Journal of Environmental Management 330 (2023) 117099

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Performance effects of green production capability and technology in manufacturing firms

Jakeline Serrano-García [a,b,*], Josep Llach [c,d], Andrea Bikfalvi [c], Juan José Arbeláez-Toro [e,f]

[a] Universitat Politècnica de València, Valencia, Spain
[b] Faculty of Economic and Administrative Sciences, Instituto Tecnológico Metropolitano, Medellín, Colombia
[c] Department of Business Administration and Product Design, Universitat de Girona, Girona, Spain
[d] UPF Barcelona School of Management, Universitat Pompeu Fabra, Barcelona, Spain
[e] AMADE, Polytechnic School, Universitat de Girona, Girona, Spain
[f] Faculty of Engineering, Instituto Tecnológico Metropolitano, Medellín, Colombia

ARTICLE INFO

Keywords:
Financial performance
Environmental performance
Green production capability
Green product innovation
Manufacturing companies
Technology

ABSTRACT

The proclamation of the sustainable development goals is driving companies to implement protective measures that favour the environment, thereby occupying a strategic place in the creation of green product innovation (GPI). This new management paradigm could be impacting capabilities, techniques, technologies, efficient energy use and green-oriented production policies and systems. Therefore, one of the challenges is to configure green production capabilities (GPC) coordinated with the technology dimension (TECH) because the design of ecological products and their manufacture requires the backup of capabilities and the possible support of green technology. To this effect, this article aims to establish the impact of the association of GPC and TECH on organisational performance. To do so, we test whether the adoption and high implementation of GPC and TECH affect environmental and financial performance. Empirical evidence is supported by the European Manufacturing Survey (EMS), using a sample of 1018 manufacturing companies from seven European countries. Our results show that the adoption of GPC and TECH and their high levels of implementation have a significant impact on environmental and financial performance. Regarding the association between the implementation of GPC and TECH, its contribution to environmental performance but not financial performance is evidenced. Furthermore, at high levels of implementation of this association, there is no significant effect on either environmental or financial performance. These findings drive theoretical and practical implications and provide opportunities for academics, managers and government bodies.

1. Introduction

"*Advances in technology and science have left no aspect of life untouched. The fourth industrial revolution has been deeply transformative, connecting and networking the world in hitherto unimaginable ways, generating innovation and being a driver of progress for sustainable development […] Let us not have any illusions. It would be easy to assume that "business as usual" would simply mean continuing as we are. That is not what will happen. A business-as-usual approach will produce […] disaster. […] We need more innovation […] and the need to work and act together will help us seize the opportunity to correct course and shape a better future*" (United Nations, 2022). These are the words and vision statement formulated by the current secretary of the UN, an institution that has become the flagship of sustainable development. Collective action calls for all actors of regional, national and international eco-systems to contribute to this cause, business being highly relevant due to its capacity for innovation. Greening innovation -in both product and process-is both a challenge and an opportunity for the sustainability agenda.

The proclamation of the UN's Sustainable Development Goal (United Nations, 2015), already almost a decade ago, together with stakeholders' increasing environmental awareness and pressure from this direction, are prompting companies to implement environmental prevention and protection measures. Sustainable orientation is gradually being considered as crucial, followed by its potential inclusion in the area of strategic management (He et al., 2021; Suganthi, 2019) and operations. Its most material and visible effect is the creation of green

* Corresponding author. Faculty of Economic and Administrative Sciences, Instituto Tecnológico Metropolitano, Cl. 54a # 30-01, Medellín, Colombia.
E-mail addresses: jserrano2005@gmail.com, jakelineserrano@itm.edu.co (J. Serrano-García), josep.llach@udg.edu, josep.llach@bsm.upf.edu (J. Llach), andrea.bikfalvi@udg.edu (A. Bikfalvi), juanarbelaez@itm.edu.co, jjarbetoro@gmail.com (J.J. Arbeláez-Toro).

https://doi.org/10.1016/j.jenvman.2022.117099
Received 6 August 2022; Received in revised form 13 December 2022; Accepted 19 December 2022
Available online 6 January 2023
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product innovation.

With business practice finding opportunities in green production techniques and products with positive environmental impact, academic research is likewise devoting attention to the field. A recent trend in this field with a growing body of knowledge and research (Begum et al., 2022) suggests that green innovation could be considered a critical factor of productivity since its creation harmonises with the reduction of costs and greenhouse gas emissions, energy savings, use of clean technologies and production and processing, making better use of raw materials (Dost et al., 2019; He et al., 2021). Therefore, green product innovation should favour a company's progress towards sustainable development (Chen et al., 2006; Lin et al., 2013), which would further contribute to reducing environmental impacts and, in consequence, favour the company's image, business objectives and competitive advantage.

However, many companies are still hesitant about or distrust the value that the development of green product innovation can provide. The literature suggests different reasons to explain this lack of conviction: (i) lack of experience in green issues, causing core competencies to be neglected and competitiveness to be lost (Vrchota et al., 2020); (ii) dealing with new paradigms in terms of changes in technologies, operations management and commercial strategies (Suganthi, 2019), with a focus on the reorganisation of resources and capabilities, generating additional costs; and (iii) limiting responsiveness on the part of the company given the production conditions, the economic situation and the real value of the integration of technologies and organisational and operational systems (Yan and Zhang, 2021). Based on these reasons, the reorganisation of resources and capabilities seems to be a common concern to adopt this new management paradigm, although some authors (Ikram et al., 2021) even formulate and suggest a roadmap for green technology, explicitly making reference to organisational structure, in the first stage, and afterwards implementation.

To gain knowledge of the management approach leading to GPI development, Serrano-García et al. (2021) identified and categorised the determinants of GPI in association with green capabilities (GIC) and organisational dimensions (OD). Specifically, they identified seven GICs: green strategic planning capability, green organisational innovation capability, green research and development capability, green production capability, green organisational learning and relationship capability, green resource management capability and green marketing capability; and five ODs: human resources, organisational behaviour, technology, corporate environmental responsibility and environmental regulation. The same authors (Serrano-García et al., 2022) later demonstrated how these capabilities and dimensions form a system of interrelated elements contributing to the restructuring of organisational processes in favour of the creation of GPI. Therefore, companies that have the ability to reconfigure their capabilities to meet the challenges of the natural environment in conjunction with green technology could thrive in the long term by achieving sustainable competitive advantage (Celikyay and Adiguzel, 2020; Hart, 1995; Teece, 2007). The inclusion of green technologies contributes to reducing ecological degradation, driven by efficient production modes that contribute to the elimination of non-ecological products (Ahmad and Wu, 2022), shaping a more efficient, ecological and sustainable product in the long term (Lopes et al., 2022).

Having recognised that GICs are a strategic factor for creating GPI, one of the challenges is to reconfigure green production capability (GPC) and interrelate it with the technology organisational dimension (TECH) (Serrano-García et al., 2021) because the design of ecological products and their manufacture and production require the support of capabilities (Hartmann and Germain, 2015). It likewise requires the support of green technology as competition, since the essence of green processes is underpinned by the ecological technologies that will promote the production of more green goods, in coordination with the company's structure, system and resources (Celikyay and Adiguzel, 2020; Chang et al., 2022), seeking the transformation and ecological updating that could generate sustainable industrial advances. However, there is a lack of research on the challenges of integrating technologies at the organisational level for the manufacture of green products (Khan et al., 2021a, b). There is also a demand for more research and empirical studies that describe how green technology influences economic and environmental performance (Li et al., 2020). Few studies have considered organisational factors that link innovation in green technology to performance (Xie et al., 2019). Furthermore, it is necessary to respond to environmental challenges vis-à-vis green technology innovation and the mechanisms that intervene to achieve business performance (Wang et al., 2021). Likewise, it is necessary to explore what capacities companies may possess to respond to the challenges of sustainable development (Amui et al., 2017). Therefore, it is necessary to advance in the identification, for example, of the effect of the green production capacity and the link with the performance of the company. A recent and comprehensive review published by (Jasti et al., 2022) analyses more than 900 articles on the topic of sustainable production system, identifies a series of gaps such as the need to implement sustainable constructs as a coherent set instead of individual constructs, relating them to sustainable performance, and provides sound evidence from multiple sectors and several countries. However, a previous step to implementation and an important predecessor of green manufacturing are drivers. In the list published by Mittal and Sangwan (2014), technology and organisational resources appear as selected drivers, but they do not rank among priorities as incentives, public pressure, present and future legislation and public image. Additionally, future research needs to focus on a broad geographical scope to explore organizational factors in pursuit of the adoption and profitability of environmental innovation (Vasileiou et al., 2022).

Positioned at the confluence of these gaps, our study aims to describe performance effects of the association between GPC and TECH on performance, considering different nuances of performance from their mere implementation or the rather high adoption of separate or combined practices, tested in the European companies surveyed. The empirical context for the study is built using first-hand information provided by companies covering the entire manufacturing range of economic activities, with data from seven European countries included in the European Manufacturing Survey (EMS). The structure of this international survey is based on thematic blocks designed to obtain information on the respective characteristics and effects at the level of organisational and environmental concepts. Data from different rounds of the EMS have already been used in several works under environmental approaches, including the study performed by (Gerstlberger et al., 2014; Palčič and Prester, 2020; Pons et al., 2013, 2018; Šebo et al., 2021).

This study's overall contribution is the experimental orchestration of the relationship between green production capability and technology in the pursuit of organisational performance, further detailed for ecological and financial performance perspectives. The ultimate aim is to contribute to the emerging and growing body of knowledge on green innovation, a key ingredient and a crucial mechanism towards the achievement of sustainable development.

The article is structured as follows. In section two, the theoretical background is presented, and the hypotheses developed. Section three describes the methodology. The results and discussions are presented in section four. Last, in section five, the conclusions, implications, limitations and future lines of research are considered.

2. Theoretical background and hypothesis development

2.1. Literature review

The purpose of this review is to examine previous research papers in chronological order from the theory of resource-based view (RBV) and its variants to the approach of green technology innovation, to understand the progress of the creation of GPI in pursuit of organisational performance (Table 1).

Table 1
Review of quantitative studies on the topic of GPI performance.

Author(s)	Objective/questions	Theoretical perspectives	Methodology	Key findings
Chen & Chang (2013)	To explore the influences of green dynamic capabilities and green transformational leadership on green product development performance.	Dynamic capabilities theory	Taiwan's electronics industry using structural equation modelling	Support for how green dynamic capabilities and green transformational leadership are positively related to green product development performance.
Hartmann & Germain (2015)	To understand the relationships between integration capabilities, ecological product design, and manufacturing performance	RBV	769 Russian manufacturers and use of structural equation modelling	Identification of how integration capabilities can be exploited to help improve the effects of ecological product design in pursuit of manufacturing performance.
Dangelico et al. (2016)	Which sustainability-oriented dynamic capability SODC are needed to develop green innovation and eco-design capabilities? Which of these capabilities leads to the better market performance of green products?	Sustainability-oriented dynamic capability	Use of survey data collected from 189 Italian manufacturing firms, with confirmatory factor analysis and structural equation modelling.	Indicates how the creation and reconfiguration of sustainability-oriented dynamic capabilities affect market performance; and how external resource integration, internal resource integration, and resource building and reconfiguration affect capacity for ecological design and, consequently, market performance. Also identified is how the integration of external resources is the only factor that impacts capability for ecological innovation and intervenes in the link between the integration of external resources and market performance.
Andersén (2021)	To contribute to the development of a relational NRBV (RNRBV) on product innovation by examining the relationships between GPI, green suppliers, and differentiation advantage	The natural-resource-based view (N-RBV)	305 Swedish small manufacturing firms using structural equation modelling.	Identifies a direct relationship between GPI and organisational performance. Likewise, it identifies how suppliers that contribute green inputs facilitate the achievement of GPI, generating an essential alliance and confirming the importance of the relationship between NRBV and product innovation.
Huang & Chen (2022)	Evaluate the coercive, normative, mimetic institutional pressures and the "green firm's slack", referring to the excess of resources available for the implementation of green alternatives, identifying them from the perspective of the resource-based view (RBV) for green product innovation success. The company's green slack is also examined as a mediator between institutional pressures and GPI.	Institutional theory and resource-based perspective.	A sample of 170 Taiwanese high-tech firms, including electrical and electronics manufacturers, with confirmatory factor analysis and structural equation modelling	Verifies a positive relationship between the analysed variables affecting company performance, identifying that the greater the environmental pressure and the extra availability of resources, the more likely the company is to develop successful green products, resulting in better environmental and economic performance.
Xie et al. (2019)	What are the relationships between green process innovation, green product innovation and firms' financial performance?	Green technology innovation	209 companies that belong to polluting manufacturing industries, using regression analysis.	Identifies how green process innovation has a positive impact on green product innovation and how the two can contribute to financial performance, needing to complement each other to ensure benefits from green technology innovation.
Afum et al. (2021)	Are there any significant interrelationships between green lean production systems, green technology adoption, green product innovation, social sustainability performance and green competitiveness? Do green technology adoption and green product innovation play mediation roles between lean production systems, social sustainability performance and green competitiveness?	Green technology	197 managers of manufacturing firms in Ghana, using structural equation modelling	Findings support how green as lean production systems present a positive effect on the interrelationships between green technology adoption, green product innovation and green competitiveness, but not so much on social sustainability performance.
Wang et al. (2021)	To test the relationships between different types of green technology innovation and the similarities and differences of their transmission paths in economic performance.	Green technology innovation	642 industrial enterprises in China with exploratory factor analysis.	Verifies how green technology innovation can effectively improve the economic performance of enterprises.

Although there are valuable studies investigating how alternatives that may favour the development of GPI to impact organisational performance are interrelated, the need for additional research from the RVB perspective with its extension to GIC is identified, and particularly in this case from GPC and from the perspective of the TECH organisational dimension given that various studies identify technology as a tool, thus limiting its scope and strategic position in the organisation. Therefore, the original contribution we make with this research is the association of GPC and TECH in pursuit of the development of GPI that facilitates organisational performance.

2.2. *Green production capability*

The post-industrial system based on mass production (Mark et al., 2001) is undoubtedly an advantage for the company. However, this behaviour may be far from compatible with the environment. In its need to offer products, the company may be transforming its production into an excessive use of resources, converting them into massive amounts of waste and pollution (Mark et al., 2001). Considering that current profit margins are very narrow, failure to address environmental challenges could also lead to difficulties in surviving (Shete et al., 2020). It is therefore necessary to opt for sustainable production under the protection of a diligent organisation and with a strategic focus on green innovation, especially since green manufacturing consists in the creation of products whose essence lies in the reduction and/or elimination of harmful substances and use of natural resources, focusing production on renewable raw materials and clean technologies (Vrchota et al., 2020). Further, green production involves the ecological design and use of packaging that is respectful to the environment, and involves putting the 6 Rs - reduce, reuse, recycle, recover, redesign and remanufacturing resources conservation (Seth et al., 2018)- into practice. To this effect, green production is explicitly focused on maximising efficiency, which impacts on operations and productivity, favouring the creation of green products aimed at creating customer satisfaction in pursuit of financial profit (Ikram et al., 2021; Le, 2022).

Since production is directly related to eco-efficiency, the company could acquire a competitive advantage over traditional manufacturing industries given that green production facilitates the creation of GPI, which contributes to environmental protection and is a competitive factor aligned with adaptation and resilience (Forés, 2019; Serrano-García, Bikfalvi, Llach, Arbeláez-Toro et al., 2022). Consequently, companies may currently require the design and development of green processes and products, which have a positive effect on the environment and at the same time preserve the sustainable operation of the organisation (Wang et al., 2022).

Production practices to avoid material losses due to leakage or overuse to reduce or eliminate the presence of heavy metals, carcinogenic substances or chlorofluorocarbons; the use of technologies that help to optimise production, control overall quality, and save water and energy; and the creation of recycling circuits and the recovery of residual resources to be used in production, among others (Fiksel, 1996; Viñolas Marlet, 2005), are valuable production capabilities currently needed by the organisation in pursuit of the competitive advantage that allows financial and environmental performance to be impacted, given that the creation and implementation of environmental solutions depends significantly on the capabilities possessed by the organisation (Bhupendra and Sangle, 2016). This is consistent with Barney (1991), whose RBV identifies resources and capabilities as valuable and determinants of competitive advantage, facilitating the formulation and implementation of strategies that lead to process efficiency and effectiveness, thereby empowering the bases for creating GPI.

From the RBV perspective, when creating GPI the company can accumulate unique and valuable knowledge resources, giving them the advantage and creating difficulties for competitors, and consequently impacting on the performance of the company (Barney, 1991; Xie et al., 2019). In this regard, it is key to involve the natural resource-based view (NRBV) (Hart, 1995), which identifies how resources and capabilities oriented towards green production could be an organisational tool that favours environmental protection, meaning a future competitive advantage. A necessary feature to this effect is the dynamism focused on green innovation, calling on dynamic capabilities (DCs) that represent the potential for adapting resources and competencies to the companies' various evolution and developmental challenges (Teece, 2007). Next, and with the aim of responding to the challenge of innovation, innovation capabilities (ICs) emerge from DCs, corresponding to the integration of technological innovation and capability (Rhodes et al., 2018), as commented in (Yoo et al., 2018). According to the Oslo Manual, ICs are the organisational and managerial capabilities to mobilise, command and exploit resources in pursuit of the creation, development and introduction of technological innovations in new or improved products (goods or services), production processes and company marketing and organisation (OECD/Eurostat, 2005, 2018).

Therefore, and given the current challenge of companies to take environmental sustainability on board, a strategic approach of ICs is their orientation towards the green (GIC). In light of the determinants of GPI, Serrano-García et al. (2021) propose an original notion about GICs:

"[GICs] are understood as organisational and dynamic abilities built and/or acquired by an organisation in accordance with its strategic and operational management and aimed at developing GPI and contributing to solving the environmental challenges. GIC must be identified and integrated into each organisational function to respond to the new demands or necessary improvements within the context of GPI development. As a result, this would help firms to reduce and/or eliminate the pollution they cause, thus gaining comparative and competitive advantages" (p. 5).

GICs influence sustainable competitive advantages (Mellett et al., 2018). To this effect, from the manufacturing function, the deployment of GPC could be required to facilitate the redesign, transformation and support of resources and processes towards formulating the organisation's environmental strategy in pursuit of the development of GPI, hence the need for and importance of distinguishing and possessing GPC. Serrano-García et al. (2021) propose an original notion about GPC: "firms' abilities to develop and manufacture GPI based on stakeholders' needs, and R&D results aimed at preventing the generation of waste, minimising the use of materials and inputs, and fostering the employment of eco-efficient materials and waste reuse" (p. 6); and in such a way where manufacturing executives and the company management identify GPC as a strategic tool and generator of competitive advantage in the current environment.

Previous research by Andersén (2021) and Hartmann & Germain (2015) identifies the probability of financial and environmental performance being associated with companies' capabilities to innovate in pursuit of green development. Similarly, previous studies highlight the substantial benefits of the green innovation strategy, boosting performance and represented in green production capacity that facilitates reduced production costs and energy consumption and the reuse of materials, ultimately impacting on organisational efficiency (Wang et al., 2022). Since green innovation is considered an organisational phenomenon that involves the potential to design, develop and launch new sustainable products in the market, GPC could be directly linked to the development of GPI because this would facilitate the operability of an eco-sustainable production, meaning lowered expenses and environmental impacts, thereby contributing to the improvement of environmental and financial performance standards. To this effect, in line with the previous approach, we believe that GPC is associated with the performance of the organisation and the following hypothesis is formulated:

H1. The adoption of green production capability has a positive effect on performance.

To complement the above hypothesis, we want to distinguish between different degrees of adoption regarding the capabilities implemented. This may be possible because the EMS categorises the estimate of the degree of adoption of capabilities as "low" (recently introduced, without reaching full potential), "medium" (partial adoption) or "high" (adoption close to total potential), allowing the company to identify the degree of actual adoption of capabilities in relation to the level identified as potential for the company. Based on adoption categories and emerging from this approach, we would expect to confirm H1a:

H1a. : A high degree of adoption of green production capability has a positive effect on performance.

2.3. Technology

Under the notion of organisational architecture, the manager is required to consider a model of organisational congruence supported by organisational dimensions that facilitate the transformation of processes in the company (Nadler et al., 2011). Organisational dimensions are made up of people, the structure, processes, technology, culture and organisational behaviour (Daft, 2011; Nadler et al., 2011; Robledo-Velásquez, 2019). Therefore, the challenge is to detect what dimensions and their congruence improve company performance (Nadler et al., 2011). In line with the results of Serrano-García et al. (2021) and Serrano-García et al. (2022) on the characterisation of the five organisational dimensions, in this article we focus on TECH from devices, technical methods and systems as part of an organisational strategy vis-à-vis the challenge of responding to the constitutive determinants of GPI. To this effect, and in brief, in pursuit of implementing green product design and creation strategies, the use of technology coordinated with the company structure, system, resources and capacities is essential (Celikyay and Adiguzel, 2020).

The catastrophic increase in environmental pollution in recent decades, the use of energy inefficient technologies (Khan et al., 2021a, b) and managers' understanding of reliance on current technologies may be generating incompatibility in terms of advancing towards the manufacture of green products (Dost et al., 2019). In turn, technology should not be considered strictly as the net description of the "artifact", but as the sum of knowledge and skills that enables the transformation of organisational processes to modify traditional manufacturing in an approach of separation and unpacking, enabling recycling, waste management, reuse and a reduction in energy consumption, harmful substances and materials (Fiksel, 1996), all key determinants in the achievement of GPI (Albino et al., 2009; Berchicci and Bodewes, 2005; Jabbour et al., 2015). The transfer and acquisition of clean technology and environmentally friendly management methods are also needed (Viñolas Marlet, 2005), identifying technology as a strategic factor for optimising the design, production and development of green products; requiring the establishment of a planning system to understand the importance of the transfer of green technology and the identification of possible financial effects (Ikram et al., 2021); and, given that the implementation of green technology could be impacting on improving the corporate image, reducing the environmental impact, increasing participation in the capital market and boosting corporate financing (Ma et al., 2021). The research by Shahzad et al. (2022) suggests how innovative green technology can be a simple process for implementation, facilitating the capacities required in green production and enabling long-term financial results.

The concept of green technologies and processes was introduced in the 1960s, emerging from the international activism of the environmental movements of industrialised nations, and gaining popularity thanks to the Kyoto Protocol, the Copenhagen Conferences and the Paris Agreement of the United States Nations Framework Convention on Climate Change (Vrchota et al., 2020). Green technology "refers to technology that can save resources and reduce environmental pollution during the production process" (Dong et al., 2021, p. 2). Furthermore, technological orientation could be interpreted as the possibility of opening companies up to new ideas and the tendency to adopt technologies for the development of ecological products (Celikyay and Adiguzel, 2020). For its part, ecological technology is directly related to the application of green innovation to launch the resulting ecological products in the market, in line with the concept of sustainable development (Wang et al., 2021). The use of green technologies therefore enables the introduction of green processes in production, favouring the environmental impact (Vrchota et al., 2020). Green technology innovation is recognised as a necessary and contributing factor for the reduction of greenhouse gas emissions (Sun et al., 2020), and implementing innovation in pollution prevention technologies can impact on achieving green products (Dost et al., 2019). In synchronicity with the current dynamic environment, not considering the development of technology would be disastrous for the viability of businesses that seek to take care of the environment with their actions (Le, 2022). Thus, the role of technology must be further expanded to facilitate the management of green manufacturing, from eco-innovative designs to the reduction and recycling of waste, emissions and energy, among others (Seth et al., 2018). Similarly, green technologies could play a vital role in balancing the economic objectives of the company and environmental protection (Palmer and Truong, 2017). There is an imperative need to develop clean and ecological technologies that lead to the reduction of pollution and emissions, favouring production processes (Erzurumlu and Erzurumlu, 2013; Khan et al., 2021a, b).

Palmer and Truong (2017) identify the lack of attention to understanding how upgrades in green technology can contribute in a commercially and environmentally viable approach. From the financial perspective of innovation, green technology can also achieve an unprecedented level of performance in reducing resources, production and operating costs; improving the quality of processes, the manufactured product, and the scalability and response of new products; achieving more efficient management of manufacturing data; improving communication between departments; and increasing market share, which could lead to an impact on productivity resulting in production efficiency (Llach Pagès et al., 2009; M. Wang et al., 2021), prompting the creation of a market accepted offer of GPI that can impact the environmental and financial performance of the company. According to Yin et al. (2021), "systematic innovation of green technology is the key to implement green manufacturing, and it is hugely significant to promote high-quality financial development" (p. 1).

Therefore, in light of the above, we believe that TECH is associated with organisational performance, implying the following hypothesis:

H2. The adoption of technology has a positive effect on performance.

To complement the above hypothesis, we want to distinguish between the different degrees of adoption of the technologies implemented, in which case we expect the following hypothesis to be confirmed:

H2a. : A high degree of adoption of technology has a positive effect on performance.

3. Methodology and measurement

3.1. Data collection

For the evaluation and empirical analysis, we proceeded using data collected from the EMS 2018 edition, which is the sum of thematic blocks that seek to measure attributes and impacts at the level of organisational, environmental and technological concepts. The objective of the survey is to obtain information on production processes, asking companies in the manufacturing sector about the use of new technologies and innovative organisational concepts. The survey questions are decided by the participants of a consortium made up of European research centres and universities, administered by the Fraunhofer Institute for Systems and Innovation Research ISI. EMS-2018 was answered by approximately 3250 manufacturing companies from 15 European countries: Germany, Switzerland, Austria, Croatia, Slovenia, Spain, the Netherlands, Denmark, Portugal, Sweden, Serbia, Lithuania, Slovakia, the Czech Republic and Norway (Fraunhofer Institute for Systems and Innovation Research ISI, 2021)).

Various research projects associated with environmental approaches have been carried out based on the data gathered in different versions of the EMS. Under empirical evidence, and using a sample of manufacturing companies in Spain, the study of Llach et al. (2012) present the relationship between implementing the environmental management system and organisational innovations. From a sample of 335 manufacturing companies in Denmark, the authors Gerstlberger et al. (2014) study the interaction between product innovation and energy efficiency measures in pursuit of the generation of strategies for sustainable development. Using the Spain and Slovenia samples, Palčič et al. (2013) map the relationship between the adoption of technologies in pursuit of energy reduction and the consumption of resources in the production of the manufacturing companies evaluated. Based on the samples from France, the Netherlands, Slovenia, Spain and Croatia, with a total of 763 firms, Sartal et al. (2017) investigate the contribution of environmental and information technologies to lean manufacturing (LM) capability to achieve better performance. Under the empirical evidence of a sample of 206 manufacturing companies in Spain and Serrano-García et al. (2022a, b) analyse what configuration of green innovation capabilities and organisational dimensions leads to achieving green product innovation.

3.2. Sample

The data sample in this article is represented by n = 1018 companies, corresponding to the sub-samples of Croatia (101), Lithuania (199), Spain (81), Serbia (235), Slovakia (108), Slovenia (127) and Sweden (167). Five criteria were considered in selecting and organising the samples of the seven countries under study: a) the sample selection approach and the EMS questions were applied across the board to all seven countries; b) according to the result of the Global Innovation Index, which calculates the indices referring to inputs - capabilities for the generation of innovation - and the results for innovation of the economies of 126 countries analysed in the 2018 version, finding how in Europe, and specifically at the level of the countries observed in this paper (Sweden, Spain, Slovenia, Slovakia, Lithuania, Croatia and Serbia with efficiency ratios of 0.82, 0.7, 0.74, 0.74, 0.63, 0.7, 0.63, respectively), the countries present scores close to each other, exceeding the median 0.61 for efficiency in innovation of the evaluated countries, which is above 50% of the efficiency of the group of evaluated countries (Cornell, INSEAD, WIPO, 2018); c) according to the European Innovation Scoreboard, which presents the comparative results classified into four categories-leader, strong, moderate and modest - in terms of research and innovation in European countries. For the year 2018, Sweden ranks as a leader in innovation; Slovenia is in the range of strong innovators; and Croatia, Slovakia, Spain, Lithuania and Serbia are moderate innovators (Hollanders and Es-Sadki, 2018), showing how the seven countries evaluated are located in the upper ranks of innovative countries, positioning them as promoters of innovation in favour of economic development at European level; d) according to the results of the Environmental Performance Index, which measures the behaviour of 180 countries based on two environmental policy objectives, divided into ten thematic categories and projected onto 24 indicators with a score from 0 to 100, where 0 and 100 indicate the worst and best performances, respectively. Thus, for the year 2018, Sweden ranks fifth with a score of 80.51, Spain 12th with 78.39, Slovakia 28th with 70.60, Lithuania 29th with 69.33, Slovenia 34th with 67.57, Croatia 41st with 65.45, and Serbia 84th with 57.49. These results show how the countries in question occupy important positions in the achievement of the established objectives in pursuit of a good general environmental performance (Wendling et al., 2018); e) the total number of companies analysed is located within the manufacturing industrial sector listed in NACE Rev. 2, codes 10 to 33, with at least 20 employees.

Table 2 relates the descriptive statistics of the sample, following the OECD classification and according to the technological intensity identified based on the investment in R&D of the manufacturing industries (Galindo-Rueda and Verger, 2016). It is inferred that the companies with the largest participation, both at the industrial sector level and in terms of the number of samples, are located in low-technology, followed by medium-low-technology industries. The highest number of average employees is in the medium-high-technology sector, denoting a lower share of the classification of industrial sectors with respect to medium-low and low-technology industries. Manufacturing industries that have medium-high intensity and high-technology industries are only minimally different from medium-low and low-technology industries in the adoption of GPC. Companies that have high-technology industries present a better TECH than the industrial sectors that have a greater number of average employees and a greater grouping of manufacturing sectors. Furthermore, it is inferred how investment in R&D of companies that are classified in the different levels of technological intensity is also reflected positively in both GPC and TECH.

Table 2
Descriptive features of the sample by technological intensity.

	Low-technology Industries	Medium-low-technology industries	Medium-high-technology industries	High-technology industries
NACE	10-18, 31	19, 22–25, 32, 33	20, 27-30	21, 26
N	339	291	211	40
Average number of employees	142	119	188	130
Average green production capability adoption	4	4	5	5
Average TECH adoption	3	4	4	5

3.3. The measures

3.3.1. Dependents variables: environmental performance and financial performance

In this study, organisational performance was determined using the measurement of environmental performance and financial performance. To measure environmental performance, objectives need to be identified and the implementation of green processes and products must be monitored. The variable used to measure environmental performance was whether new or improved products generate an improvement in environmental impact during use or when discarded, with the option of a dichotomous (YES/NO) response. Environmental performance can refer to actions such as the selection and use of clean raw materials in the production process; the maximisation of materials; energy and water; the control of atmospheric emissions and the reduction of hazardous substances; the prolongation of the useful life of the product; and the coherent management of waste, among others (Asociación Española de Normalización y Certificación - Asociación Española de Normalización Certificación - EANOR, 2010; Madden et al., 2006).

For financial performance, the variable considered was return on sales (ROS), which corresponds to the ratio of profitability to sales operations, enabling the operational efficiency of the company to be evaluated. ROS is calculated as the net profit divided by sales for the period assessed and expressed as a percentage. A positive ROS shows how the company is moving towards its operational efficiency since it shows the amount of profitability obtained from each unit of sales revenue (Llach Pagès et al., 2009). Given that the EMS asked about the value of ROS in ranges and not in unit values, for the object of this study ROS was preserved in a categorised way in the ranges of 1 for ROS 0%–2%, 2 for ROS >2%–5%, 3 for ROS 5%–10% and 4 for ROS >10%.

3.3.2. Independent variables: green production capability and technology

The variables referring to the organisation of production and management/control were considered to measure GPC. The variables related to production control, automation and robotics, additive manufacturing technologies and energy efficiency technologies were used to measure TECH. The list of variables is presented in Table 3. For both GPC and TECH, the variables required a dichotomous (YES/NO) response and were characterised by the levels of potential use corresponding to low, *medium* or *high* implementation, only for when the answer was *YES*.

Likewise, and following the methodology proposed by Llach Pagès et al. (2009) and Pons et al. (2013), Table 4 presents the variable SUM_GPC, which takes values between zero and twelve and corresponds to the count of the total capabilities applied. We proceeded in a similar way for the levels of SUM_TECH, the high levels of SUMHIGH_GPC and SUMHIGH_TECH.

3.3.3. Control variables

Seeking to control the heterogeneity of the industry and the company

Table 3
Green production capability and _ technology included in the European Manufacturing Survey.

	Green production capability		Technology
1.	STANDARDISED WORK INSTRUCTIONS: Standardised and detailed work instructions (e.g., standard operation procedures SOP, MOST).	1.	MOBILE/WIRELESS DEVICES: Mobile/wireless devices for programming and controlling facilities and machinery (e.g., tablets).
2.	INTERNAL LOGISTICS: Measures to improve internal logistics (e.g., Value Stream Mapping/Design, changed spatial arrangements of production steps).	2.	DIGITAL SOLUTIONS FOR THE SHOP FLOOR: Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor.
3.	FIXED PROCESS FLOWS: Fixed process flows to reduce setup time or optimise change-over time (e.g., SMED, QCO).	3.	SOFTWARE FOR PRODUCTION: Software for production planning and scheduling (e.g., ERP system).
4.	INTEGRATION OF TASKS: Integration of tasks (planning, operating, or controlling functions with the machine operator)	4.	DIGITAL EXCHANGE OF DATA: Digital Exchange of product/process data with suppliers/customers (Electronic Data Interchange EDI).
5.	PRODUCTION CONTROLLING: Production controlling following the Pull principle (e.g., KANBAN, Internal zero-buffer principle).	5.	CONTROL SYSTEM: Near real-time production control system (e.g., Systems of centralised operating and machine data acquisition, MES).
6.	DISPLAY BOARDS IN PRODUCTION: Display boards in production to illustrate work processes and work status (e.g., Visual Management).	6.	SYSTEMS FOR INTERNAL LOGISTICS: Systems for automation and management of internal logistics (e.g., Warehouse management systems, RFID).
7.	QUALITY IN PRODUCTION: Methods of assuring quality in production (e.g., CIP, TQM, SixSigma, preventive maintenance).	7.	VIRTUAL REALITY OR SIMULATION: Virtual Reality or simulation for product design or product development (e.g., FEM, Digital Prototyping, computer models).
8.	CERTIFIED QUALITY: Certified quality standards (e.g., ISO 900xx)	8.	INDUSTRIAL ROBOTS FOR MANUFACTURING: Industrial robots for manufacturing processes (e.g., welding, painting, cutting).
9.	CERTIFIED ENERGY: Certified energy management system (e.g., EN ISO 50001)	9.	INDUSTRIAL ROBOTS FOR HANDLING: Industrial robots for handling processes (e.g., depositing, assembling, sorting, packing processes, AGV).
10.	MATHEMATICAL ANALYSIS: Methods of operation management for mathematical analyses of production (e.g., regression analysis, queening models).	10.	3D FOR PROTOTYPING: 3D printing technologies for prototyping (prototypes, demonstration models, 0 series).
11.	CERTIFIED ENVIRONMENTAL MANAGEMENT: Certified environmental management system (e.g., EN ISO 14001).	11.	3D FOR MANUFACTURING: 3D printing technologies for manufacturing of products, components and forms, tools, etc.
12.	PRODUCT LIFECYCLE MANAGEMENT: Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	12.	TECHNOLOGIES FOR WATER RE-USE: Technologies for recycling and re-use of water (e.g., water recirculating system).
		13.	TECHNOLOGIES RECUPERATE ENERGY: Technologies to recuperate kinetic and process energy (e.g., waste heat recovery, energy storage).

(Dangelico et al., 2016), two control variables were present in the model: the number of employees and the technological intensity of the industry. The size of the company was selected because it may impact productivity and therefore technological innovation and financial performance (Bridoux and Stoelhorst, 2014). Its measurement was

Table 4
Description of SUM_GPC – SUMHIGH_GPC and SUM_TECH – SUMHIGH_TECH.

Variables	Construction Variable	Values
SUM_GPC	Total capabilities used, representing the number of chosen green production capabilities the company has implemented.	For N = 12, which is the maximum number of capabilities analysed
SUMHIGH_GPC	Total green production capabilities that have a high level of implementation, representing the number of chosen capabilities with a high level of adoption in the enterprise.	
SUM_TECH	Total technologies used, representing the number of chosen technologies the company has implemented.	For N = 13, which is the maximum number of technologies analysed
SUMHIGH_TECH	Total technologies that have a high level of implementation, representing the number of technologies chosen with a high level of adoption in the enterprise.	

calculated from the number of employees. The classifications listed in NACE Rev. 2, codes 10 to 33, were taken to identify the technology-intensive industry, since they reflect the classification of technological development and structural changes in the European community (Eurostat European Commission, 2008). Its measurement was projected according to the level of intensity of research and development, in line with the classification reported by the OECD corresponding to the year 2016 (Galindo-Rueda and Verger, 2016).

3.4. Statistical modelling

The environmental variable was labelled with the values *YES* and *NO*, applying binary logistic regression, with SUM_GPC, SUM_TECH, SUMHIGH_GPC, SUMHIGH_TECH as the independent and control variables. ROS was categorised in the previously described ranges, and for this dependent variable the ordinal logistic regression was executed. For both types of regression, the pseudo R^2 was used, following the method proposed by Cox and Snell and Nagelkerke, since the degree to which the independent variables explain the dependent variable is determined by the result of R^2. Statistical modelling was performed with the original data from the samples of the seven countries, using SPSS Statistics version 24®.

Fig. 1 presents the analytical framework where modelling is projected in six sequences for both environmental and financial performance.

4. Results and discussions

4.1. Descriptive analysis

Fig. 2 shows the adoption of GPC in the companies surveyed. *Standardised and detailed work instructions (e.g., standard operation procedures SOP, MOST)* with 77%, followed by *Certified quality standards (e.g., ISO 900xx)* with 69%, *Methods of assuring quality in production* with 61%, and *Display boards in production to illustrate work processes and work status* with 53%, were the most adopted of the twelve capabilities for GPC. The opposite occurs with capabilities: *Production controlling, following the Pull principle (e.g., KANBAN, Internal zero-buffer principle), Product-Lifecycle-Management-Systems (PLM)* and *Product/Process Data Management, Certified energy management system (e.g., EN ISO 50001)* do not exceed 30% in their adoption, which stands out considering that they could be strategic capabilities in pursuit of GPI.

Regarding the levels of the implementation of GPC (low, medium, and high) presented in Fig. 3, it is identified how some capabilities that

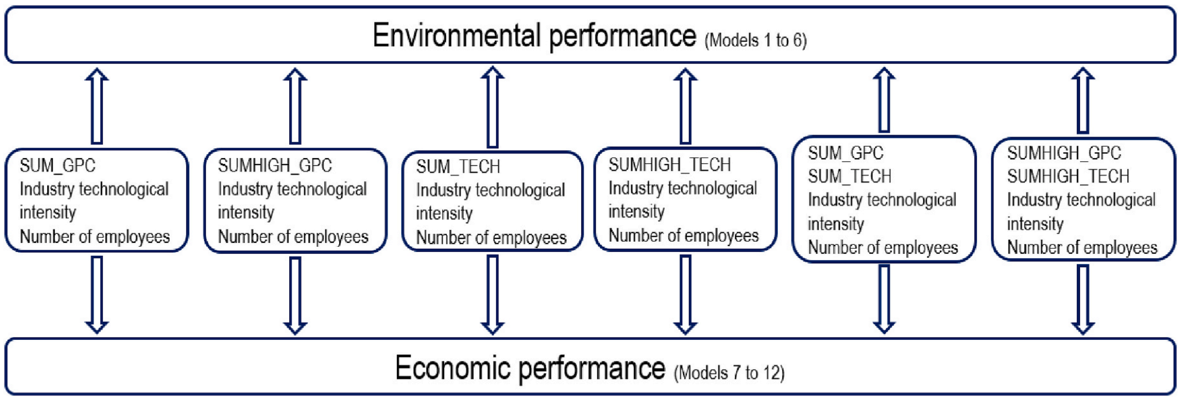

Fig. 1. Analytical framework of the research.

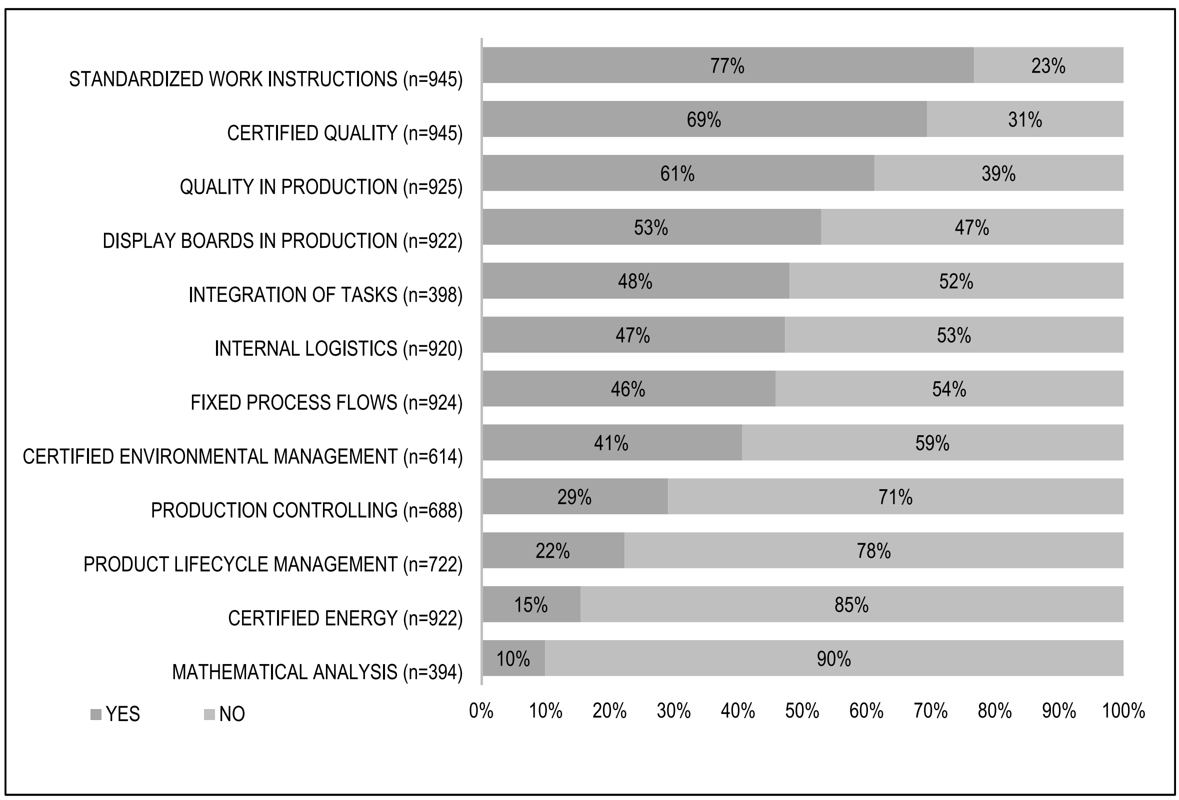

Fig. 2. Use of green production capability.

have a high adoption are related to a high level of implementation. To this effect, *Certified quality standards (e.g., ISO 900xx)* presents a higher level of implementation (66%) than adoption of GPC, at 61%, followed by *Certified environmental management system (e.g., EN ISO 14001),* with a 61% level of adoption, as opposed to the implementation of GPC, at 69%. Furthermore, Fig. 2 shows that 69% of companies implement *Certified quality standards (e.g., ISO 900xx),* and of these 66% do so at a high level, as identified in Fig. 3, observing a correspondence between adoption and implementation at high levels.

Fig. 4 lists the percentages of TECH adoption. *Software for production planning and scheduling* (e.g., ERP system) ranks as the most adopted at 60%, followed by *Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor* with 46%, and *Digital Exchange of product/process data with suppliers/customers* with 44%. *3D printing technologies for prototyping* with 18% and *3D printing technologies for manufacturing of products, components and forms,* tools, *etc.,* with 12% each, are the least adopted.

Regarding the results of the adoption of TECH corresponding to low, medium, and high presented in Fig. 5, it is observed that *Software for production planning and scheduling (e.g., ERP system)* presents the highest level of implementation, with 57%, while *3D printing technologies for the manufacturing of products, components, and forms, tools, etc.* Presents the lowest level of implementation, at 19%. Retaining a high level, *Industrial robots for manufacturing processes* and *Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor* take second place in terms of the technology most adopted in companies, with 42% each.

4.2. *Impact of green production capability and technology on organisational performance*

The following section presents the results and discussion, with the aim of contributing with new knowledge relating to the adoption of green production capability and technology together with their high

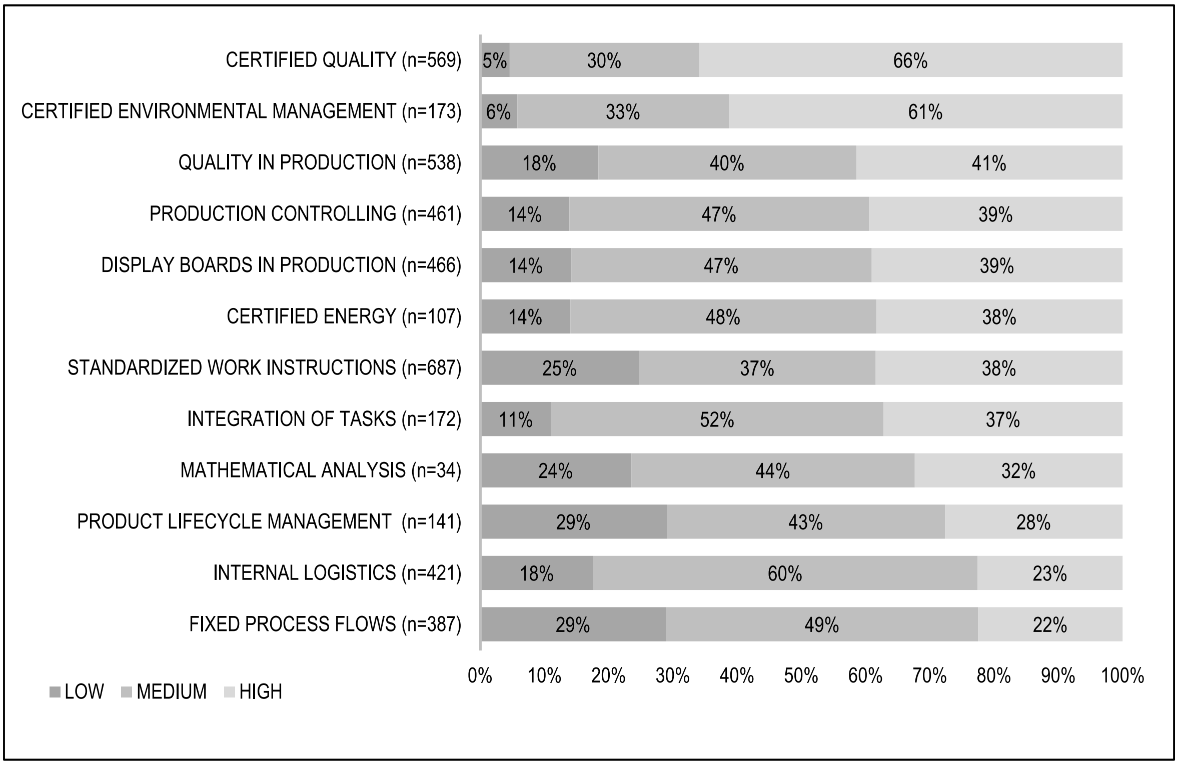

Fig. 3. Implementation degree of green production capability.

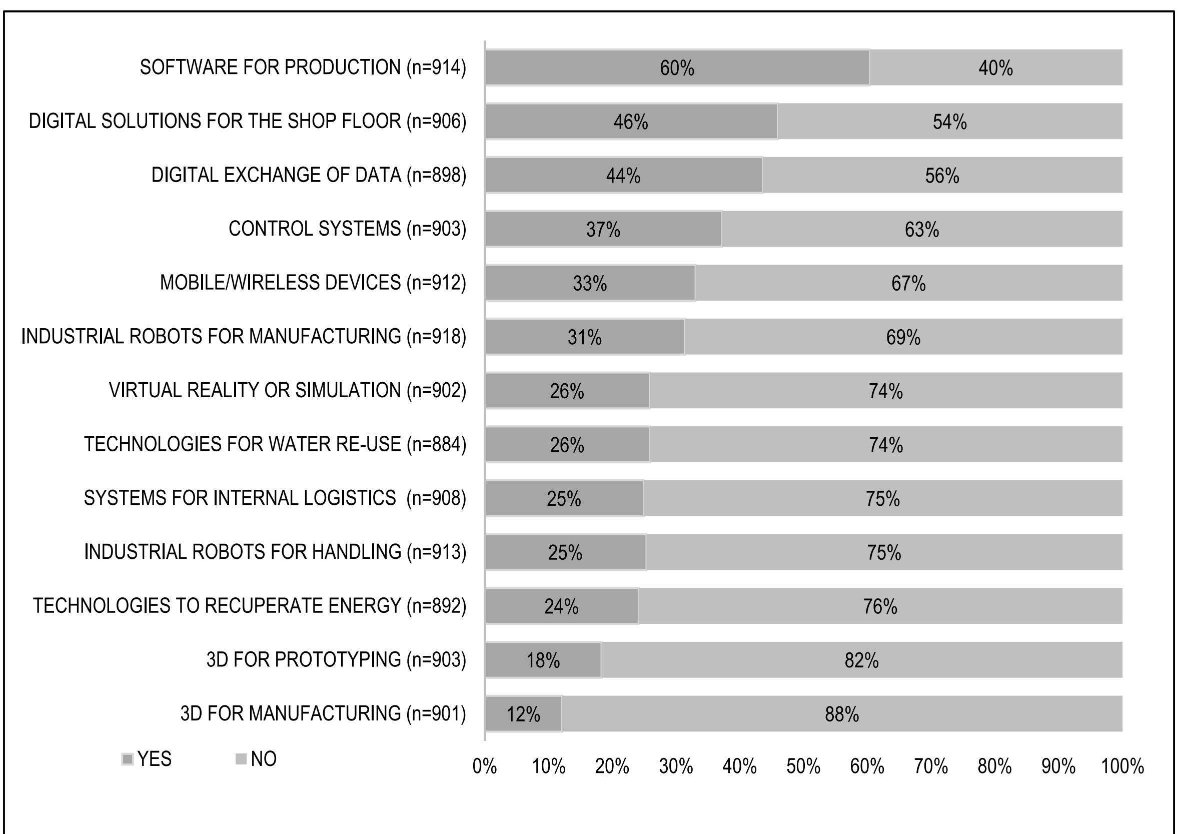

Fig. 4. Use of technology.

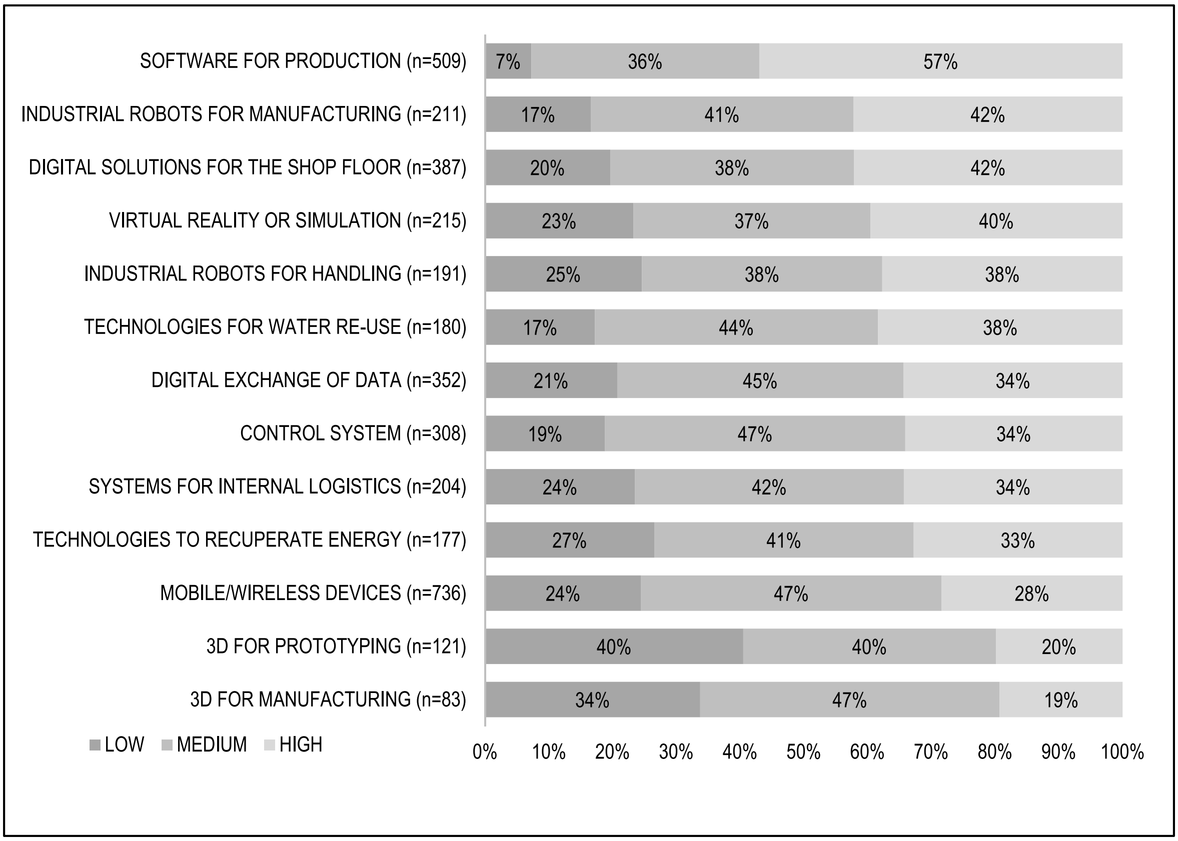

Fig. 5. Implementation degree of technology.

levels of implementation, to know their contribution to organisational performance.

4.2.1. Exploring the relationship between green production capability, technology, their level of implementation and environmental performance

Table 5 presents the results of the models implemented to test the relationship between green production capability, technology and their levels of implementation, in conjunction with the control variables, to determine the impact on environmental performance, considering the significant * value of $p < 0.1$, ** value of $p < 0.05$ and *** value of $p < 0.01$, which determine the explanation of the dependent variable with respect to the independent ones. The results produced using the SPSS® software in terms of beta values (β), β index values, the constant and R^2 for the analysis and interpretation of the results of the models are also presented.

Model 1 includes the SUM_GPC variable, while model 2 includes the

Table 5

Environmetal performance - regression models SUM_GPC, SUM_TECH, SUMHIGH_GPC and SUMHIGH_TECH.

Model 1	β	Exp(β)	Model 2	β	Exp(β)
SUM_GPC	0.1614***	1.1751	SUMHIGH_GPC	0.1492***	1.1609
Industry technological intensity	0.2470***	1.2802	Industry technological intensity	0.2858***	1.3309
Number of employees	0.0005	1.0005	Number of employees	0.0005*	1.0005
Constant	−1.5740***		Constant	−1.2378***	
R^2 Cox & Snell	0.0699		R^2 Cox & Snell	0.0564	
R^2 Nagelkerke	0.0939		R^2 Nagelkerke	0.0757	
Model 3	β	Exp(β)	Model 4	β	Exp(β)
SUM_TECH	0.1237***	1.1317	SUMHIGH_TECH	0.0994**	1.1045
Industry technological intensity	0.2610***	1.2982	Industry technological intensity	0.3071***	1.3595
Number of employees	0.0005	1.0005	Number of employees	0.0007**	1.0007
Constant	−1.4023***		Constant	−1.1820	
R^2 Cox & Snell	0.0611		R^2 Cox & Snell	0.0430	
R^2 Nagelkerke	0.0820		R^2 Nagelkerke	0.0578	
Model 5	β	Exp(β)	Model 6	β	Exp(β)
SUM_GPC	0.1252***	1.1334	SUMHIGH_GPC	0.1346***	1.1441
SUM_TECH	0.0740**	1.0768	SUMHIGH_TECH	0.0313	1.0318
Industry technological intensity	0.2358**	1.2659	Industry technological intensity	0.2938***	1.3415
Number of employees	0.0003	1.0003	Number of employees	0.0005	1.0005
Constant	−1.6760***		Constant	−1.2758***	
R^2 Cox & Snell	0.0776		R^2 Cox & Snell	0.0565	
R^2 Nagelkerke	0.1042		R^2 Nagelkerke	0.0759	

Significant in * $p < 0.1$ value; **$p < 0.05$ value; ***$p < 0.01$ value.

variable SUMHIGH_GPC, and both models integrate the control variables. The results show that the values of the exponentials of β in SUM_GPC and SUMHIGH_GPC are 1.1751 and 1.1609, respectively, indicating that these variables have a significant impact on environmental performance. In both models, the control variable industry technological intensity explains the impact with respect to the dependent variable since it is significant at $p < 0.01$. As for the values of R^2 Cox and Snell and Nagelkerke, Model 1 behaves better than Model 2, which means that Model 1 has greater goodness of fit with respect to the dependent variable. These results support how GPC is a key factor in the development of GPI, showing that manufacturing products with renewable materials that minimise the use of inputs and reduce waste have a positive impact on environmental performance. These findings are consistent with Wang et al. (2021), who find that design and manufacturing in an ecological way are key business processes in pursuit of organisational performance. Therefore, a high implementation of SUM_GPC positively impacts the development of a coherent environmental strategy.

The SUM_TECH and SUMHIGH_TECH variables were processed in Model 3 and Model 4, together with the control variables. The two variables have a respective incidence of 1.1317 and 1.1045 times more likely to have a significant impact on environmental performance. For both models, the variable industry technological intensity has a significant impact on this performance, $p < 0.01$. The goodness of fit values of Cox and Snell and Nagelkerke that best describe the dependent variables are the ones presented in Model 3, as opposed to Model 4, indicating that this model explains to a greater degree the behaviour of environmental performance. The results obtained indicate how innovation in technologies aimed at prevention and the reduction of non-renewable resources implies the production of green products. This means that the sustainable innovation measures that organisations can implement to reduce their environmental impact also improve the company's production processes (Wei et al., 2022). These findings also coincide with Forés (2019), who identifies how several empirical studies find a positive impact of green technology on environmental performance, derived from the measures developed based on the prevention of pollution and the healthy use of resources. Therefore, considering these results, the implementation of a high level of green technologies contributes to the reduction of environmentally destructive substances by linking green technology to the manufacture of products.

Last, Model 5 is presented, which includes the association of the variables SUM_GPC, SUM_TECH and the control variables, showing that SUM_GPC and SUM_TECH are 1.1334 and 1.0768 times more likely, respectively, to have a significant impact on environmental performance. Following the sequence, the SUMHIGH_GPC variable of Model 6 is 1.1441 times more likely to significantly impact environmental performance. Another variable that has a significant effect in both models is industry technological intensity. To this effect, the variables used in Model 5 explain to a greater degree the percentage of independent variables that impact environmental performance, based on the significant values presented in the model. These relationships among associations are most significant in the case of the implementation of SUM_GPC and SUM_TECH, as with industry technological intensity.

In summary, regarding the goodness of fit produced by all the models, the one with the best R^2 values is Model 5, indicating that this model best explains the behaviour of the dependent variable.

It is generally observed that the variables evaluated are identified as predictors contributing to environmental performance, except for number of employees, the impact of which is only identified in Models 2 and 4. How the implementation of SUM_GPC, SUMHIGH_GPC, SUM_TECH and SUMHIGH_TECH is an excellent measure in pursuit of a good environmental performance is inferred. This result agrees with the findings of Seth et al. (2018), who identify that by understanding and applying drivers of green manufacturing and green technology, strategic organisational benefits manifested in eco-efficiency can be obtained. Our result also concurs with Afum et al. (2021), who identify a unique contribution made by developing ecological products, improved corporate image and the generation of ecological competitiveness.

Regarding the association of SUMHIGH_GPC, Industry technological intensity and SUMHIGH_TECH, it is observed that this does not contribute to the model for good environmental performance. This result is in line with the findings of Forés (2019), who identifies how high levels of adoption of ecological technologies can affect production capabilities that are respectful of the environment, but do not generate a significant impact on environmental performance.

Therefore, we can conclude that for environmental performance the adoption of GPC and its high level of implementation, even when in association with TECH, satisfy hypotheses H1 and H1a; the adoption of SUM_TECH, its high implementation and its association with SUM_GPC satisfy hypotheses H2 and H2a; but the association between SUMHIGH_GPC and SUMHIGH_TECH does not satisfy hypothesis H2a.

In summary, this study contributes to the literature and to practice with new knowledge about the association of green production capability, technology and their levels of implementation in environmental performance. In this regard, the adoption of green production capability in association with technology contributes directly to environmental performance. However, and as we explore next in the association of high levels of implementation, it is observed that technology does not have a significant impact on environmental performance.

4.2.2. Exploring the relationship between green production capability, technology, their level of implementation and financial performance

Next, Tables 6–8 present the results of the models that seek to test the relationship between green production capability, the organisational dimension technology and their levels of implementation, in conjunction with the control variables, to determine the impact on financial performance.

Model 7 includes the SUM_GPC variable and the control variables as predictors of ROS. It can be observed that SUM_GPC increases the probability of having a ROS greater than 5% and greater than or equal to 10%, while the control variables are revealed to be weak predictors of financial performance. In terms of SUM_GPC, which has a positive effect on ROS, this result confirms the arguments presented by Hartmann & Germain (2015) and Wang et al. (2021), who identify that reconfiguring capacities for the design and manufacture of green products leads to the strengthening of the organisation, whose reputation, financial performance and ecological image improve.

The opposite happens in Model 8, where the intensity of the technological industry is a contributing variable to financial performance; that is, the greater the participation of industrial sectors, the greater the probability of having a performance in ROS greater than or equal to 10%. A similar observation is made with SUMHIGH_GPC, where it is identified that the greater the implementation, the higher the percentage of the achievement of ROS $p < 0.1$ in the ranges of 5%–10% and above 10%; that is, it is possible to show how the adoption of green production capabilities can be an influential factor in the pursuit of good financial performance. These results are consistent with the findings of Clarkson et al. (2011), who identify how companies that choose to improve their capabilities towards green development can experience improvements in their financial resources. This is how companies with high capabilities focused on a proactive environmental strategy are associated with better financial performance (Clarkson et al., 2011).

Table 7 presents Model 9, which includes the variable SUM_TECH, affecting ROS with an incidence of occurrence 1.08 times in the range of 2% al 5%, 1.13 times in the range of 5%–10%, and 1.10 times when the range is greater than or equal to 10%, evidencing how TECH impacts directly on financial performance. However, the control variables for this model show that they are not a good predictor for higher performance. Furthermore, Table 7 presents Model 10, where it is observed that increasing SUMHIGH_TECH raises the probability of having a ROS greater than 5% or 10%, while having a high industrial-technological intensity increases the probability of having an impact greater than or

Table 6
Financial performance - regression models SUM_GPC and SUMHIGH_GPC.

ROS Ranges	(2%–5%)		(5%–10%)		(>10%)	
Model 7	β	Exp(β)	β	Exp(β)	β	Exp (β)
SUM_GPC	0.0658	1.10680	0.1089*	1.1151	0.1021*	1.1075
Industry technological intensity	0.0153	1.0154	0.1034	1.1089	0.2291	1.2574
Number of employees	−0.0002	0.9998	−0.0003	0.9997	−0.0007	0.9993
Constant	−0.0646		−0.1583		−0.7729	
R^2 Cox & Snell	0.0184					
R^2 Nagelkerke	0.0197					
Model 8	β	Exp(β)	β	Exp(β)	β	Exp (β)
SUMHIGH_GPC	0.0537	1.0552	01569**	1.1698	0.1299*	1.1387
Industry technological intensity	0.0374	1.0382	0.1232	1.1311	0.2522*	1.2869
Number of employees	−0.0002	0.9998	−0.0003	0.9997	−0.0007	0.9993
Constant	0.0587		−0.0245		−0.6210	
R^2 Cox & Snell	0.0224					
R^2 Nagelkerke	0.0240					

Reference category, ROS (0–2%). Significant in * $p < 0.1$ value; **$p < 0.05$ value; ***$p < 0.01$ value.

Table 7
Financial performance - regression models SUM_TECH and SUMHIGH_TECH.

ROS Ranges	(2%–5%)		(5%–10%)		(>10%)	
Model 9	β	Exp(β)	β	Exp(β)	β	Exp (β)
SUM_TECH	0.0857*	1.0895	0.1222***	1.1300	0.1002**	1.1053
Industry technological intensity	−0.0258	0.9746	0.0751	1.0780	0.2111	1.2351
Number of employees	−0.0003	0.9997	−0.0004	0.9996	−0.0007	0.9993
Constant	0.0493		0.0006		−0.6034	
R^2 Cox & Snell	0.0218					
R^2 Nagelkerke	0.0234					
Model 10	β	Exp(β)	β	Exp(β)	β	Exp(β)
SUMHIGH_TECH	−0.0059	0.9942	0.1209*	1.1285	0.1106	1.1170
Industry technological intensity	0.0343	1.0349	0.1359	1.1455	0.2651*	1.3036
Number of employees	−0.0001	0.9999	−0.0002	0.9998	−0.0007	0.9993
Constant	0.2211		0.1477		−0.4965	
R^2 Cox & Snell	0.0202					
R^2 Nagelkerke	0.0216					

Reference category, ROS (0–2%). Significative in * value of $p < 0.1$; ** value of $p < 0.05$; *** value of $p < 0.01$.

Table 8
Financial performance - regression models SUM_GPC, SUM_TECH, SUMHIGH_GPC and SUMHIGH_TECH.

Ratios of ROS	(2%–5%)		(5%–10%)		(>10%)	
Model 11	β	Exp(β)	β	Exp(β)	β	Exp(β)
SUM_GPC	0.0159	1.0161	0.0359	1.0366	0.0449	1.0459
SUM_TECH	0.0790	1.0822	0.1102**	1.1164	0.0807	1.0841
Industry technological intensity	−0.0309	0.9695	0.0571	1.0588	0.1984	1.2195
Number of employees	−0.0004	0.9996	−0.0005	0.9995	−0.0008	0.9992
Constant	0.0139		−0.0787		−0.6817	
R^2 Cox & Snell	0.0237					
R^2 Nagelkerke	0.0254					
Model 12	β	Exp(β)	β	Exp(β)	β	Exp(β)
SUMHIGH_GPC	0.0546	1.0561	0.1077	1.1137	0.0757	1.0786
SUMHIGH_TECH	−0.0360	0.9646	0.0755	1.0785	0.0726	1.0753
Industry technological intensity	0.0260	1.0263	0.1112	1.1176	0.2520*	1.2866
Number of employees	−0.0002	0.9998	−0.0003	0.9997	−0.0008	0.9992
Constant	0.1862		0.0651		−0.5326	
R^2 Cox & Snell	0.0260					
R^2 Nagelkerke	0.0278					

Reference category, ROS (0–2%). Significant in * $p < 0.1$ value; **$p < 0.05$ value; ***$p < 0.01$ value.

equal to 10% in ROS. However, it is noted that presenting a high adoption of technology does not significantly impact ROS in a range greater than 10%. This result is consistent with the studies by Forés (2019) and He et al. (2021), who identify that beyond a certain level of adoption, green technology can represent a high cost of implementation, which can make it difficult to manage, requiring high investment and extensive financial support.

Last, Table 8 shows the results of the association of the SUM_GPC variables, SUM_TECH and their levels of implementation, together with the control variables. Model 11, which includes the sum of green production capability and technology, shows that the variable SUM_TECH increases the probability of having an impact on ROS greater than 5%

and up to 10%, because innovation in green technology can contribute to improving energy efficiency (Shahzad et al., 2022). These technologies also play an important role among the financial objectives, with the requirement of protecting the natural world (Palmer and Truong, 2017). These results show that SUM_GPC and the control variables are not significant contributors to the model. It can be identified how, regarding the variables SUM_GPC and the industry technological intensity, the greater the participation in these, the greater the possibility of increasing ROS, thereby improving financial performance. Therefore, we can conclude that only the variable SUM_TECH contributes to the model. Similarly, in Model 12, when changing from the sums to a high level of implementation together with the control variables, there is a minimal difference compared to Model 11, wherein only the variable industry technological intensity is significant for a ROS of over 10%.

Considering the results, the association between SUM_GPC and SUM_TECH, like the association between SUMHIGH_GPC and SUMHIGH_TECH, was expected to have a significant impact on financial performance. However, the opposite in fact occurred. We believe that these associations could be affected by various factors such as the company's need for production capacities oriented to green development; the implementation of programs related to the minimisation of waste; the consumption of natural resources and energy; the cost of renewable raw materials; and the acquisition of insurance premiums and environmental regulations (Viñolas Marlet, 2005). At the same time, for the organisation the complexity involved in the management of green technology involves a shift in customs and paradigms, as well as a large investment to acquire the technology and the organisational reconfiguration of its capabilities. All the above affects financial performance.

Therefore, we can conclude that H1 and H1a, contrasted in Models 7 and 8, can be accepted. Likewise, Models 9 and 10 confirm H2 and H2a. Regarding the association of SUM_GPC and SUM_TECH, contrasted in Model 11, H1 is not accepted, whereas H2 is. The opposite result is obtained for the association of high implementation contrasted in Model 12, the findings of which indicate that H1a and H2a cannot be accepted.

In conclusion, the present study makes an important contribution to the knowledge of green production capabilities, technology and their levels of implementation in pursuit of better financial performance, allowing us to show that these factors contribute positively in this respect. Regarding the association of green production capabilities and technology, it is shown how only the adoption of the latter contributes to improved financial performance, while the association of its high implementation does not contribute significantly.

In summary, Table 9 shows the results of the relationship between green production capability, technology and its levels of use, and environmental and financial performance.

5. Conclusions and theoretical and management implications

Following the suggestions for future research stated in Serrano-García et al. (2021) and Serrano-García et al. (2022) in relation to the separate analysis and statistical validation of each of the seven green

Table 9
Summary of the behaviour of the independent variables in relation to environmental and financial performance.

Independent variables	Dependent variables	Dependent variables
	environmental performance	financial performance
SUM_GPC	✔	✔
SUM_TECH	✔	✔
SUMHIGH_GPC	✔	✔
SUMHIGH_TECH	✔	✔
	Association	
SUM_GPC	✔	χ
SUM_TECH	✔	✔
SUMHIGH_GPC	✔	χ
SUMHIGH_TECH	χ	χ

innovation capabilities in association with each of the five organisational dimensions to identify their impact on organisational performance, this research is an exploratory analysis of the association between green production capability, the technology organisational dimension and their respective levels of implementation, seeking to determine their impact on environmental and financial performance. We carried out this research recognising the need for a series of determinants focused on the green. This in turn implies the reconfiguring of capabilities and dimensions that allow green innovation to be managed in pursuit of improving organisational performance, leading to competitive advantage.

According to the evidence collected by the European Manufacturing Survey 2018 edition, referring to the manufacturing companies studied in Croatia, Lithuania, Spain, Serbia, Slovakia, Slovenia and Sweden, we identified how, based on the percentage of implementation of green production capability, technology and their level of implementation, the variables are being adopted at different levels to improve environmental and financial performance. This fact is especially relevant because greater implementation could be aimed at improving financial performance, in particular given that, based on the percentages identified when analysing the most implemented variables, an impact on environmental performance is generally reflected. This suggests that, as a strategic resource, companies in the manufacturing sector are earmarking financial resources for the creation and adoption of green technologies, both software and/or hardware, and for investment to constitute or reconfigure their current green production capacity as a dynamic approach that will lead to improved organisational performance.

One of the outstanding findings of the present study is the decisive relationship between technology and environmental and financial performance. This is because ecological technologies can be a fundamental tool for implementing strategies relating to green production processes in line with the financial and ecological aims of companies in the manufacturing sector.

The same can be said for green production capability, which is being adopted in most manufacturing companies, given that it significantly impacts on environmental and financial performance. Our results show how green production capability is relevant for achieving organisational performance, suggesting the need for its implementation in processes related to the reduction and/or elimination of harmful materials and to the use and optimisation of renewable raw materials to ensure alignment with the constitution of GPI in pursuit of competitive advantage.

Another aspect to highlight is the result regarding high levels of implementation, showing how the high implementation of green production capability has a significant impact on both environmental and financial performance. This finding has important implications because it shows how the perspective of the resource-based view is an excellent framework for implementing environmental solutions in manufacturing firms, confirming its potential as a facilitator for reconfiguring green creation and production processes in relation to the performance of the organisation. The same happens with the high implementation of technology, which has a significant impact on both environmental and financial performance. This finding, therefore, is a challenge for companies, academia, and government agents in pursuit of ongoing incentivisation towards an increased implementation of green technology as a contribution to the creation of green production innovation, which resonates on financial performance. Consequently, and in accordance with the findings of Begum et al. (2022), a key aspect for the question in hand is the ongoing and appropriate training of human talent in the area of environmental sustainability and the management of green technologies, such that employees can become more involved and play a greater and more effective part in the creation of green processes and products, with the support of a higher degree of implementation of green technology, which will impact positively on financial performance.

Another finding is how the association of the adoption of green production capability and technology is contributing to better environmental performance. This is especially relevant given that it confirms how production capabilities aimed at preventing the generation of waste, the use of eco-efficient materials and the reuse of waste (Serrano-García et al., 2021) lead to the creation of green production innovation. Furthermore, technology intervenes in reducing pollution and the resources used, decreasing environmental impacts and favouring the green production process, which merges with reputation and organisational image, as well as with green competitiveness.

Contrarily, and again in regard to the association of green production capability and technology, it can be seen how this does not contribute significantly to improving financial performance, having detected the weakness that the only significant variable is technology. Nonetheless, the possibility of this performance impacting positively, though to a lesser degree, only by improving the percentage of implementation of green production capability is presented. In this regard, how to seek the strengthening of green production capability in association with the organisational dimension of technology is an outstanding contribution, as both tend to become key organisational tools, facilitating manufacturing processes and reducing pollution, the cost of materials and even taxes, and formulating environmental regulations to support sustainable competitive advantage, resulting in financial impact.

The present research, based on a subsample of 1018 companies in the manufacturing sectors of seven European countries and structured under a statistical model, makes relevant contributions to the field of management and organisational theories, as well as to business practice for managerial reconfiguration and transition directed towards sustainable development from the authentic operation of green innovation. In summary, we have tested and proven the following assumption: the adoption and high level of implementation of green production capability and technology have a positive effect on environmental and financial performance. In association, this adoption also has a significant impact on environmental performance but not on financial performance. However, for high levels of implementation it was identified that this association is not decisive for the two types of performance given that only green production capability contributes to environmental performance.

5.1. Implications for scholars, managers, and policy makers

Our findings confirm theoretical and practical implications that may correspond to opportunities for academics, practitioners and government entities. Regarding the theoretical contributions of this research, the theoretical approach of green production capability and the approach of green technology are analysed, identifying them as necessary to study the achievement of green product innovation. In turn, these theoretical approaches shed light on how green technology is contributing to the impact on environmental and financial performance. Notably, the radicality of green production capability is identified as a support for the determinants of green product innovation, benefiting environmental and financial performance. Therefore, from an academic perspective, this article contributes to the resource-based view, the natural resource-based view and dynamic capabilities, with its extension to green innovation capabilities and more specifically to green production capabilities, providing solid exploratory evidence of their positive relationship with organisational performance. This was achieved by verifying how production capabilities directed towards reducing/eliminating the use of elements that are harmful to the environment, no longer using natural resources and optimising the use of biodegradable raw materials, among others, favour the achievement of sustainable production and impact organisational performance. This research also contributes to advancing knowledge about how technology is an essential resource in the pursuit of financial performance.

In terms of contributions for managers of manufacturing companies, the results show the need to implement green innovation capabilities. Specifically, it is identified how green production capability impacts on organisational performance. Therefore, it is recommended that managers continue to strengthen the implementation and high use of this capability to continue with the good environmental and financial performance that allows them to strengthen the positioning of their comparative and competitive advantages. In addition, and with respect to technology, it is identified that its implementation is necessary to achieve environmental and financial performance, but that special care must be taken in terms of its high level of implementation since at a certain level of adoption technology does not significantly contribute to performance. Based on these findings, a call is made for manufacturing companies to continue implementing green production capability and technology as strategic and differentiating factors that advance organisational performance.

Our findings are valuable for formulating government policies since they identify the need for manufacturing companies to persist with the promotion of green production capability and technology as a solution to reducing harm to the environment. In this regard, governments must offer incentives so that companies can acquire green production capabilities and the necessary technology to proceed towards the creation of green production innovation, with a view to improving organisational performance and impacting on sustainable development. This promotion is also in line with environmental regulations and is therefore a way for companies, society and the state to comply with and benefit from them.

5.2. Limitations and future work

A series of research opportunities are identified from the limitations presented in the current research, calling for future studies to pursue creativity and debate to generate green product innovation directed towards organisational performance:

a) In this research, we worked under the theoretical contextualisation of green production capability and technology. Other theoretical lenses of industrial organisation and technology management could also be considered. b) In this research, the variable *number of employees* only contributed to environmental performance in statistical models 2 and 4. Therefore, more studies are required to evaluate the contribution of this variable to organisational performance. c) The hypotheses of the present paper were accepted. However, it was not statistically evident that the overall effect of the association between green production capability and the adoption of technology has a significative impact on financial performance. Furthermore, it was shown how, at high levels of use, this association does not have a significant impact on environmental and financial performance since it was observed in the association to determine environmental performance that only green production capability significantly contributes to the model. Therefore, more research is required to corroborate or contradict these results, and other statistical and analytical methods that can account for different options that allow the framework proposed in this research to be tested must be considered. d) In this research, we focus on several existing technologies and capabilities. Consequently, new research should include new technologies and capabilities that emerge in the market to identify whether they also have an impact on organisational performance. e) Globally, sustainability is regarded from social, ecological and financial perspectives (Mittal and Sangwan, 2014). The current research covers only the last two and does not consider any social sustainability measures, as some other authors do (Awan et al., 2018; Awan, 2019), although their importance, relevance and value is recognised. f) In this research we collect data on the manufacturing sector, so future studies could consider other sectors to broaden the context of this investigation and to verify further sectoral patterns. g) Although we worked with the sub-samples of seven European countries, a subsequent investigation could include data from the other eight sub-samples of the EMS to have a more robust sample that further enhances the research and allows the results of the first seven countries to be transposed to the other eight countries to carry out comparative analyses. h) Data collection from companies is a complex process and companies are invited to identify the importance of reporting the information consulted and to increase participation by providing effective responses. Information systems can thereby be strengthened, and academics can process these data to generate recommendations for companies in the productive sector more effectively, with the aim of contributing to sustainable progress.

Credit author statement

Jakeline Serrano-García: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – original draft, Visualization, Project administration, Funding acquisition. Andrea Bikfalvi: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition. Josep Llach: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition. Juan José Arbeláez-Toro: Conceptualization, Methodology, Formal analysis, Writing – review & editing, Project administration.

Funding

This research received no external funding.

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 authors do not have permission to share data.

Acknowledgements

The authors thank Instituto Tecnológico Metropolitano of Medellín, Colombia, for funding Jakeline Serrano García's doctoral research placement, and Professor Fernando Jiménez-Sáez of the Universitat Politècnica de València for his accompaniment and assistance in the doctoral process. We also thank all the plant and production managers in Croatia, Lithuania, Spain, Serbia, Slovakia, Slovenia and Sweden who consented to answer the EMS survey. Likewise, we extend our gratitude to Jasna Prester (University of Zagreb), Iztok Palčič (Maribor University), Mantas Vilkas (Kaunas University of Technology), Juraj Šebo (Technical University of Košice), Robin Von Haartman (University of Gävle) and Ugljesa Marjanovic (University of Novi Sad) for making the data available, which contributed to making the results of the present research more robust. We would also like to thank the editor and the anonymous referees for their constructive comments and suggestions.

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