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Case study

Adoption of 4.0 technologies in MSMEs in the Caribbean: A multiple cases study

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Abstract: By employing the qualitative methodology of multiple case studies, the adoption of 4.0 technologies in MSMEs in Puerto Rico is explored in terms of the drivers, benefits, problems, and challenges of the incorporation processes. The findings reflect that MSMEs belong mostly to the regulated sector and agree that adopting technologies allows them interoperability, data analysis, projections, efficiency, and effectiveness in real-time and close and frequent linkage with customers. Study participants highlight their dependence on the power energy system and its instability as the most significant obstacles, in addition to the lack of capital. The resilient infrastructure component (energy and technology) evidences the need for future research on the subject from a geospatial approach, which imparts originality to this study and determines its importance in developing public policies and resilient business models.

Keywords: 4.0 technologies, MSMEs, digitalization, regulated industry.

1. Introduction

Digital technologies can generate opportunities for improvement in all areas of companies' business: in production processes, in the increase of the portfolio of contact networks, and also in the extension of their information capacity in an almost infinite way, both towards new cognitive areas, as well as towards areas of specialization already consolidated in the company and, in cases of disruptive events, in their ability to reconfigure their resources and thus respond more quickly to crises (Ascúa et al., 2021; ECLAC, 2022). In Canada, for example, these technologies adopted by micro, small, and medium-sized enterprises (MSMEs)have implied higher productivity, lower costs, and better product quality (Bédard-Maltais, 2018). A study conducted in the central region of Malaysia on small and medium-sized enterprises (SMEs) found that digital transformation has relevant implications for business performance (Nor al., 2021). However, in developing countries, many SMEs are experiencing delays in introducing smart manufacturing and the digitalization of factories due to a lack of knowledge and communication problems, which implies a lag (Atieh et al., 2023).

Empirical data in Latin America and the Caribbean (LAC) indicate that the digitalization process has been uneven between large and MSMEs (Cuéllar, 2020). The most critical elements that explain this disparity are the lack of knowledge about these technologies, the dearth of infrastructure, necessary internal connectivity, skills, access to qualified human resources, organizational culture, financing, and education system (Ascúa, 2021).

In the case of small island economies, additional challenges are added to these elements, namely, vulnerabilities associated with the size of the territory, scarcity of resources, and exposure to disruptions related to climatic events, which in turn impact economies and their energy, water, transportation, technological and supply chain infrastructures. Addressing this issue in island economies makes conducting studies such as this one essential. This study proposes an exploratory approach to the technologies that make up Industry 4.0 based on multiple case studies of companies operating in Puerto Rico, essentially MSMEs from various commercial and/or

industrial sectors. The aim is to identify those technologies that are most used or essential for the flow of daily operations, and that impact the parameters that define efficiency and effectiveness. The scope of adopting 4.0 technologies in Puerto Rico companies is explored regarding the incorporation processes' motivations, benefits, problems, challenges, and results. In what instance were the new 4.0 technologies implemented? Are they in implementation, or are they projected to be implemented? What were the motivations and benefits of the introduction of 4.0 technologies? What were the relevant obstacles to the incorporation of 4.0 technologies? What were those relevant obstacles to incorporating 4.0 technologies from the perspective of the disruptions to which the country is exposed due to its geomorphology? What modes of financing and types of non-financial aid did you report? These are the questions that guide this study.

The existing literature on adopting 4.0 technologies in Latin America is mainly limited to large companies, especially in the technology and service sectors, with scarce analyses on MSMEs (Carmona et al., 2020). This research is original in that it is one of the few studies to explore 4.0 technologies in MSMEs in island territories, which present a complicated environment due to their geomorphology, contributing to public policy, academia, and the private sector regarding the adoption of these technologies, of the Fourth Industrial Revolution (4IR). The following section outlines a theoretical framework focused on MSMEs and 4.0 technologies. Then, the method used for the study is presented, followed by the results and conclusions.

2. Literature review

After the COVID-19 pandemic, the shift to exploration and use of 4.0 technologies by companies in Latin America favored the continuity of their operations and organizational restructuring. This highlighted the importance of these technologies in business competitiveness. Despite this shift towards companies' adoption of technologies, the region's ability to compete with other nations remains limited. According to the 2020 Digital Competitiveness Index, prepared by the Institute for Management Development, among the 63 countries considered by the study, Chile was the economy with the best score in digital competitiveness, with approximately 61.5 points out of 100, ranking 41st. It is followed by Brazil in 51st place, with 52.1 points. The third and fourth places are occupied by Mexico and Peru, with 51.5 and 50.1 points, respectively, occupying the 54th and 55th positions in that range (IMD, 2020). This does not mean that the region has not experienced progress in digitalization but that the impact on performance in digital transformation has been moderate. While some companies have managed to capture much of the benefits of digital technologies, there is a long tail of companies lagging in digital matters, mainly composed of MSMEs and businesses in traditional and vulnerable activities, all of which are generally associated with lower levels of productivity and greater informality (ECLAC, 2022). Financial services and the information and communications technology (ICT) sector are the activities with the highest level of digitalization in the region and worldwide, while agriculture, real estate services, and education are lagging behind sectors.

Within the manufacturing industry, there is substantial heterogeneity between countries. In Argentina, there are high levels of digitalization in the biopharmaceutical and automotive sectors, while in the agricultural machinery, food, and textile sectors, lower levels of digitalization predominate. In Colombia and Brazil, the levels of digitization in services are high, medium in logistics services, and low in agribusiness. Colombia and Brazil reflect a moderate and low level of manufacturing (ECLAC, 2022). In the case of Brazil, companies in the high-tech sector still reflect that digital adoption has advanced but is still in an incipient stage (Urraca-Ruiz et al., 2023).

It is observed that there is a lag in terms of the adoption of 4.0 technologies in companies in Latin America. However, a study reveals that in Colombia, Ecuador, Mexico, Panama, and Peru, there is a positive attitude on the part of companies towards the adoption of these technologies due to the perceived ease and usefulness as well as the attitude towards 4IR technologies (Cordero et al., 2023). In Brazil, a study of companies in the high-tech sector shows that current adoption, size, belonging to digitally intensive industries, exporter, and training the workforce have a significant positive effect on the adoption of 4.0 technologies. (Urraca-Ruiz et al., 2023). On the contrary, the size of the company, access to contact networks, capital, skilled and professional workforce, as well as infrastructure are elements that inhibit the adoption and implementation of 4.0 technologies in Latin American companies (Ascúa, 2021; Carmona et al., 2020; ECLAC, 2022).

Of all the elements, the one linked to vocational training is an imminent brake on the acceleration towards adopting 4.0 technologies. Although most countries in the region have increased coverage of and access to basic, secondary, and technical-vocational education, there are no positive results in terms of quality. The education system does not have connectivity, devices, and teaching skills to develop logical thinking, problem-solving skills, and socio-emotional and collaborative work skills, essential components for assimilating and exploiting new technologies (ECLAC, 2022). The region's PISA scores in mathematics, reading, and science are below the average for the Organization for Economic Cooperation and Development (OECD) member countries. Less than 20 percent of students aged 24 to 35 have completed tertiary or university studies in Argentina and Brazil, compared with almost 50 percent in OECD member countries (ECLAC, 2022).

Few students are inclined toward technical careers or science, technology, engineering, and mathematics, which are the most in-demand by companies whose growth potential is based on innovation and new technologies (ECLAC, 2022). In other elements that are essential for the adoption of digital technologies, the lack of knowledge and proper training slows down and hinders the development of the digital ecosystem required to develop networks, attract capital investments, and prioritize the infrastructures that are needed (Ascúa, 2021; ECLAC, 2022).

3. Material and methods

This study employed a multiple case study. The instrument for data collection is a guide of structured, open, and closed questions, designed from the methodological guide of Carmona et al. (2020) in the context of the Euromipyme project led by the Economic Commission for Latin America and the Caribbean (ECLAC) to promote the adoption of new digital technologies in Latin American MSMEs.

The instrument is configured in three blocks. Block 1 collected data on the incorporation and use of new digital technologies. Block 2 included questions about the general description of the projects, investments, or services contracted in new digital technologies. Block 3 grouped questions aligned with projects, investments, or contracted services. This block focuses on questions about the motivations, problems, obstacles, and benefits of adopting 4.0 technologies with an emphasis on internal and external elements of the company. It is incorporated into the component of resilience to disruptive events. This component allowed us to observe whether or not the experiences of companies influenced the adoption of these technologies before disruptions associated with geomorphology and infrastructure.

Motivations, benefits, and obstacles were collected on a scale of 1 to 4, with 1 being the main reasons, 2 being Relevant but not the main reason, 3 being little or not relevant, and 4 not applicable. Likewise, the companies were asked to elaborate on the reasons for the categorizations and responses. Built-in reasons include improving the efficiency of a function or process, cost savings, staff replacement, quality, customer relations, supplier relationships, new product development or associated new services, and new business model development. Internal obstacles to the company include Lack of knowledge about the technology, Lack of interest/other more urgent projects require attention, Lack of interest/negative benefit-cost evaluation, Lack of qualified human resources for implementation, Lack of financial resources for investment, Lack of necessary infrastructure and internal connectivity, others to be specified. For External Obstacles to the company, the selection includes Immature technology, Lack of suppliers of technological products or services, Lack of financing supply or financing conditions are not adequate, Lack of availability of qualified personnel in the labor market, Insufficient training and training system for new requirements, Weak or insufficient information and communications infrastructure, Macroeconomic context, Instability of the economy.

Those related to the resilience component at the level of internal obstacles included 100% dependence on electricity, Lack of a renewable energy supplier or system, Lack of an alternate provider (backup) of cell phones, Lack of backup data storage and cybersecurity, Lack of a backup or alternate drinking water system, other. At the external level, they were Vulnerable and/or unreliable electricity supply systems, Vulnerable and/or unreliable telecommunications systems, Weak or insufficient or short-range satellite or cable connectivity systems, and Bureaucracy of government agencies for acquiring permits and licenses for financing solar energy systems.

Finally, the interviews sought to identify aspects related to financing modes and types of non-financial aid. Puerto Rican companies were identified and selected for the Puerto Rico Parallel18 accelerator, which manages and hosts projects that facilitate entrepreneurship through grants, technical support, networking, and resources for researchers, entrepreneurs, farmers, investors, and other groups.

A sample of 39 companies was selected according to their industrial classification or economic activity, especially looking for sectors related to technology that met the following requirements: MSMEs with five years or more of operation, belonging to different business sectors, with at least 3 vectors of the 4IR incorporated in their company and with a presence on the Internet. The shortlist was sent an invitation letter by email and contacted by phone. Data triangulation was used to obtain greater quality control in the analysis process and to guarantee validity, credibility, and rigor in the results (Aguilar et al., 2015; Benavides & Gomes-Restrepo, 2005). Of the 39 MSMEs selected, 22 completed the pre-selection form, 18 agreed to be interviewed, and 18 finished the interview and data corroboration process. The entire study was conducted between October 2022 and April 2023.

The interviews show that 67% (12/18) tend to incorporate applications and software that allow them to be integrated into the network to which the business belongs. These are primarily services to the regulated health industry, whose operations are audited and controlled by the government, authorities, and regulatory agencies. This sector is characterized by harmonizing operational standards, which allows processes to be structured within a network of suppliers, auditors, and suppliers (insurers, medical equipment producers, engineers, distributors, retailers, and health professionals). These standards are determined by the industry, which requires companies or businesses to operate with operating systems, platforms, software, and equipment approved by local and federal health laws, which allows their members (entrepreneurs) to exchange data, develop regulated products and

services, security and confidentiality, market intelligence, among other functions. Although being a regulated industry guarantees the entrepreneur reliability in the data exchanged (non-duplication, updating, etc.), referrals, etc., it limits its autonomy for the acquisition of 4.0 technologies that are not authorized by the industry and its regulatory agencies, such as the Food and Drug Administration (FDA) or the European Medicines Agency (EMA). This implies that the entrepreneur is subject to constant investments, auditing, and validation processes, and the costs could rise and impact the company's competitiveness and survival. Those who determine which 4.0 technologies companies can or cannot adopt rely on the authorities that regulate the health industry. This explains why MSMEs in this sector are a priority for the adoption of 4.0 technologies, the need for digitalization with the platforms and equipment required by the industry, and thus guarantee the continuity of operations.

As can be seen in Table 1, the MSMEs mainly studied respond to the services sector, with health services standing out. Similarly, cloud computing, sensors and the Internet of Things (IoT), and *Big Data* analysis constitute the 4.0 technologies the participating companies have integrated for more outstanding performance and efficiencies in their operational processes (human resources management, payment system, accounting and finance, inventory, etc.). As with the findings reported in the study by Ascúa et al. (2021) on the case of Colombia, the technologies implemented, in process, or projected to be implemented included IoT sensors, advanced robotics, 3D additive printing, cloud computing, *Big Data analytics*, and artificial intelligence.

The MSMEs studied were developed between the initial and intermediate stages of adopting 4.0 technologies. Eight (8) recognize the need to invest in moving to a phase of technology expansion, which, according to the future projects they mentioned, mainly facilitates the application of predictive intelligence techniques to the different areas of the company.

Advanced robotics and process automation are among the 4.0 technologies that MSMEs in the regulated industry combine with those mentioned above. Some reported that these two technologies are projected to be adopted in the future. These are MSMEs in the agribusiness sector, namely ABAC and SCIEN. On the other hand, all participating MSMEs recognize that to remain competitive, financial investment in state-of-the-art technologies must be continuous to ensure continuity as a company. The participating MSMEs in the health services sector agree that the adoption of IoT, artificial intelligence, and cloud computing technologies allows them interoperability, data analysis, projections, efficiency, and effectiveness in real-time and linking with customers through virtual assistants and, in some cases, through *Customer relationship management* (CRM) software. Medical services offices, equipment manufacturers, medical devices and software, and validation and audit services stand out in this sector. Two (2) participating companies excel in implementing advanced robotics and 3D printing: DBA and INSU. The former offers medical services dedicated to studies and interventional procedures to patients with gastrointestinal, liver, kidney, or biliary tract problems. This company uses advanced robotics using a gastroscope, which they acquired in 2022, with NBI (*Narrow Band Imaging*) technology to analyze tissues more precisely. Incorporating artificial intelligence facilitates the analysis of images obtained with NBI technology.

In the case of INSU, a manufacturer of refrigerators that transport medicines that require special refrigeration, 3D printing allows different designs (prototypes) to be tested at a lower cost to improve their product. In the case of SHAPR, a manufacturer of virtual reality glasses that provide cognitive training to improve the skills of people diagnosed with autism or any user who wants to improve some other skill, such as athletes and/or others, 3D printing facilitates the creation of different prototypes that allow the incorporation of accessories and meet specific demands for other niche markets. For ADOR, the combination of 3D printing with programmed (*AutoCad, Solidworks,* and *MasterCam)* and other technologies such as CNC, Milling, EDM, and Lathe provides flexibility and speed when designing parts according to the needs of its customers and, in turn, allows it to work with different materials, such as plastic and metal (steel, *stainless steel*, etc.)., bronze, aluminum, copper, among others). In the case of BLUE, which provides engineers and scientists with auditing and validating processes and automation of the regulated industry, 3D printing has contributed to identifying attachments that result in innovations, efficiency, increased production, and quality of the audited processes. For ABAC and E-FULL, incorporating advanced robotics has improved their customer portfolio, maximized logistics and supply processes efficiency, and reduced errors and redundancy.

Table 1 New digital technology projects implemented, under implementation, or projected in MSMEs in Puerto Rico.

							Implementation level		
MSMEs	**Sector**	**Location**	**Type of project**	**Implementation**	**Project Initiation (Year)**	**Financing**	**Implemented**	**In process**	**For the future**
DBA	Health Services	San Juan	Advanced robotics, sensors and the Internet of Things, cloud computing, Big Data analytics and artificial intelligence (AI)	Advanced robotics with an NBI (Narrow Band Imaging) gastroscope for tissue analysis, using electronic records with links to perform telemedicine and virtual assistant for appointment and call management (LARA).	Electronic File (2010). Virtual Assistant (2020), Gastroscope (2022).	The surplus income is used for extraordinary investments. They do not consider external financing and receive support from academia.	X		X Update Big Data
INSU	Medical Equipment Manufacturing	San Juan	3D printing, advanced robotics, sensors and the Internet of Things, cloud computing, big data analytics, and AI.	3D printing, advanced robotics, sensors and the Internet of Things, cloud computing, big data analytics, and AI.	2018	It has received money from business organizations and the government but has not yet generated its own sales income. It has also received support from academia.	X		X Update Big Data and Advanced Robotics
ABAC	Agricultural technology	Peñuelas	Big Data, Sensors & IoT, Advanced Robotics	Documentation, analysis, and management of historical data and automation of current data. Microclimate monitoring, invoice automation collection system, and geolocation of animals and pests within the farm. Automation of the sowing and harvesting process.	2021	$125K was awarded by the business support organization Parallel18.	X Big Data		X Sensors, IoTs, and Advanced Robotics
CLIN	Medical Services	San Juan	Cloud Computing and IoTs	Archiving medical records. Communication and delivery of electronic prescriptions directly to the pharmacy.	2015	$20K Small Business Administration (SBA) Business Loan)	X		X Sensors and equipment for IoTs
ADOR	Die Cutting Services, Manufacturing for the Pharmaceutical Sector	Bayamón	3D, Laser, and WaterJet cutting machines	Part design using AutoCAD, SolidWorks, and Mastercam systems. Manufacturing metal or plastic parts with 3D cutting, Laser, and Waterjet machines	2017	Own business cash reserve and SBA loans.	X		
LABO	Biological Sample Analysis Services	Las Piedras	Digital recording, digitized communication of results, IoTs, and cloud computing.	Entry into digital cooperation agreements through the laboratory networks of Assertus Puerto Rico to establish a system of registration and delivery of results online. IoTs for Productive Online Data Availability.	2020	The corporation's funds are contributions from the owners and external capital collateralized by company or family assets.	X		
E-FULL	Digital Wholesaler	Guaynabo	Advanced Robotics, Cloud Computing, and AI	Software that facilitates accounting, customer relationship management, purchasing, and sales	2020		X Cloud Computing		X Advanced robotics and AI to facilitate inventory and warehousing operational processes

DELG	Legal Services	Rio Piedras	AI, Cloud Computing, and Big Data Analytics	AI software for case management, legal-legal data analysis, and integration of organizational areas and activities through cloud computing.	2019 (AI), 2020 (Cloud Computing), 2023 (Big Data)		X		
BERR	Technological services to Pharmaceutical, Biotechnology, Medical Devices, and Consumer corporations, among others	Caguas	IoT, cloud computing, and big data analytics	IoTs-Process automation in areas of production, marketing, and customer relations. (Ex. Customer Support); Cloud computing to facilitate the integration of organizational areas (e.g., Workflow: roles, creation of activities, and reporting). Big data integrates data from production, business (sales, inventories, logistics), validation processes, and scientific experimentation through different business intelligence platforms.	2015		X		
BRAN	Digital retail services	Guaynabo	Cloud computing, big data analytics, authentication and fraud detection, AI	Cloud computing-. Internal - Company information is in one place through a platform built in PHP (programming language) using the e-commerce library. It has several integrations through Google Analytics, Google marketing, Facebook, Apps, and hotspot integration such as CRM Big Data- Internal - Data integration through Microsoft BI for clear and timely information visualization. Authentication and Fraud	2016		X		X Additive 3D printing
				Detection-Internal—The Payment processor (always on) was purchased with the provider STRIPE, which has its own algorithm that identifies risk patterns that may indicate fraud when people are shopping (credit card thefts).					
ASPP	Health Services	San Juan	Sensors, IoTs, Cloud Computing, Big Data Analytics, AI	IoTs and artificial intelligence are used for interoperability, data analytics, and telemedicine. Cloud computing for data analysis. Big Data Analytics for 330 Center Data Analytics	2015	U.S. Department of Health State Funding	X		X (Advanced Robotics)
DIMED	Health Services	San Juan	Sensors, IoTs, Cloud Computing, Big Data Analytics, AI	IoTs for remote patient monitoring. Cloud computing via the iUGO Care platform. Artificial intelligence through a SaaS (software as a service) platform).	2020	Parent Company, Surgical Solutions Puerto Rico	X	X Big Data	
BRAIN	Health Services	San Juan	AI (chatbots), Data analytics and automation	Virtual assistant chatbot to recover missed calls. Database system to assist in monitoring, call flow analysis, and customer experience. Automation of the appointment scheduling process for clients.	2017	The owners initially financed the company. Then, it won the Start-up competition and received private funding from accelerators and incubators.	X		
SHARP	Health Services	Barceloneta	AI, Virtual Reality	AI and virtual reality systems are used to develop digital products and applications that improve customers' reactions and attention skills.	2018	Private capital of the owners. Scholarships from incubators such as Parallel18, the American Heart Association, and some entrepreneurship and development programs.	X		
SCIEN	Agroindustry	Gurabo	Big data, IoT, cloud computing, AI	Big data analytical technologies that make it easier to understand the botanical material and discover the correct chemical composition, real-time integration of processes and data.	2017		X (IoTs, cloud computing)	X AI	X (Big data, chemometric methodologies to improve the quality of botanical supplements).

SORRI	Technology Services	Carolina	Sensors, IoTs, Big data	Applications that facilitate the interconnection between customers (B2B) and end customers (B2C) through Self-Service Technology (SST) Door Dash. Cloud Based POS System Clover.	2019		X		
PHAR	Develops solutions and software for regulated industry	San Juan	IoT Sensors, Cloud Computing, and Big Data Analytics	IoT Platform Development uses Raspberry Pi devices and integrates the data with the client's ERP systems. The project was developed with its own personnel and validated in a medicine storage and distribution company.	2014		X		
BLUE	Regulated Industry Consulting and Validation Services	San Juan	Big Data Analytics & Automation, AI	Algorithms are being developed to analyze analytical qualities using innovative technologies (PAT) and infrared sensors. Automation equipment is being validated, and 3D printing is being considered.	2016		X	X AI	

Source: Author's elaboration, 2024.

As can be seen in Table 2, in order of priority, the motivations of 50% of the participants (9/18) indicate that maintaining efficiency in the company's daily operations is the first trigger to consider the adoption of 4.0 technologies; 39% (7/18) consider guaranteeing the continuity of operations through digitalization as the primary trigger, and 2/18 (12%) indicate that improving customer service and optimizing the quality of the product/service are the primary motivators, respectively. These findings coincide with some motivations reported by the cases in Colombia, Argentina, and Brazil, where the central motivators for the adoption of these technologies are to improve the efficiency of a function or process, save on costs, and improve quality (Carmona et al., 2020; Maggi et al., 2020; Motta et al., 2019). In the case of Chile, according to Maggi et al. (2020), the primary motivators in the adoption of 4.0 technologies are to improve competitive positioning, develop differentiating attributes of the offer, improve customer pre-sales, improve product quality, build customer loyalty against new competitors, update to stay current in the market and diversify their offer, which makes it easier for them to remain competitive.

It should be noted that adopting these technologies was influenced by disruptive events (hurricanes, earthquakes, and pandemics) on daily operations when the alternative of digitalization, as well as the incorporation of energy backup equipment, was critical in this decision-making. This allowed companies to offer digital registration services, telemedicine, electronic invoicing, digitized data communication, cloud storage, and cybersecurity. In the Colombian case, adopting these technologies was influenced by an external element linked to the Government and its support, in tax exemptions, to companies that adopted these technologies (Ascúa et al., 2021).

Table 2. Motivations and proceeds from the adoption of 4.0 technologies

Scale	MSMEs	#	Motivations	Proceeds
Foremost (1)	INSU, BERRY, BRAND, BRAIN, E-FULL, ADORN, SORRI, ABRAC, SCIEN	9/18 50%	Improve the company's operational processes	Efficiencies in daily operations
	ASPP, DIGIMED, DELGA, LABO, CLINI, BLUE, PHARMA	7/18 38.8%	Ensuring continuity of operations through digitalization	Competitiveness through retention and increase in the portfolio of customers and suppliers
	DBA	1/18 5.5%	Improve customer service	Efficiency and effectiveness in the relationship with the client
	SHARP	1/18 5.5%	Optimize the quality of the product or service	Product and service development
Relevant (2)	INSU, BERRY, BRAND, DIGIMED, SORR	6/18 33.3%	Cost reduction or savings	Elimination of redundancy in tasks and labor optimization
	Scale			
	I, ADORN			
	ABRAC, LABO, SCIEN, BLUE, PHARMA	5/18 27.7%	Digitization of core operations	Automation of operations
	INSU, BRAND, DIGIMED, ASPP	4/18 22.2%	Improve the relationship with suppliers	Effectiveness in the relationship and contractual relationships with suppliers
	SHARP, DIGIMED, ASPP, ADORN	4/18 22.2%	Attracting new customers with new value propositions	Expansion of the customer portfolio
	DBA, BRAND, E-FULL	3/18 16.6%	Strengthening data security	Robust and reliable system for users

Source: Author's elaboration, 2024.

Participants cited other relevant but not the main reasons for adopting technologies, achieving cost savings (33%), digitizing operations (28%), improving relationships with suppliers (22%), attracting new customers with innovative value propositions (22%) and strengthening data security (17%). It is interesting to note that for most MSMEs that belong to the regulated industry, the issue of confidentiality for information sensitivity has not been the primary motivation for most companies. However, only 3/18 (17%) incorporated the issue of security as a mechanism that benefits from a robust and reliable system, it is also interesting to note that 22% or 4 of the 18

companies indicated as a trigger to improve the relationship with suppliers, whose benefit is to improve or comply with the contractual relationships assumed as part of the business model in the regulated industry, whose actors are obliged to have their operational processes harmonized; This includes programs, equipment and cybersecurity systems. This allows them to have greater control and reliability in the exchanged data.

When analyzing the setbacks for the implementation of technologies, it is observed that the lack of qualified human resources (4/18) and capital for investment (6/18), as well as dependence on the country's energy system (4/18), were the internal obstacles highlighted by the participants, followed by dependence on external servers from customers and/or suppliers (1/18). Slow and complex implementation processes, either because they do not yet have the appropriate or updated infrastructure and/or because most of the tasks are manual (3/18. The first two internal obstacles reported here were also suggested as the most challenging by MSMEs in Nueva Ecija, Philippines, in their digital transformation (Agustin et al., 2024), in addition to resistance to change.

Regarding external obstacles, most participants mentioned instability in the energy system that the State controls under the Electric Power Authority (PREPA) as the major obstacle (11/18). The lack of financing (5/18) and the availability of qualified personnel in the labor market (2) were also added.

It is interesting to note that the resilience component (due to natural events or the country's infrastructure) was selected among the first obstacles mentioned by the participants. This should come as no surprise because the government has experienced ongoing disruptions in recent years: hurricanes (Irma and Maria in 2017), earthquakes (2020, 2021), supply chain disruptions from Hurricane Harvey in Texas (2017), and the COVID-19 pandemic (2020). These disruptions have propelled new business models in SMEs and the digitization of their most pressing operations as resilient strategies (Lozada-Contreras et al., 2022; Orengo-Serra et al., 2022). These obstacles associated with energy infrastructure hurt drinking water and telecommunications infrastructure, which depend 100% on the country's energy system, which is an obsolete and bankrupt monopoly of the State (Orengo Serra et al., 2023).

4. Discussion

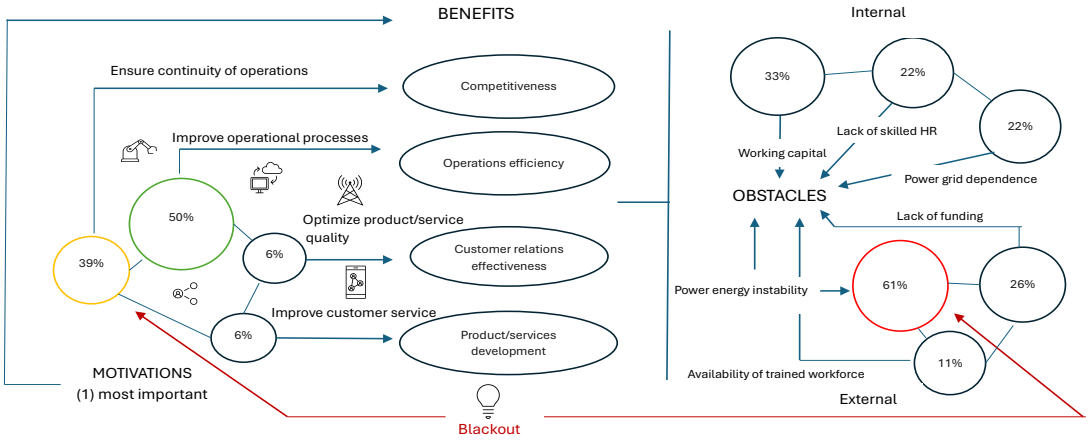
4.0 technologies are changing how we do business and impacting the performance of companies at an economic and business level (Mushtaq et al., 2023; Nor al., 2021). In this study, the adoption of 4.0 technologies responds mainly to the need to achieve efficiency and effectiveness in the company's daily operations within the challenges and obstacles they face. Challenges and obstacles include: 1. regulated industry provisions that require uniformity and interdependence of industry actors (firms), 2. accelerated changes in the industry at a global level impacted by advances in these technologies, 3. access to capital of companies for financing, 4. skilled labor, 5. dependence on a single available energy supplier, and 6. instability of the country's energy system characterized by constant blackouts that affect critical infrastructure (water and telecommunications), among other elements.

As shown in Figure 1, digitalization and the adoption of other 4.0 technologies are critical components for the survival of MSMEs and access to their backup energy infrastructure in case of frequent disruptions, thus providing autonomy and continuity of operations. The resilient infrastructure component, both energy and technology, sheds light on this issue from a geospatial approach that little research addresses, which imparts originality to this study. A disruption that affects the energy system has repercussions on the continuity and efficiency of daily operations, among others. Precisely 61% of the participants recognize that energy (see Figure 1) is the most important threat they face.

Another component is the capital required to maintain the latest generation technologies, which suggests the need for companies to have a budget allocated to technological innovations and training (Agustin et al., 2024; Nor et al., 2021). The issue of training is critical in business digitalization. A study in Pakistan found that SMEs that adopt technological advances to promote digital literacy in management and invest in digital infrastructure demonstrate greater operational efficiency and market adaptability (Mushtaq et al., 2023). Similarly, the state must develop a technological ecosystem to promote digital policies to support MSMEs in adopting technologies and digital literacy (Mushtaq et al., 2023). This ecosystem must be supported by a resilient energy and telecommunications infrastructure, which facilitates the exchange of knowledge and contact networks.

Creating an environment that develops networks of collaboration and awareness of the need to incorporate these technologies for the competitiveness and survival of companies in this 4IR must be one of the main goals of every company operating in today's business world. Technologies will be even more disruptive and changing. The profile of markets continues to evolve rapidly, so companies, especially MSMEs, are forced to insert themselves into the change, or they will be exposed to disappearing. The companies studied reflect these advances that fluctuate between incipient and intermediate stages. Healthcare industry has undergone significant transformations in recent

decades, from introducing nanotechnology medicines, precise medical devices and equipment connected to AI, telemedicine, and next-generation genomic medicine (Ahsan et al., 2022), all driven by 4.0 technologies.



Source: author's own elaboration, 2024.

5. Conclusions

This study is original because it offers an ontological approach to MSMEs adopting and implementing 4.0 technologies in a particular geomorphological environment (open island economy in the Caribbean). This environment reflects the vulnerability to which these companies are exposed. These vulnerabilities consist of a market closely linked to the United States, constant exposure of companies to natural disruptions – storms, hurricanes, earthquakes – that affect the supply chain, a complex and costly business climate for the development and positioning of MSMEs, competition from subsidiaries of business groups in the regulated industry due to the free market provided by the legal relationship between the United States and the territory, and the exodus of professionals to the metropolis in search of better working conditions.

Because 4.0 technologies and MSMEs in the Caribbean are rarely addressed, this research contributes to the scientific legacy of the phenomenon with practical and theoretical implications. On a practical level, the study sheds light on the technological instances in which MSMEs operate, which allows policymakers and practitioners operating in similar environments to develop projects and initiatives, enabling systematic and progressive insertion of MSMEs in the digital business world. On the other hand, this study opens a space for the employment of quantitative methodologies that enable the extension of the research to a broader and more representative sample for various industrial sectors in a transversal, comparative, national, and international scope.

As observed in this study, AI is a 4.0 technological vector that has assisted in developing other technologies widely used by MSMEs. AI expands the possibilities for many economies to move towards R&D of products and services with 4.0 technologies. However, global hardware and software monopolies by a tiny group of big tech companies represent a challenge for governments and companies, particularly MSMEs, the most significant contributor to GDP (UNESCO, 2022). A future additional line of research could unlock the debate on whether MSMEs in the region will continue to consume these technologies or will be able to move towards the process of absorption and creation of knowledge as a gateway to playing a leading role in specific niche markets for the region (UNESCO, 2024).

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References

Aguilar, S., & Barroso, J. (2015). La triangulación de datos como estrategia en investigación educativa. España: Píxel- Bit. *Revista de Medios y Educación.* https://doi.org/10.12795/pixelbit.2015.i47.05.

Agustín, N., Hidalgo, D. T., & Morante, B. J. (2024). Challenges in Digital Transformation of Microenterprises in Nueva Ecija: A Basis for Risk Management Plan. *Journal of Economics, Management and Trade*, *30*(4), 13-26. https://doi.org/10.9734/jemt/2024/v30i41201

Ahsan, M. M., & Siddique, Z. (2022). Industry 4.0 in Healthcare: A systematic review. *International Journal of Information Management Data Insights*, 2(1), 100079. https://doi.org/10.1016/j.jjimei.2022.100079

Ascúa, R. B. (2021). Industry 4.0 in manufacturing SMEs of Argentina and Brazil. *Journal of the International Council for Small Business*, 2:3, 203-222. https://doi.org/10.1080/26437015.2021.1899773

Ascúa, R. B., Rojas-Berrio, S., Ravale, H. & Rincón-Novoa, J. (2021). Tecnologías Digitales Emergentes en Emprendimientos y Mipymes (Colombia). *Documentos FCE-CID Escuela de Administración y Contaduría Pública*, 39, octubre de 2020. https://ssrn.com/abstract=3712627.

Atieh, A. M., Cooke, K. O., & Osiyevskyy, O. (2023). The role of intelligent manufacturing systems in the implementation of Industry 4.0 by small and medium enterprises in developing countries. *Engineering Reports*, *5*(3), e12578. https://doi.org/10.1002/eng2.12578.

Bédard-Maltais, P. O. (2018). *Digitize Now: How to Make the Digital Shift in Your Business*. BDC. https://www.thorhildcounty.com/Portals/0/Documents/Brochures/Why-Doing-Business-Online-Matters-Full-Study.pdf

Benavides, M. O., & Gómez-Restrepo, C. (2005). Métodos en investigación cualitativa: triangulación. *Revista Colombiana de Psiquiatría*, *34*(1), 118-124. http://www.scielo.org.co/pdf/rcp/v34n1/v34n1a08.pdf

Carmona, Amato Neto & Ascúa, R. (2020). Industria 4.0 en empresas manufactureras del Brasil, Documentos de Proyectos (LC/TS.2020/136), Santiago, CEPAL. https://repositorio.cepal.org/server/api/core/bitstreams/ae2c0407-e1dc-41ee-acde-5187657045d9/content.

Cordero, D., Altamirano, K. L., Parra, J. O., & Espinoza, W. S. (2023). Intention to adopt industry 4.0 by organizations in Colombia, Ecuador, Mexico, Panama, and Peru. *IEEE Access*, *11*, 8362-8386. https://doi.org/10.1109/ACCESS.2023.3238384.

Cuéllar, S. (2020, September 30). Industry 4.0: Latin America SMEs Challenges. *Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI)*, 1-6. IEEE. https://doi.org/10.1109/CONIITI51147.2020.9240428.

ECLAC. (2022). *Tecnologías digitales para un nuevo futuro*. Economic Commission for Latin America and the Caribbean. UN. https://repositorio.cepal.org/server/api/core/bitstreams/879779be-c0a0-4e11-8e08-cf80b41a4fd9/content

IMD World Global Competitiveness. (2020). *IMD World Digital competitiveness ranking 2020*. Institute for Management Development. https://digitalswitzerland.com/wp-content/uploads/2020/10/digital_2020.pdf

Lozada-Contreras, F., Orengo-Serra, K. L., & Sánchez-Jauregui, M. (2022). Adaptive customer relationship management contingency model under disruptive events. *Journal of Advances in Management Research*, *19*(2), 198-219. https://doi.org/10.1108/JAMR-12-2020-0347

Maggi, C., Ramos, M. & Vergara, R. (2020). Adopción de tecnologías digitales 4.0 por parte de pequeñas y medianas empresas manufactureras en la Región del Biobío (Chile). *Documentos de Proyectos* (LC/TS.2020/133), Santiago, Comisión Económica para América Latina y el Caribe (CEPAL). https://www.cepal.org/es/publicaciones/46387-adopcion-tecnologias-digitales-40-parte-pequenas-medianas-empresas.

Motta, J.J., Morero, H. & Ascúa, R. (2019). Industria 4.0 en MiPymes manufactureras de la Argentina. Documentos de Proyectos (LC/TS.2019/93), Santiago, Comisión Económica para América Latina y el Caribe (Cepal). https://www.cepal.org/es/publicaciones/45033-industria-40-mipymes-manufactureras-la-argentina.

Mushtaq, N., Hussain, F., Dad, A., Rehman, S. U., & Waseem, M. (2023). Digital Transformation and Its Impact on Business Performance in SMEs of Pakistan: An Empirical Study. *The Asian Bulletin of Big Data Management*, *3*(2), 103-114. https://doi.org/10.62019/abbdm.v3i2.92

Nor, S. M., Ahmad, M. B., Azizan, M. R. M., & Ahmad, M. A. (2021). Emerging economy: digital transformation and business performance: investigating the relationship among SMEs in Kuala Lumpur, Malaysia. *Asian Journal of Social Science Research*, *3*(1), 49-60. https://doi.org/10.5281/zenodo.8063141.

Orengo Serra, K. L., & Sánchez-Jauregui, M. (2022). Food supply chain resilience model for critical infrastructure collapses due to natural disasters. *British Food Journal*, *124*(13), 14-34. https://doi.org/10.1108/BFJ-11-2020-1066.

Orengo Serra, K. L., & Sánchez-Jauregui, M. (2023). Promoting a resilient food supply chain model facing disruptions associated with black sky hazards. *Continuity & Resilience Review*, *5*(1), 79-93. https://doi.org/10.1108/CRR-12- 2022-0035

UNESCO. (2022). *Recomendación sobre la Ética de la Inteligencia Artificial*. https://www.unesco.org/es/articles/recomendacion- sobre-la-etica-de-la-inteligencia-artificial

UNESCO. (2024). *Foro CILAC: Inteligencia Artificial y Políticas Públicas*. Ciencias, Latinoamérica y el Caribe. https://forocilac.org/en/28-ago-inteligencia-artificial-y-politicas-publicas/.

Urraca-Ruiz, A., Torraca, J., Britto, J., & Ferraz, J. C. (2023). Factors determining the path of digital technologies adoption of Brazilian industrial firms. *Revista Brasileira de Inovação*, *22*, e023014. https://doi.org/10.20396/rbi.v22i00.8668448