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Navigating Storms: Organizational Resilience of Small and Medium Sized Knowledge-Intensive Enterprises

Navegando tormentas: resiliencia organizacional de pequeñas y medianas empresas intensivas en conocimiento

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ABSTRACT

The article aims to identify the factors influencing the organizational resilience of knowledge-intensive SMEs in Northern Mexico, specifically in the context of the COVID-19 pandemic (2020-2021). The empirical study is based on a follow-up survey conducted in 2022, which included enterprises from four metropolitan areas within the region. The findings indicate that the most resilient knowledge-intensive Mexican SMEs are those that originated as spinoffs, maintain organic connections with at least one multinational enterprise (MNE), and serve as suppliers to MNEs. These results are consistent with prior research highlighting the relationship between technology spillovers from MNEs and the absorptive capacities of SMEs. Additionally, they emphasize the need for further investigation into the role of regional innovation systems in supporting SME resilience.

Keywords: 1. organizational resilience, 2. knowledge-intensive SMEs, 3. global value chains, 4. North America, 5. Northern Mexico.

RESUMEN

El objetivo del artículo es identificar los factores que influyen en la resiliencia organizacional de las pymes intensivas en conocimiento en el norte de México en el marco de la crisis asociada a la pandemia por el COVID-19 (2020-2021). El estudio empírico está basado en una encuesta de seguimiento aplicada en 2022 a empresas de cuatro zonas metropolitanas de la región. Los resultados muestran que las pymes mexicanas intensivas en conocimiento más resilientes son aquellas que surgieron a través de desprendimientos tipo *spin-off,* mantienen vínculos orgánicos con al menos una empresa multinacional (EMN), y son proveedoras de EMN. Estos resultados coinciden con estudios previos que destacan la relación entre las derramas tecnológicas de las EMN y la capacidad de absorción de las pymes, a la vez que sugieren la importancia de profundizar en las investigaciones sobre el papel de los sistemas regionales de innovación en la resiliencia de las pymes.

Palabras clave: 1. resiliencia organizacional, 2. pymes intensivas en conocimiento, 3. cadenas globales de valor, 4. Norteamérica, 5. norte de México.

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INTRODUCTION

The survival of small and medium-sized enterprises (SMEs) has long been recognized as a critical concern by governments in nearly all nations, as well as by various international organizations. This concern was particularly heightened by the COVID-19 pandemic, which exposed many enterprises to severe disruptions, threatening their long-term viability. In the business context, resilience is conceptualized as the strengthening of organizational capabilities necessary for adapting to and responding effectively to crises. More specifically, it refers to a set of internal capacities that enable an enterprise to withstand and navigate external challenges.

In Mexico, the study of organizational resilience is a relatively recent field of inquiry. While SMEs are widely acknowledged for their significant economic and social contributions, knowledge-intensive SMEs represent a particularly important subset. These enterprises operate within dynamic and technologically complex niches, employ a highly skilled workforce, and are capable of generating higher-quality jobs compared to the broader industry average. Despite their importance, however, research on resilience within this specific type of enterprise remains largely underexplored.

The aim of this article is to identify the factors that influence the organizational resilience of knowledge-intensive SMEs in northern Mexico. This analysis focuses on examining the survival of these enterprises during the COVID-19 pandemic, specifically within the period from 2020 to 2021.

KNOWLEDGE-INTENSIVE SMEs AND ORGANIZATIONAL RESILIENCE

The global economy is marked by significant interdependence among countries and regions, resulting in widespread and severe repercussions from economic crises. Recent events, such as the 2008-2009 financial crisis and the COVID-19 health crisis of 2020-2021, have underscored the extensive and profound challenges faced on a global scale. In both cases, SMEs were particularly affected. Beyond the usual difficulties they face in ensuring their survival, SMEs had to contend with the additional impacts of these global crises.

Within the diverse and expansive realm of SMEs, knowledge-intensive enterprises stand out by offering products grounded in knowledge and technology or by delivering non-routine services characterized by a high level of knowledge intensity (Granstrand, 1998; Muller & Doloreux, 2009; Figueiredo et al., 2017). Despite the considerable structural weaknesses affecting most SMEs in the country, some studies have highlighted a modest yet growing trend of these SMEs integrating into global value chains (GVCs) by supplying multinational enterprises (MNEs) (Olea Miranda et al., 2018; Contreras Montellano & García Fuentes, 2019).

Although the resilience of knowledge-intensive SMEs has not been widely explored in the academic literature, two theoretical perspectives offer insights into the processes contributing to their resilience: (a) the maturation of regional innovation systems within the country, and (b) technological and knowledge spillovers from MNEs, which have enabled some local companies

to enhance their capabilities and improve their position within value chains (Dutrénit & De Fuentes, 2009; Contreras et al., 2012).

Organizational Resilience

The concept of resilience appears across various academic disciplines, including physics, ecology, health, psychology, and sociology. Despite its diverse interpretations, the central notion of resilience generally refers to the ability to withstand and maintain integrity in the face of adverse and disruptive events (Thorén, 2014; Rogers, 2020). In the business context, organizational resilience specifically relates to a company's capacity to adapt to and manage vulnerabilities arising from unpredictable events (De Carvalho et al., 2016).

When studying resilience in SMEs, it is often assumed that theories, conceptual frameworks, and methodologies developed for large companies can be directly applied to smaller enterprises. However, small businesses possess distinct operational characteristics and face unique vulnerabilities. SMEs encounter greater challenges in adapting to and recovering from adversity due to their heightened susceptibility to structural obstacles and constraints associated with their size, such as limited access to financing, technology, and market diversification. These challenges are further exacerbated by additional issues related to financial and human resources (Saad et al., 2021).

Numerous studies have documented the various barriers SMEs face when entering international markets and integrating into global supply chains. These barriers include insufficient capital, limited access to advanced technologies, a shortage of workers with specialized skills, restrictions on market entry, a lack of relevant and timely information, and deficiencies in business management skills and knowledge (Bair & Gereffi, 2001; Frederick & Gereffi, 2011; Chandra et al., 2020; Nurfarida et al., 2022). While these challenges are partly attributed to governance structures in GVCs, which are characterized by power imbalances (Gereffi et al., 2005), they are also linked to the intrinsic capabilities of local companies and their efforts to develop these capabilities (Da Costa et al., 2023).

Regional Innovation Systems

Despite structural obstacles and internal weaknesses, various studies have shown that local SMEs can enhance their capabilities and improve their position within value chains when operating in conducive business and institutional environments. This improvement occurs in regions with proactive business networks and supportive entities that facilitate advancements, enabling SMEs to access higher value-added segments (De Fuentes, 2010; Contreras et al., 2012; Fransen & Knorringa, 2019; Matsuzaki et al., 2021).

Innovation systems (IS) theory, which emerged in the late 1980s, posits that technological learning and innovation are driven by a series of interactive learning processes among various actors, rather than by mere market transactions. Freeman (1987) describes IS as networks of public and private institutions involved in the adoption, diffusion, and evolution of new

technologies. Lundvall (1992) refines this definition, emphasizing that IS include the elements and relationships essential for applying novel knowledge within a country. Nelson (1993) characterizes IS as a collection of institutions whose interactions shape the innovation capacity of national firms. IS comprise entities such as universities, research centers, and government agencies responsible for scientific, technological, and innovation policy, as well as sectors engaged in the dissemination and adoption of innovations. Additionally, IS include intangible resources, such as norms that guide interactions among different agents (Lundvall, 2007; Edquist, 2013).

A central argument of the IS approach is that learning processes are embedded within institutional and productive structures, emphasizing the importance of proximity and various types of interactions in the learning process (Lundquist & Trippl, 2013). Innovation, therefore, does not occur in isolation within individual companies but through a complex network of continuous interactions with other actors in a specific geographical area. Moreover, innovation encompasses not only technological advancements but also improvements in products, processes, and non-technological innovations, such as those emerging in service organizations (Lundvall, 2007; Iizuka, 2013).

In summary, the core principles of this perspective include: 1) the understanding that knowledge relevant to innovation is geographically localized and its transfer is not straightforward; 2) the recognition that essential aspects of knowledge are embedded in the capabilities, practices, routines, and interactions of individuals and organizations; and 3) the thesis that learning and innovation processes are deeply rooted in social contexts and should be understood as products of interaction.

The agents involved in an IS encompass a range of organizations that generate and disseminate knowledge, including universities, technological institutes, training centers, research and development (R&D) centers, technology transfer agencies, business associations, financial institutions, and others. These organizations contribute to regional innovation through functions such as transmitting technical knowledge, training the workforce, and providing financing. Innovation systems consist of two subsystems: 1) the knowledge application and exploitation subsystem, primarily involving companies integrated into supply chains, and 2) the knowledge generation and dissemination subsystem, which mainly comprises public organizations (Isaksen, 2001).

Global Value Chains

The theory of global value chains (GVCs) emerged alongside the theory of innovation systems in the late 20th century. The concept of a GVC refers to the entire sequence of activities required to produce a good or service, including raw material extraction, manufacturing, transportation, marketing, distribution, and after-sales services (Gereffi et al., 2005; Gereffi & Fernandez-Stark, 2016). The GVC approach facilitates the analysis of how production processes are segmented and relocated across various global locations. It also enables the identification of

governance structures within supply chains and the evaluation of opportunities for enhancing the capabilities of local firms in developing countries (Humphrey & Schmitz, 2000, 2004).

The governance of GVCs refers to the framework of "authority and power relationships that determine how financial, material, and human resources are allocated and flow within a chain" (Gereffi, 1994, p. 97). Gereffi et al. (2005) identified five types of value chain governance based on three parameters: 1) the complexity of transferring information and knowledge for product and process specifications; 2) the extent to which this information and knowledge can be codified; and 3) the current and potential capabilities of the supplier relative to transaction requirements. The five types of governance relationships are: a) market; b) modular; c) relational; d) hierarchical; and e) captive (Gereffi et al., 2005). The concept of upgrading pertains to the opportunities for local firms to improve their productivity, wages, and profits by engaging in global markets, while developing capabilities to produce higher-quality and higher-value-added goods and services.

According to Humphrey and Schmitz (2000), upgrading refers to processes that enhance value addition. The authors distinguish four types of upgrading based on the complexity and scope of improvements, which are detailed later. Additionally, Dutrénit and De Fuentes (2009) identify three conditions necessary for SMEs to capture spillovers from MNEs and strengthen their capabilities: 1) the presence of an MNE strategy related to supplying; 2) a certain level of technological and organizational capabilities within the local firm to absorb potential benefits; and 3) the existence of a mature regional or local innovation system.

In the past decade, significant efforts have been made to conceptually and methodologically integrate the IS and GVC approaches (Pietrobelli & Rabellotti, 2011; Lema et al., 2018; Mehta, 2021). Evidence suggests that co-evolution processes can occur between GVC governance patterns and the maturity level of IS. In this context, local firms can enhance their absorptive capacities and achieve improved innovative performance (Sampath & Vallejo, 2018). Empirical studies from countries as diverse as Kenya and Pakistan demonstrate how national and local institutions can strengthen the links between GVCs and IS, facilitating local firms' learning and enabling them to become suppliers to MNEs (Park & Gachukia, 2020; Naqvi et al., 2021).

METHODOLOGY

The study aimed to identify the factors influencing the organizational resilience of knowledge-intensive SMEs in four metropolitan areas of northern Mexico during the COVID-19 crisis of 2020-2021. To define the population of companies for the study, a directory of small knowledge-intensive enterprises in Mexico's 60 metropolitan areas was created, using the Directorio Estadístico Nacional de Unidades Económicas (DENUE) (National Statistical Directory of Economic Units) (Instituto Nacional de Estadística y Geografía [INEGI], 2018a). Companies were classified according to the North American Industry Classification System (NAICS) (*Sistema de Clasificación Industrial de América del Norte*; SCIAN) of INEGI (2018b), which facilitated the identification of six-digit industrial classes recognized in

academic literature as knowledge-intensive or technology-based (Hecker, 2005; Kile & Phillips, 2009; Alarcón Osuna & Díaz Pérez, 2016). This process resulted in 45 classes across seven sectors, generating a list of 2 056 companies fitting these classifications (see Table 1).

Table 1. Knowledge-Intensive SMEs by Region, According to Selected NAICS Classes (Frequencies)

NAICS CLASS		Northwest	Northeast	Metropolitan	Southeast	Center-west	Center-south	Total
332710	Machining of metal parts	31	191	53	14	78	63	430
541330	Engineering Services	15	29	53	25	27	19	168
541380	Testing laboratories	17	37	43	14	27	19	157
541510	Computer system design services	34	71	187	38	123	34	487
541620	Environmental consulting services	16	14	37	28	20	8	123
541690	Other scientific and technical consulting services	2	13	34	10	12	6	77
811219	Repair and maintenance of other electronic equipment	1	16	28	15	5	2	67
	Other classes	40	132	114	60	157	44	547
	Total	156	503	549	204	449	195	2056

Source: Own elaboration based on the Directorio Estadístico Nacional de Unidades Económicas (INEGI, 2018a, 2018b).

The sample size was determined based on the 748 companies located in the four metropolitan areas selected for this study, using a 95% confidence level (z = 1.96) and a sampling error of ±7% (p). A random sample of 127 knowledge-intensive SMEs was calculated, ensuring a representative distribution across each geographic location (see Table 2).

Table 2. Sample Distribution by Primary Activity and Metropolitan Area (Frequencies)

Primary activity of the company	Metropolitan area				
	Tijuana	Juárez	Hermosillo	Monterrey	Total
Manufacture	12	5	8	5	30
Services	23	25	22	27	97
Total	35	30	30	32	127

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

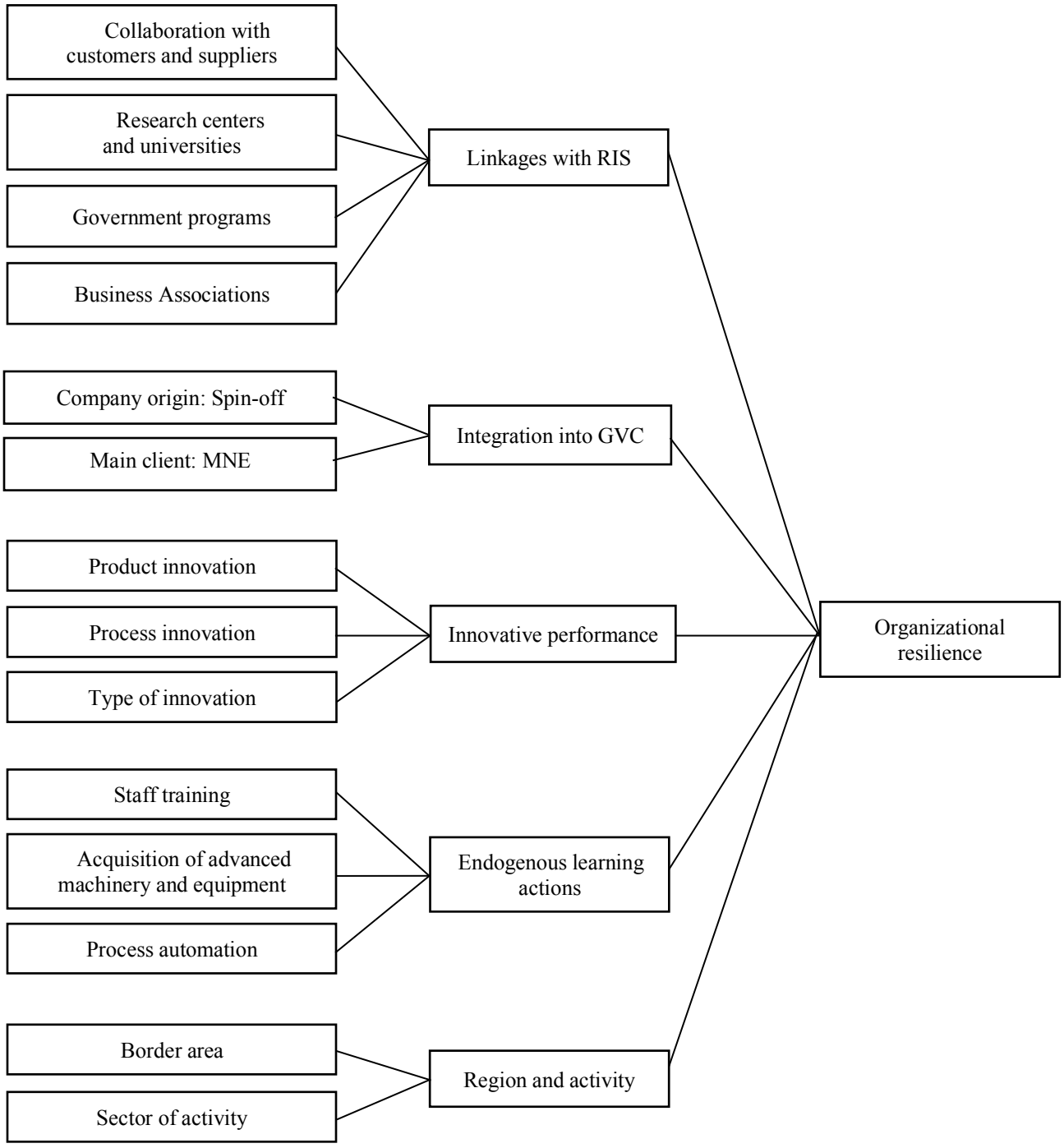
A standardized questionnaire consisting of 73 questions was administered to the owners of these companies to collect information on: a) the profile of the companies and entrepreneurs; b)

market entry mechanisms; c) learning processes; d) capacity building; e) the SMEs' linkages with MNEs and regional innovation systems (RIS); and f) value chain upgrading.

In June 2022, a follow-up survey was conducted using the database generated in 2018 to assess the status of the 127 companies in the sample after the critical phase of the pandemic had passed. This involved making phone calls, supplemented by visits to the companies' websites, to gather secondary information and determine whether they were still operational and what their primary activities were at the time of the follow-up.

For the statistical analysis of the results, Pearson's χ^2 test and logistic regression were applied, with the categorical variable Y expressed as "survival." The analysis focused on expressing the probability of the event $P(Y = 1)$, specifically the influence of the selected independent variables on survival during the pandemic. The analytical framework of the study is illustrated in Figure 1.

Figure 1. Analytical Framework



Source: Own elaboration

LEARNING, INNOVATION AND RESILIENCE: EXPLANATORY VARIABLES

From the literature on GVC and IS, several key variables emerge as relevant for defining an analytical framework to explain organizational resilience, particularly in the context of knowledge-intensive SMEs.

Linkages with Regional Innovation Systems

A. Collaboration with Customers and Suppliers

The relationships between SMEs and their clients and suppliers are critical for the maturation of regional innovation systems (RIS), particularly in technological and knowledge-intensive sectors. These relationships foster interactive learning processes that enhance SMEs' capabilities in dynamic markets and environments characterized by constant innovation. Regional collaboration networks among companies generate resources that are often difficult for individual firms to acquire, especially intangible resources such as informal rules and coordination mechanisms that strengthen their ability to navigate uncertainty. In various countries and technological sectors, such collaborative networks have demonstrated resilience against market turbulence, even when lacking a formal or explicit structure (Isaksen, 2001; Oh et al., 2015; Stojčić, 2021).

Conversely, in environments with a high concentration of large companies, interactions between local suppliers and MNEs often become a significant source of new knowledge. The structure and management of the supply chain can either facilitate or hinder learning processes. When mutual trust and strong interdependence exist, information flows more freely, leading to more effective knowledge transfer. Consequently, relationships based on trust and supplier reputation with MNEs can enable local SMEs to enhance their absorptive capacities and improve their position within the supply chain (Gundlach & Murphy, 1993; Görg & Greenaway, 2001; Dutrénit & De Fuentes, 2009; Sampath et al., 2018). Furthermore, research in various countries indicates that such relationships promote learning and strengthen absorptive capacities, thereby improving market performance (Becerra Rodríguez et al., 2013; Kim et al., 2018; Najafi-Tavani et al., 2020).

B. Linkages with Research Centers and Universities

In addition to relationships with other companies, the connections between SMEs and research and development centers, as well as other agents involved in knowledge creation and dissemination, play a crucial role in strengthening their learning processes and innovation capacities (Cohen & Levinthal, 1990; Lema et al., 2018).

Given the numerous limitations associated with their size, SMEs' participation in collaborative networks—whether formal or informal—with academic centers is essential for adapting to rapid technological changes and fostering product innovation. For SMEs operating in knowledge-intensive niches, these linkages with universities and research centers provide access to knowledge resources that would otherwise be difficult to obtain.

Numerous studies have shown that these linkages can enhance learning processes, operational skills, innovative performance, and market access (Pereira & Franco, 2022). For example, Gudda (2017) identified technology transfer from research institutions as a key predictor of product innovation in manufacturing SMEs in Kenya. Similarly, Bautista (2014) found that Mexican companies leveraging higher education institutions (HEIs) for their improvement processes demonstrated a greater capacity to enter the global market. Furthermore, a study assessing the Mexican government's support for business innovation and upgrading in GVCs noted that such support often facilitates functional improvements, though it rarely leads to intersectoral advancements (Martinez-Covarrubias et al., 2017).

C. Government Funds

Regardless of direct linkages with surrounding institutions, financial support through government funding can significantly enhance the absorptive capacities and overall competitiveness of local SMEs. This is especially true when programs are designed to foster connections between MNEs and national companies at the local and regional levels (Crescenzi & Harman, 2023).

Key public instruments supporting innovation include public funds for innovation projects, subsidies, tax reductions, and assistance with networking, information acquisition, and trade fair participation. A study in the European Union found that funding in these areas positively impacts product innovation (Antolín-López et al., 2016). In Argentina, public program funds have enabled SMEs to increase investment in the development of new services and products, as well as in machinery and equipment (Castro & Jorrat, 2013). In Brazil, government funds have facilitated the effective utilization of technological and knowledge spillovers from global value chains by small businesses (Navas-Alemán, 2011). In Mexico, prior to 2018, some startups benefited from incentives provided by government funds, trusts, and state and federal programs that supported entrepreneurship and the establishment of new companies (Casalet et al., 2009; López de Alba, 2014; Valenzuela & Bracamonte, 2014; Contreras Montellano & García Fuentes, 2019).

Insertion into Global Value Chains

The discussion on global value chains (GVCs) in Latin America has largely focused on the opportunities and challenges faced by companies in integrating into global markets, enhancing productivity, and acquiring capabilities to deliver higher-quality and value-added products and services (Pietrobelli & Rabelotti, 2006; Fernandez-Stark et al., 2014). Humphrey and Schmitz (2000) classify upgrading into four categories: Product Upgrading—transitioning to the production of more advanced goods and services; Process Upgrading—restructuring the production process or implementing technological advancements; Functional Upgrading—adding higher-value functions such as design and marketing while replacing lower-value functions like assembly; and Intersectoral Upgrading—applying skills from one sector to enter a new sector that requires greater investment in capital and technology.

While the debate over the positive effects on SMEs remains contentious in academic literature (Mancini, 2015; Hernández Chavarria, 2017), numerous studies from various regions suggest that SMEs' integration into GVCs can enhance their innovation, knowledge, and competitiveness, benefiting both individual firms and developing economies more broadly (Romero Luna, 2009; Abe, 2016; Deyshappriya & Maduwanthi, 2020). Along these lines, in an extensive study on the integration of local firms into global value chains in developing countries, Urata and Baek (2020) find that the benefits of GVC integration are greater for SMEs than for large enterprises.

Conversely, various empirical studies on the Mexican context highlight that connecting with MNEs is a key mechanism for SME upgrading within GVCs. This is either because it strengthens their absorptive capacities through knowledge and technology transfer (Olea Miranda et al., 2016), promotes the formation of new knowledge-intensive firms that serve as suppliers to MNEs from their inception (Contreras Montellano & García Fuentes, 2018), or enables firms to improve their productive and management capacities (Castillo et al., 2014).

In summary, research from various regions around the world suggests that integrating SMEs into GVCs facilitates access to new markets and advanced technologies. This integration enhances their competitiveness through knowledge transfer, innovation, and improved management practices—critical factors for the growth and long-term sustainability of SMEs operating in knowledge-intensive market niches.

Innovative Performance

Although innovation is extensively studied in the business literature (Nelson, 1993; Kim, 1997; Nooteboom, 2000; Lester & Piore, 2004), with a focus on its dynamics, determinants, and key actors, research often overlooks innovation as an independent variable in studies on firm performance.

Recent research has explored the impact of innovation on business resilience, revealing that more innovative companies tend to adapt better to sudden changes and exhibit a greater capacity to overcome adversities (De Carvalho et al., 2016). Additionally, diversification and productive innovation enhance resilience by improving companies' ability to recover swiftly from unexpected disruptions (Menéndez Blanco & Montes Botella, 2016). Furthermore, innovation in business models has been shown to positively influence adaptability and is recognized as a key element of resilience (Buliga et al., 2016).

From a broader perspective, a comprehensive study on the impacts of the 2007-2008 economic crisis in Europe found that more innovative regions were better equipped to withstand the crisis and experienced a faster recovery, demonstrating that innovation strengthens resilience (Bristow & Healy, 2018).

Similarly, research on the influence of innovation capabilities during the COVID-19 pandemic found that innovation acts as a critical mediator in the relationship between technological capacity and business resilience (Anggadwita et al., 2021).

Endogenous Learning Effort

In the literature on technological spillovers and knowledge flows, it has been demonstrated that a company's ability to harness and utilize new knowledge to enhance its capabilities depends not only on the availability of such knowledge but also on a deliberate and active effort to understand, integrate, and fully apply it, along with the associated technological tools (Cohen & Levinthal, 1990; Ernst & Kim, 2002). This process of appropriating knowledge may involve activities such as staff training, the adoption of new technologies, and investment in research and development (R&D), among others.

Among the internal actions companies take to enhance their capabilities, staff training is regarded as one of the most crucial, according to the literature. Continuous exposure to new knowledge and techniques equips employees to perform more effectively in highly competitive and rapidly evolving environments, where innovation is often a key resource (Panagiotakopoulos, 2011; Cerdá Suárez et al., 2023).

Empirical research has consistently demonstrated a positive correlation between investment in employee training and improvements across various aspects of innovation. These include advancements in product innovation (Demirkan et al., 2022), process innovation (Dostie, 2018), and key dimensions of innovation such as opportunity exploration, idea generation, and the promotion and implementation of new ideas (Abdullah et al., 2014). Furthermore, employee training is particularly crucial for smaller SMEs that have a lower proportion of university-educated employees and those that do not consistently invest in R&D (Demirkan et al., 2022).

RESULTS

For the purposes of this article, organizational resilience is measured by the survival capacity of companies during the health crisis triggered by the COVID-19 pandemic. The survival rate of SMEs in the sample was 84%. In comparison, Inegi (2021) reports that the general survival rate for small businesses in Mexico between 2019 and 2021 was 67% for microenterprises and 79% for small and medium-sized enterprises. Given that the Inegi study covers only two years, while this survey spans three years (2019-2022), the survival rate of knowledge-intensive SMEs in this study appears to be significantly higher than that of other SMEs in the country.

Characteristics of the Enterprises

Among the companies in the sample, 76.4% are technology service providers, primarily from sectors 51 (Information in Mass Media) and 54 (Professional, Scientific, and Technical Services). These companies typically offer services that address issues related to the acquisition, implementation, exploitation, maintenance, enhancement, and dissemination of emerging technologies for other businesses and organizations. The remaining 23.6% are manufacturing companies from sectors 31-33, producing high-value-added and technology-intensive goods such as computing equipment, metal products, machinery and equipment, and automobile accessories.

Regarding the size of the companies, just over a third (37.01%) are microenterprises with a maximum of 10 employees, while the majority (46.4%) are small enterprises with between 11 and 50 employees. The remaining 16.6% are medium-sized enterprises with between 51 and 100 employees.

Following the pandemic crisis, manufacturing SMEs had a higher survival rate of 90%, compared to 82.5% for service-oriented SMEs (see Table 3). This disparity can be attributed to a combination of sectoral, structural, and organizational factors that influenced each sector's ability to adapt and endure in a challenging economic and social environment.

Table 3. Knowledge-intensive SMEs by Survival, by Main Activity

	Survival of knowledge-intensive SMEs		
Main activity	Did not survive	Survived	Total
Manufacture	10	90	100
Services	17.5	82.5	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

Regarding survival by metropolitan area, Table 4 reveals that SMEs in the Monterrey metropolitan area had the highest survival rate, while those in Hermosillo had the lowest. These differences can be attributed to the specific business and institutional environments of each metropolitan area, as well as the presence and effectiveness of regional innovation systems (RIS) and varying degrees of integration into global value chains (GVCs)—factors that are essential for business performance and resilience

Table 4. Knowledge-Intensive SMEs by Survival, by Metropolitan Area

	Survival of knowledge-intensive SMEs		
Metropolitan area	Did not survive	Survived	Total
Tijuana	11.4	88.6	100
Cd. Juárez	23.3	76.7	100
Hermosillo	26.7	73.3	100
Monterrey	3.1	96.9	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

The RIS linkage index aggregates values from four variables related to the intensity and nature of connections with universities, research centers, government programs, and business associations. The index shows that SMEs' survival rates during the pandemic improved progressively with stronger linkages to RIS agents and institutions (see Table 5). This finding aligns with the literature on innovation systems, which suggests that such linkages enhance access to resources, technologies, and specialized knowledge, thereby fostering innovation capacity, adaptability, and business resilience during economic and social crises.

Table 5. Knowledge-Intensive SMEs by Survival, According to the RSI Index

	Survival of knowledge-intensive SMEs		
RSI linkage index	Did not survive	Survived	Total
Null	19.6	80.4	100
Low	15.2	84.8	100
Medium	0	100	100
High	0	100	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

The literature on technological spillovers and absorptive capacity often highlights that companies spun off from multinational corporations tend to have better scaling abilities within value chains. In a bivariate comparison of the origin type of knowledge-intensive SMEs and their survival during the pandemic, the results reveal a slight advantage in survival for startups (see Table 6). However, as will be discussed later, this relationship reverses in the multivariate analysis.

Table 6. Knowledge-Intensive SMEs by survival, by Type of Company (Spin-Off or Startup)

	Survival of knowledge-intensive SMEs		
Type of company	Did not survive	Survived	Total
Startup	12.5	87.5	100
Spin-off	17.7	82.3	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

The SME linkage index with MNEs encompasses six variables reflecting the type and intensity of the connection: staff visits, training in quality standards, induction into MNC norms and

policies, knowledge transfer through manuals, designs, and technical plans, support for certification as an MNE supplier, integration of information systems with an MNE, and collaboration on process innovation projects. The results of the index reveal that the survival rate of SMEs increases progressively with stronger linkage to MNEs (see Table 7).

Table 7. Knowledge-Intensive SMEs by Survival, According to Linkage with Multinational Enterprises

Index of linkage with multinationals	Survival of knowledge-intensive SMEs		Total
	Did not survive	Survived	
Null	36.7	63.3	100
Low	11.8	88.2	100
Medium	12.9	87.1	100
High	3.8	96.2	100
Very High	0	100	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

In addition to the origin of SMEs through spin-offs and their initial linkage with multinational clients, being a supplier to a MNE often plays a crucial role in the performance and survival of knowledge-intensive SMEs. As shown in Table 8, the disparity in survival rates among surveyed SMEs is significant: only 50% of those not supplying a multinational survived the pandemic, compared to 89.9% of those that did. This difference may be attributed to the enhanced financial stability and broader access to international resources and markets that supplier SMEs gain through their commercial relationships with MNEs. These relationships also provide access to technical knowledge, advanced technology, and best management practices, all of which contribute to improved competitiveness and adaptability.

Table 8. Knowledge-Intensive SMEs by Survival, According to Multinational Supplier Status

Is a supplier to a multinational enterprise	Survival of knowledge-intensive SMEs		Total
	Did not survive	Survived	
No	50	50	100
Yes	10.1	89.9	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

The automation index consolidates data from five variables related to the level of automation in a company's administrative processes, supplier interactions, customer relations, production processes, and management analysis. The results show that SMEs with higher levels of automation exhibit higher survival rates (see Table 9). This finding aligns with the academic literature, which underscores the advantages of automation, including enhanced operational efficiency, reduced costs, improved quality, and greater adaptability to changing conditions.

Table 9. Knowledge-Intensive SMEs by Survival, According to Level of Automation and Digitalization

	Survival of knowledge-intensive SMEs		
Automation index	Did not survive	Survived	Total
Null	16.7	83.3	100
Up to 50 %	18.6	81.4	100
Up to 75 %	0	100	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

Regarding the relationship between innovation capacity and survival, Table 10 indicates that the difference in survival rates is relatively modest. SMEs that introduced product or process innovations had a survival rate of 86.5%, compared to 81.1% for those that did not engage in innovation.

Table 10. Knowledge-Intensive SMEs by Survival, According to Introduction of Innovations to the Main Product or Service

Introduced innovations	Survival of knowledge-intensive SMEs		
	Did not survive	Survived	Total
No	18.9	81.1	100
Yes	13.5	86.5	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

The learning index aggregates values from eight variables related to internal learning activities: staff training, acquisition or adaptation of machinery and equipment, adoption of information technologies, use of software and mobile applications, process automation, business intelligence, development of technical and organizational manuals, research for new products or services, and performance evaluations. Table 11 shows that survival rates improve progressively with a higher

learning index, indicating that more extensive internal learning efforts are associated with a greater likelihood of business survival.

Table 11. Knowledge-Intensive SMEs by Survival, According to Endogenous Learning Actions

	Survival of knowledge-intensive SMEs		
Learning index	Did not survive	Survived	Total
Low	33.3	66.7	100
Medium	16.7	83.3	100
High	17.5	82.5	100
Very high	5.3	94.7	100
Total	15.7	84.3	100

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

Interpretation of Results

Table 12 presents the Pearson chi-square test values, which assess whether the selected variables influence the resilience of the studied companies. The null hypothesis of independence is rejected if the p-value is less than 0.05. For p-values greater than 0.05, the variables are considered not to be related. The table reveals that variables showing statistical significance (p-values less than 0.05) in relation to the survival probability (*Y*) include metropolitan area, organic link with MNEs, MNE supplier status, and company origin (spin-off/startup). These variables significantly contribute to explaining the likelihood of company survival.

Table 12. Test of Independence of Variable *Y* (Survival)

Variable	Test statistic (Pearson) χ^2_c	Degrees of freedom (df)	Theoretical value $\chi^2_{0.05\ gl}$	Significance p value	Relationship with variable *Y*
Relationship with customers and suppliers	0.982	3	7.815	0.805615	Independence
Main client MNE	1.231	2	5.991	0.745661	Independence
Endogenous learning actions	2.439	3	7.815	0.486343	Independence
Linkage with the RIS	2.460	3	7.815	0.482651	Independence
Innovative performance	0.667	1	3.841	0.413995	Independence
Main activity	0.978	1	3.841	0.322667	Independence

(continues)

(continuation)

Level of automation	4.193	2	5.991	0.241403	Independence
Metropolitan area	8.332	3	7.815	0.039631	Dependence
Organic link with MNE	14.387	4	9.488	0.002423	Dependence
MNE Supplier	18.544	1	3.841	0.000017	Dependence
Company origin (spin-off/startup)	22.483	1	3.841	0.000002	Dependence

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

To enhance the interpretation of the model results, 127 cases from the empirical study database are analyzed. The dependent variable is coded to assign a value of one to indicate the evaluated outcome, which in this case is "probability of survival." This coding facilitates the understanding of the β_i coefficients for the independent variables: a positive regression coefficient will suggest that the probability of survival increases with stronger organic links with MNEs. In the model, *confounding* variables are used as references to calculate the probability of survival, focusing specifically on supplier relationships with MNEs and the company's origin.

Table 13 compares the expected values with the observed values using a diagnostic test to assess the overall fit of the logistic regression model. The model shows medium-low specificity (30%) and high sensitivity (94.8%). These metrics indicate that the model fits the data very well, with an overall prediction accuracy of 87.4%.

Table 13. Classification between Observed and Predicted Values

Observed		Predicted		
		Survival of knowledge-intensive SMEs		Correct percentage
		Did not survive	Survived	
Survival of knowledge-intensive SMEs	Did not survive	6	14	30
	Survived	2	105	98.1
	Overall percentage			87.4

Note: The cut-off point is 0.500.

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

Table 14 presents the values of the variables in the logistic regression model equation as provided by the model. The positive coefficients β_1 (1.268) and β_2 (0.663) indicate that the probability of survival increases with higher values of these variables, which pertain to the origin of the company and its connections with MNEs. In contrast, the coefficient β_3, related to supply

links with MNEs, has a value of -1.469, reflecting its impact on survival probabilities. The constant (α) does not have a specific interpretation and serves as an adjustment value in the model. The statistical significance of the variables (all close to 0.05) as indicated by the Wald index supports their inclusion in the model. Additionally, the confidence intervals for the odds ratios ($Exp^{[\beta]}$) show that these variables positively influence the probability of survival for SMEs, with the likelihood of the effect increasing as the confidence interval values exceed one.

Table 14. Variables in the Logistic Regression Model Equation

Variables in the model	β_i	E.T.	Wald	df	Sig.	$Exp^{(\beta)}$	95% C.I. for $Exp^{(\beta)}$	
							Lower	Upper
Origin of the company	1.268	0.637	3.959	1	0.047	3.553	1.019	12.385
Organic link with MNE	0.663	0.348	3.626	1	0.057	1.940	0.981	3.836
MNE Supplier	-1.469	0.763	3.704	1	0.054	0.230	0.052	1.027
Constant (α)	0.760	0.642	1.398	1	0.237	2.137		

Source: Own elaboration based on data from the project "Formación y escalamiento de pymes mexicanas intensivas en conocimiento" (Contreras Montellano et al., 2020).

An important finding from the model results is that technology-based SMEs that were established as spin-offs, are suppliers to at least one multinational company, and maintain organic links with at least one MNE, exhibit higher survival probabilities during disruptive crises like the COVID-19 pandemic.

CONCLUSIONS

The COVID-19 pandemic, which began in 2020 and continues to affect various aspects of global social and economic life, caused severe disruptions in economic activity. This upheaval altered business dynamics and, in many cases, threatened the survival of companies. In Mexico, SMEs were among the hardest hit by the crisis due to their limited resources for managing instability and uncertainty.

This research aimed to identify the factors influencing the resilience of knowledge-intensive SMEs in northern Mexico. Organizational resilience was used as a framework to assess the capacity of companies to survive the pandemic-induced crisis. The study also examined the impact of various factors on organizational resilience, drawing from the theoretical convergence of innovation systems and global value chains. The analysis was based on an empirical study involving a follow-up survey conducted in 2022.

The research results indicate that, in the studied region, the Mexican knowledge-intensive SMEs best equipped to survive the pandemic were those that originated as spin-offs, acted as suppliers to multinational enterprises, and maintained organic links with at least one MNE. These findings align with previous studies on technological spillovers and absorptive capacity,

confirming that connections with MNEs are a crucial source of technological capacity accumulation for SMEs, especially in the absence of active, targeted policies to bolster local knowledge-intensive firms. Additionally, these results highlight the need for further research on the role of regional innovation systems in enhancing SME resilience.

Translation: Erika Morales.

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