2. Columns (4) and (5) illustrate all the variables analyzed in the model along with their corresponding VIF values.

Fig. 2 illustrates the moderating impact of SDGs on the relationship between ISS and innovation performance. Overall, the results obtained support H1a and partially support H2. These results therefore indicate that ISS are positively related to higher innovation performance where the SDG normative framework is absent. However, when considering the effect on a country's degree of SDG accomplishment, the findings sustain that Operational and Green ISS types are positively and significantly related to higher innovation performance outcomes.

6. Concluding remarks, implications, and future research

This study contributes to the current analysis on innovation performance antecedents of manufacturing firms that implement servitization-based industrial offerings in OECD countries. The findings demonstrate that the implementation of different ISS types—namely Digital, Operational and Green ISS—has a positive impact on the innovation performance of firms, especially in terms of patent productivity. In particular

Table 5
OLS model with control variables and SDG orientation.

	(1) Innovation performance	(2) Innovation performance	(3) Innovation performance	(4) ISS set in Innovation Performance
Digital ISS	0.871 (1.672) *VIF: 2.586*			0.823 (1.772) *VIF: 2.430*
Operational ISS		0.374 (1.621) *VIF: 3.050*		0.209 (1.589) *VIF: 3.232*
Green ISS			0.442 (2.330) *VIF: 3.259*	0.341 (1.837) *VIF: 3.151*
SDG-I	−0.296** (-1.230)	−0.324** (-1.335)	−0.298** (-1.402)	−0.301** (-1.345)
Digital ISS * SDG-I	0.799 (1.563) *VIF: 2.532*			0.801 (1.532) *VIF: 2.410*
Operational ISS * SDG-I		1.321* (1.402) *VIF: 3.186*		1.406* (1.421) *VIF: 0.360*
Green ISS * SDG-I			0.627** (0.588) *VIF: 3.323*	0.654** (0.531) *VIF: 3.197*
Firm turnover	−1.743*** (-3.789)	−1.836*** (-4.775)	−1.827*** (-4.301)	−1.821*** (-4.376)
Firm age	−0.038** (-2.215)	−0.043** (-2.564)	−0.042** (-2.602)	−0.039** (-2.330)
Constant	1.229*** (18.936)	1.118*** (20.675)	1.239*** (21.786)	1.278*** (20.782)
Observations	1144(154)	1144(146)	1144(202)	1144(502)
R-squared	0.246	0.221	0.127	0.286
Industry dummies	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes

P-values in *italics*. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

the results sustain that, in absence of the SDG normative framework, Digital ISS is the most relevant type of service for promoting innovation. We attribute this effect to the innovation priorities enabled by the context, which allows firms to primarily focus on satisfying customer needs and seeking new and better ways to offer highly personalized value propositions (Kohtamäki et al., 2021). Conversely, under the SDG framework, Operational ISS and Green ISS are the most significant service types related to innovation performance outcomes. Thus, following the same rationale, we ascribe this effect to the firms' need to largely comply with normative standards in order to develop innovations that, primarily, align with SDG requirements—with respect to operativeness and environmental control (Parmentola et al., 2022). Therefore, the adoption of ISS can be considered a crucial determinant in the innovation capacity of manufacturing firms, irrespective their specific contexts (Niebel et al., 2019).

In this respect, the study results suggest that in the absence of a normative framework such as SDGs, adopting Digital ISS serves as a prominent service type for promoting innovation gains. However, in the SDG framework, the inclusion of Operational and Green ISS enhances the innovation capacity of firms in countries with higher degrees of SDG accomplishment. This indicates that adopting ISS offers a comprehensive solution for industrial settings because these services can be arranged to meet specific environmental requirements (i.e., with and/or without SDGs) and improve the performance outcomes of firms (Contini et al., 2023). Furthermore, the study results reveal that establishing normative frameworks, such as SDGs, negatively affects the innovative capacity of firms. This can be attributed to the fact that such regulations engender substantial changes in a firm's economic, social and environmental actions, leading to the reformulation of strategies and capabilities (Gyimah et al., 2023), which may ultimately hinder their capability to innovate. These findings have a number of important theoretical and managerial implications for researchers and practitioners.

6.1. Theoretical implications

This study's findings have several implications for academic literature on servitization (Vandermerwe and Rada, 1988) and the natural resource-based view of the firm (Hart, 1995). First, it introduces a novel service typology (i.e., ISS) focused on manufacturing contexts, which holds considerable potential for enhancing the innovation performance of firms. While these services are widely documented in global databases (e.g., ORBIS), to the best of our knowledge, this study is the first attempt to illustrate their nature and potential impact comprehensively for research on servitization and sustainability. Moreover, this study sets the stage for ISS adoption and sustains that it can be applied across the entire product lifespan (Rabetino et al., 2015). This new service typology therefore has the potential to be widely embraced and incorporated into well-established frameworks in servitization research (cf. Brax and Visintin, 2017; Bustinza et al., 2021).

Second, the study reveals the influence of SDGs on the capability of manufacturing firms to innovate. In this regard, it suggests that this framework, on its own, can have a negative impact on innovation capacity. This constitutes a critical aspect not only for studies on innovation and servitization, but also for research on sustainability and the potential consequences of sustainable transition for the performance and competitiveness of firms (Hermundsdottir and Aspelund, 2021).

Finally, this study depicts how adopting a servitization strategy enables manufacturing firms to align with global normative frameworks and promote performance improvements (Opazo-Basáez et al., 2018). This finding is of significant theoretical relevance as it suggests that servitization equips firms with critical resources in order to adapt competitively and enhance performance outcomes across varied but, above all, increasingly stringent sustainability settings (Andersen, 2021; Bustinza et al., 2024).

6.2. Managerial implications

This study contains three main implications; first, the findings suggest that implementing ISS can assist firms in navigating environmental challenges while also fostering innovation within industrial settings. As a result, firms should view the adoption of these services as a means to enhance competitiveness and adaptability (Vendrell-Herrero et al., 2023).

Second, ISS possesses inherent attributes that can stimulate the innovative capacity of firms operating in diverse regulative contexts. In this regard, in a non-SDG context, emphasis on customer relations and product enhancement gains significance (i.e., Digital ISS). Conversely, in the SDG framework, ensuring product functionality (i.e., Operational ISS) and environmental sustainability (i.e., Green ISS) becomes paramount. As a result, ISS enables firms to devise strategies that are specifically tailored to their competitive environment (i.e., context dependent), thereby ensuring improved performance outcomes (Fernando et al., 2019).

Finally, firms must consider the potential of the SDG-I in establishing/adapting their servitization-based competitive strategy. In this respect, the SDG-I provides firms with a consistent metric that helps them understand the most appropriate ISS type according to normative requirements. As a result, firms can adjust their ISS adoption so as to comply with each country's regulations, thus ensuring that they can continue to innovate regardless of the regulatory or supervisory landscape (Azmat et al., 2023).

From a managerial perspective, these implications highlight the importance of ISS in enabling firms to adjust to a normative framework, such as that established by SDGs, while also supporting innovation and environmental managers in establishing ISS arrangements that enhance the innovation performance of firms in alignment with nationwide SDG objectives.

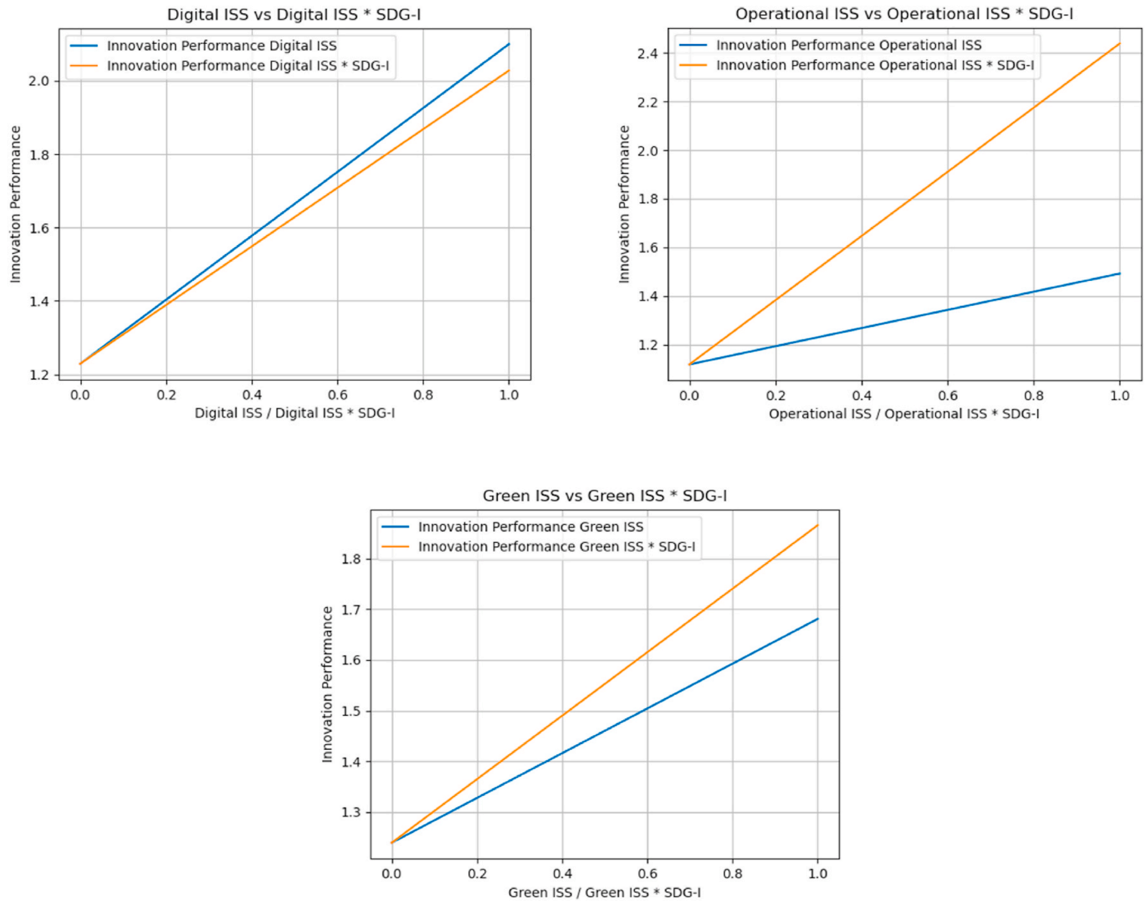

Fig. 2. Moderating effect of SDGs in the relationship between Industrial Solution Services (Digital ISS, Operational ISS, and Green ISS) and innovation performance. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

6.3. Limitations and future research

This article is subject to limitations that open doors to future research. First, it examines the effect of ISS on innovation performance, especially in terms of patent productivity, and how the normative SDG framework can moderate the innovation capacity of manufacturing firms. However, it is important to acknowledge that there may be additional unobserved variables, such the technological infrastructure or knowledge management mechanisms in firms, which could also influence analysis examining the relationship between ISS and innovation performance. Future studies should take these factors into account, since the results may depend on the influence exerted by such aspects.

Second, the observed effects focus solely on how SDGs, via the SDG-I in specific, impact the relationship between ISS and innovation performance. However, the internal mechanisms driving these effects in firms cannot be observed directly. Even though the hypotheses are supported by a theoretical rationale, future studies should include exploratory single-and multiple-case studies to either challenge or confirm the evidence provided.

Third, the study relies on cross-sectional data, and it is recommended that future studies use a longitudinal design so as to gain understanding in two areas. Firstly, to gain insight into the initial impact of adopting the SDG framework and how this effect develops over time. Secondly, to understand the gradual improvement in innovation performance as the firm integrates the required ISS provisions. Furthermore, the study examines the individual complementarity effect of ISS and SDGs without establishing a sequential path for prioritizing ISS implementation. Therefore, future longitudinal studies should strive to establish a sequential approach for ISS adoption.

Finally, the findings reached in this research are substantiated in the analysis of large manufacturing firms in OECD countries. This study should therefore be replicated in various contexts, with comparable normative frameworks and different firm sizes, in order to validate or refute the results obtained.

CRediT authorship contribution statement

Marco Opazo-Basáez: Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Oscar F. Bustinza:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Luís M. Molina:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Acknowledgements

Grant C-SEJ-020-UGR23 funded by Consejería de Universidad, Investigación e Innovación and by ERDF Andalusia Program 2021–2027. Funding for open access charge: Universidad de Granada / CBUA.

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