

Endogenous learning for innovation in knowledge-intensive SMES

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Abstract

This article explores the learning mechanisms of knowledge-intensive small and medium-sized enterprises (SMEs) in contexts with a high density of multinational companies. Based on a sampling survey in the northern region of Mexico, two primary sources of learning for innovation are identified: relationships with customers and suppliers and endogenous learning actions, notably training of personnel, investment in R&D and the acquisition of advanced technology. Contrary to expectations, Regional Innovation Systems (RIS) make a marginal contribution to the innovative capacities of SMES, suggesting a deficit in industrial policy.

Keywords: innovation; endogenous learning mechanisms; small and medium-sized enterprises (SMES); Regional Innovation Systems (RIS); Global Value Chains (GVC).

1. INTRODUCTION

In Latin America, small and medium-sized enterprises (SMEs) face severe limitations when it comes to participating in Global Value Chains (GVCs) and are generally relegated to a marginal role in the globalized economy. However, some studies argue that SMEs can benefit from innovative environments and the knowledge transferred by multinational enterprises (MNEs), facilitating their incorporation into GVCs.

Unlike those operating in low value-added niches, knowledge-intensive SMEs have greater opportunities in GVCs, but they remain the exception in Latin America. A crucial component in the accumulation of skills is technological and business learning, based on knowledge absorption and practices geared toward learning and innovation.

The objective of this study is to identify the learning mechanisms that strengthen the innovation capabilities of SMEs, i.e., those processes through which local Mexican companies accumulate, assimilate, and appropriate the technological and knowledge spillovers that occur in the convergence spaces of the global economy with local environments, favoring their propensity to innovate.

After a brief introduction, five sections of the paper are presented: the second proposes the theoretical convergence between VGC and Innovation Systems (IS) to address learning in knowledge-intensive SMEs; the third defines the relevant variables for analysis based on international literature, while the fourth presents the methodological strategy of the research. The fifth section presents the results of the study and the sixth section presents the conclusions.

2. LEARNING MECHANISMS IN SMES

The concept of "Global Value Chain" is appealing because of its simplicity and scope: it refers to the sequence of activities involved in the production of a specific good or service, including activities relating to extraction, manufacturing, transportation, marketing, distribution, after-sales service, etc. (Gereffi and Fernandez-Stark, 2011; Gereffi *et al.*, 2005). This approach makes it possible to analyze the segmentation and international relocation of production on a global scale, as well as the governance structures and opportunities for improvement of local companies in developing countries (Humphrey and Schmitz, 2000 and 2002).

Two key concepts in this perspective are governance and upgrading. Governance is defined as the "relationships of power and authority that determine the allocation of resources and cooperation among firms along the chain" (Gereffi, 1994, p. 97). Meanwhile, upgrading has been at the center of the debate on GVCs in Latin America, a discussion that has sought to elucidate how local companies can participate in global markets to improve their productivity, wages and profits, while developing skills to produce higher quality and higher value-added goods and services.

The IS approach is based on the premise that technological learning and innovation do not occur solely in market relationships, but rather in a network of interactive learning between various agents (Freeman, 1987; Lundvall, 1992; Nelson, 1993), including universities, research centers and public agencies (Lundvall, 2007).

Innovation arises from a network of continuous interactions between companies and other agents, within a framework in which technological trajectories and institutional assets foster collective learning and innovation.

Both approaches, CGV and IS, address business improvement processes. The IS approach focuses on building absorption capabilities to recognize, assimilate, and exploit knowledge (Cohen and Levinthal, 1990). Meanwhile, the GVC approach focuses on upgrading to more complex and higher value-added activities (Gereffi *et al.*, 2005; Pietrobelli and Rabellotti, 2010 and 2011; Malerba and Nelson, 2011; Jurowetzki *et al.*, 2018).

Although the integration of GVC and IS has made little progress, four points of convergence have been identified: 1) user-producer learning processes in product innovations; 2) upgrading in processes and products; 3) technological and organizational absorption capacities; and 4) interactions with universities, research centers and science, technology and innovation institutions (Kashani *et al.*, 2023; Lema *et al.*, 2018; Cooke *et al.*, 1997; Gereffi *et al.*, 2005).

The difficulties that hinder SMEs' participation in international markets and global supply chains include lack of capital, access to new technologies, skilled labor shortages, market access, adequate information, and business skills (Bair and Gereffi, 2001; Frederick and Gereffi, 2011; Nurfarida *et al.*, 2022; Chandra *et al.*, 2020).

Despite this, some local SMEs manage to improve by linking up with institutional environments and MNEs, facilitating their entry into high value-added segments of the GVC (Vera-Cruz and Dutrénit, 2004 and 2005; De Fuentes, 2010; Contreras *et al.*, 2012a; Contreras and García, 2018). Dutrénit and De Fuentes (2009) identify three conditions for capturing spillovers from MNEs and strengthening SME capabilities: 1) the MNE's supply strategy; 2) the level of technological and organizational capabilities of the local company; and 3) a mature regional or local environment.

Sampath *et al.* (2018) propose the coevolution of GVCs and IS, involving governance patterns and IS maturity, which defines the possibilities for local companies to generate innovation and learning capacities. Recent studies in Kenya and Pakistan show how national and local institutions can foster links between GVC and IS, facilitating the learning of local companies and enabling them to become suppliers to MNEs (Park and Gachukia, 2020; Naqvi *et al.*, 2021).

3. LEARNING FOR INNOVATION: RELEVANT VARIABLES

In the literature on GVC and IS, four groups of variables are identified as causal mechanisms that explain learning for innovation: 1) relationships with customers and suppliers; 2) the academic training of owners and their mobility between companies; 3) internal efforts to build knowledge absorption skills; and 4) collaboration with government entities, universities, research centers and business associations.

Customer and supplier relationships

Relationships with MNE customers are an important source of learning. The chain's system of governance can facilitate or hinder this learning since, in a relationship based on trust, information flows better, increasing knowledge transfer (Humphrey and Schmitz, 2000; Pietrobelli and Rabellotti, 2011). Trust-based relationships and reputation with MNE customers can lead local SMEs to improve their abilities and position in the value chain (Dutrénit and De Fuentes, 2009; Görg and Greenaway, 2001; Humphrey and Schmitz, 2000).

A study of Chinese companies found that links with MNE customers are positively associated with learning and the introduction of new products, especially with a relational governance structure based on mutual learning and joint capacity development (Najafi-Tavani *et al.*, 2020). In Taiwanese electronics companies, supplier learning, facilitated by joint learning capacity, played a significant role in driving various types of innovation (Kim *et al.*, 2018). In Colombian companies, the existence of links strengthens research and development activities, increasing the likelihood of innovation (Rodríguez *et al.*, 2013).

Educational level and job mobility of owners

The individual characteristics of owners and managers, including their educational level and mobility between companies, significantly influence a company's innovative performance (Renko *et al.*, 2012; Runst and Thomä, 2021). Various studies on SMEs have found that the higher the educational level of managers, the greater their ability to absorb new ideas and technologies, which increases the innovation performance of the company (Attia *et al.*, 2021; Cerdá *et al.*, 2023; Runst and Thomä, 2021).

Alongside formal education, the work experience of owners and managers plays an important role in innovation. Given that knowledge is embedded in the minds and bodies of both employees and managers, the circulation of skilled personnel with previous work experience is a source of new

knowledge for companies, strengthening their absorption capacities (Audretsch *et al.*, 2021).

In the case of knowledge-intensive SMEs, the mobility of high-level employees plays an important role in the formation of new companies, particularly in the case of engineers and managers who leave an MNE to start their own company (Contreras, 2000; Glass and Saggi, 2002; Dutrénit and Vera-Cruz, 2005; De Fuentes and Dutrénit, 2008; Contreras and Isirdia, 2010).

Several studies also show the combined effect of the educational level and previous work experience of owners on the knowledge absorption capacity of their companies, which is reflected in better innovative performance (Wang *et al.*, 2010; De Mel *et al.*, 2009).

Endogenous learning effort

The literature on technology spillovers and knowledge flows shows that the ability of firms to take advantage of new knowledge and use it to strengthen their capabilities does not depend solely on the availability of knowledge in the environment, but requires a conscious and active effort to understand, integrate and fully exploit that knowledge and technological tools (Cohen and Levinthal, 1990; Ernst and Kim, 2002).

Among internal actions to improve innovation capabilities, one of the most important is staff training since continuous exposure to new knowledge and techniques enables employees to perform better in highly competitive and rapidly changing environments, where innovation is often a fundamental resource (Cerdá *et al.*, 2023; Panagiotakopoulos, 2011). Empirical studies have found a positive association between investment in employee training and product innovation capabilities (Demirkan *et al.*, 2022), process innovation (Dostie, 2017) and the generation and implementation of novel ideas (Abdullah *et al.*, 2014). Furthermore, employee training is particularly important for smaller SMEs, which have a lower proportion of employees with university education and do not invest in research and development (R&D) on a continuous basis (Demirkan *et al.*, 2022).

Relations with agents of the Regional Research System

There is consensus that linking SMEs with research and development centers and other agents in the business environment promotes the strengthening of capacities and learning (Cohen and Levinthal, 1990; Lema *et al.*, 2018). For example, Fosfuri and Tribó (2008) found that links between MNEs and R&D and innovation centers are key to developing innovative capabilities. In contexts where private research centers are scarce, public centers take on even greater importance. Mexican companies that relied on higher education institutions (HEIs) were better able to enter the global market (Bautista, 2015). Government support is also crucial for the incorporation of local firms into GVCs, facilitating links between foreign direct investment (FDI) and domestic firms (Crescenzi and Harman, 2023; Amaro Rosales and Villavicencio, 2015). Brazilian business associations have used government funds to promote the upgrading of local companies, taking advantage of knowledge and technology spillovers from GVCs to compete globally (Navas-Alemán, 2011).

In Mexico, some startups have benefited from government incentives that support entrepreneurship and the creation of new companies, providing technology services to MNEs since their inception (Contreras and García, 2018; Casalet *et al.*, 2008).

4. METHODOLOGY

The information used in this study comes from the survey "Formation and upgrading of knowledge-intensive SMEs in Mexico," conducted between September and November 2019. To design the sample, a directory of knowledge-intensive SMEs located in Mexico was compiled based on the National Statistical Directory of Economic Units (INEGI-DENUE, 2018). The selection procedure consisted of identifying the six-digit economic activity classes of the North American Industrial Classification System (SIAN) that correspond to the productive and service activities considered "knowledge-intensive" or "technology-based" in the specialized literature (Heckler, 2005; Kile and Phillips, 2009; Alarcón Osuna and Díaz Pérez, 2016). Based on that procedure, a list of 2,056 companies belonging to 45 activity classes was obtained. The distribution of the seven most frequent is shown in Table 1.

Table 1. Knowledge-intensive SMEs by region, according to selected SCIAN classes (frequencies)

<i>SCIAN class</i>	<i>Northwest</i>	<i>Northeast</i>	<i>Metropolitan region</i>	<i>Southeast</i>	<i>Central West</i>	<i>Central South</i>	<i>Total</i>
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 systems 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	2 056

Source: prepared by the authors based on INEGI-DENUE (2018).

From this group, four metropolitan areas in northern Mexico were selected,¹ characterized by their high concentration of multinational companies: Tijuana, Ciudad Juárez, Hermosillo and Monterrey. These areas are home to 748 knowledge-intensive SMEs, representing 36% of the national inventory.

The sample size was determined based on this sample of 748 companies, with a confidence level of 95% ($z = 1.96$) and a sampling error of $\pm 7\%$ (p). An optimal sample size of 175 companies was estimated, achieving a response rate of 76.2% and a total of 127 valid questionnaires after applying consistency checks and discarding some incomplete questionnaires or those with abnormal values. Table 2 shows how a representative distribution was obtained for each geographical location.

Table 2. Distribution of the sample, according to main activity, by metropolitan area (frequencies)

<i>Main activity of the company</i>	<i>Metropolitan Area</i>				<i>Total</i>
	<i>Tijuana</i>	<i>Juárez</i>	<i>Hermosillo</i>	<i>Monterrey</i>	
Manufacturing	12	5	8	5	30
Services	23	25	22	27	97
Total	35	30	30	32	127

Source: "Knowledge-intensive Mexican SMEs" project.

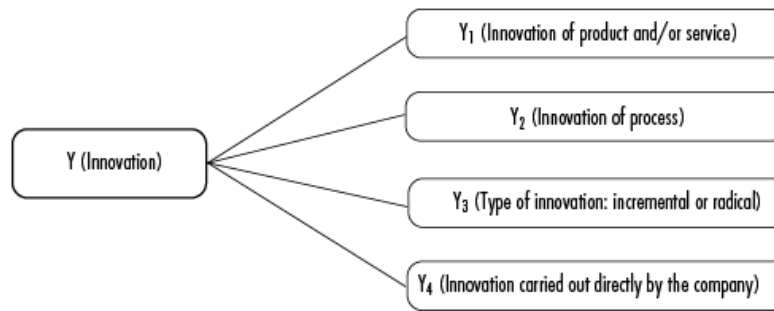
The survey was conducted online among owners of the selected companies, using a self-administered questionnaire consisting of 73 questions covering seven analytical dimensions: profile of the entrepreneurs, profile of the companies, market entry mechanisms, learning processes, technological capabilities, links with MNEs and RIS, and innovation and upgrading processes in the value chain. The data collected corresponds to the time of the survey, except for those referring to time variations, which cover the last three years of the operations of the companies.

The specific objective of this study is to identify the influence of learning mechanisms on business innovation. The dependent variable is innovation, and the independent variables come from various learning mechanisms.

In the logistic model, innovation is a dichotomous variable taken directly from the questionnaire response on whether the company has carried out innovations. In the linearized logistic model, the dependent variable is an index constructed from a set of variables that record the degree and form of these innovations. In order to make the scales comparable, it was decided to normalize the variables.²

The construction of the innovation index is shown in Figure 1.

Figure 1. Components of the dependent variable



Source: prepared by the authors.

The hypothesis argues that innovation in companies is influenced by learning mechanisms related to IS and GVCs. The learning mechanisms analyzed are: 1) the company's relationships with customers, suppliers, and other companies; 2) elements of the entrepreneur's training (education and work experience); 3) endogenous learning activities; and 4) the company's relationships with government agencies, universities, research centers and chambers of commerce.

Each of these mechanisms constitutes an independent variable (X_1 , X_2 , X_3 and X_4) constructed as a composite index that incorporates all the relevant options presented in the corresponding tables. This allows for a comprehensive capture of the different aspects of each learning mechanism based on specific responses to the questionnaire:

- X_1 (company relations with customers and suppliers): company relations with suppliers, customers, other companies, contracting of technical, professional and consulting services, digitization of such links and the company's willingness to innovate.
- X_2 (business owner's education and experience): the business owner's highest academic qualifications, language skills and number of jobs held before founding the company.
- X_3 (learning actions): staff training, acquisition and adaptation of machinery and equipment, acquisition of information and communication technologies (ICT), software, mobile applications, process automation, business intelligence, use of technical and organizational manuals, research and design to create new products, services or materials, performance evaluation, productivity indicators, income dedicated to production and purchase of R&D.
- X_4 (relations with the SRI): government support, relations with chambers of commerce, relations with universities and research centers.

To construct the independent variables, the specific variables extracted from the database were standardized due to the diversity of the original scales. Both the innovation index and the independent variables were constructed by calculating the sum of the selected and standardized variables.

It should be noted that the selection of components, both for the innovation index and the independent variables, was not based on multivariate analysis methods (such as factor or principal component analysis), but on theoretical reasons based on the experience of previous studies (Contreras *et al.*, 2012b; Valenzuela and Contreras, 2014; Mendoza León and Valenzuela, 2014).

Two econometric models are used. One is the logistic model, whose purpose is to determine the probability that companies will innovate given the presence of the independent variables defined above. In this case, the dependent variable is the dichotomous variable taken from the question of whether or not companies have innovated.

The other is an exponential model that replicates the design of the Cobb-Douglas function (Cobb and Douglas, 1928; Yotopoulos and Nugent, 1981). This model assumes that the independent variables contribute a proportion of the behavior of innovation in the businesses. In this case, the dependent variable is the innovation index shown in Figure 1.

As is well known, this model cannot be estimated directly using the method employed in this study, which is ordinary least squares (OLS). The required "linearization" was performed using natural logarithms.

There are also theoretical reasons for selecting a logarithmic model. The linear model would assume that changes in innovation occur in constant amounts (β_i) in response to unit changes in learning mechanisms (X_i). This is an unrealistic assumption since innovation shows decreasing marginal changes in response to changes in the factors that determine them.

Conversely, this decreasing change in innovation would be accurately reflected by the exponential model, expressed as follows:

$$Y_i = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} e_i^u$$

This model would have the restriction that the regression coefficients (β_i) must assume values between 0 and 1, and the sum of all of them must be less than 1.

Linearization in natural logarithms is:

$$\ln Y_i = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + u_i$$

This model can be estimated using OLS, with the added advantage that, by taking the antilogarithms, we obtain the previous exponential model.

5. ANALYSIS AND COMPARISON OF RESULTS

Characteristics of the companies

76.4% of the companies included in the sample are technology services companies, mainly in sectors 51 (mass media information) and 54 (professional, scientific, and technical services). These are companies that provide services aimed at solving problems for other companies and organizations related to the acquisition, implementation, operation, maintenance, improvement and dissemination of emerging technologies. The remaining 23.6% are manufacturing companies in sectors 31 to 33, which produce high value-added goods with technological content, including the manufacture of metal products, machinery and equipment, computer equipment and automotive accessories.

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

For the SMEs in the sample, customer relations are the main source of information and knowledge for improving products, services and processes, with 61.4% of companies collaborating frequently. This is relevant because the main customers are multinationals with high levels of technology and organization, interested in aligning standards with their local suppliers. Furthermore, 35.6% of SMEs collaborate frequently with their suppliers, which is the second source of information and knowledge for their improvements. Collaboration with other companies in the sector does not appear to be relevant (see Table 3).

Table 3. Relationship between the company and its customers, suppliers and other companies

<i>Frequency of collaboration by the company with</i>	<i>Never</i>	<i>Rarely</i>	<i>Not so frequently</i>	<i>Frequently</i>	<i>Very frequently</i>	<i>Total</i>
Suppliers (exchanges to improve processes, products, and/or services)	8.7	20.5	32.3	26	12.6	100
Customers (exchanges to improve processes, services and/or products)	1.6	9.4	27.6	40.9	20.5	100
Other companies in the sector (competitors and/or allies)	18.1	24.4	33.1	20.5	3.9	100

Source: "Knowledge-intensive Mexican SMEs" project.

Regarding the academic background of owners, 74% have a bachelor's degree or engineering degree, and 23.6% have a master's or PhD (see Table 4).

Table 4. Highest academic qualifications of entrepreneurs, by metropolitan area (percentage and absolute figures)

<i>Highest academic qualifications of the entrepreneur</i>	<i>Metropolitan Area</i>				<i>Total</i>
	<i>Tijuana</i>	<i>Juárez</i>	<i>Hermosillo</i>	<i>Monterrey</i>	
High School	0.0	0.0	10.0 (3)	0.0	2.4 (3)
Bachelor's degree / Engineering degree	74.3 (26)	80.0 (24)	70.0 (21)	71.9 (23)	74.0 (94)
Master's / PhD	25.7 (9)	20.0 (6)	20.0 (6)	28.1 (9)	23.6 (30)
Total	100.0 (35)	100.0 (30)	100.0 (30)	100.0 (32)	100.0 (127)

Source: "Knowledge-intensive Mexican SMEs" project.

Regarding the age and previous employment of entrepreneurs, Table 5 shows that the overall average age at the time of the interview was 48.5 years. In addition, before starting their own business, they had an average of 2.5 jobs, with an average length of 4.9 years in their last job.

Table 5. Average age and employment of entrepreneurs prior to starting their business, by metropolitan area

	<i>Metropolitan Area</i>				<i>Total</i>
	<i>Tijuana</i>	<i>Juárez</i>	<i>Hermosillo</i>	<i>Monterrey</i>	
Age of entrepreneur (average in years)	51.9	45.3	50.0	46.3	48.5
Average number of jobs prior to the creation of the company	2.9	2.5	2.0	2.6	2.5
Duration of last employment before starting their business (average in years)	6.2	3.9	5.5	4.0	4.9

Source: "Knowledge-intensive Mexican SMEs" project.

As shown in Table 6, regarding actions undertaken by the companies themselves to improve their capabilities, staff training stands out, with 64.6% of SMEs doing so frequently or very frequently. This is followed by performance evaluations in various areas, which 64.6% carry out frequently or very frequently. In addition, 52% focus on the acquisition of Information and Communication Technologies (ICT), software and applications, as well as the acquisition of machinery and equipment. Finally, 47.2% of SMEs carry out research and design activities for new products or services frequently or very frequently.

Table 6. Endogenous technological learning actions

<i>Frequency of learning actions</i>	<i>Never</i>	<i>Rarely</i>	<i>Not so frequently</i>	<i>Frequently</i>	<i>Very frequently</i>	<i>Total</i>
Staff training	2.4	3.1	29.9	50.4	14.2	100
Acquisition and adaptation of machinery and equipment	3.1	4.7	40.2	40.2	11.8	100
Acquisition of ICT, software and mobile applications	0.8	11	36.2	37.8	14.2	100
Process automation	7.1	7.9	39.4	34.6	11	100
Business intelligence	17.3	24.4	21.3	26	11	100
Preparation of technical and organizational manuals	8.7	18.9	34.6	22.8	15	100
Research to create new products and/or services	3.1	21.3	28.3	29.9	17.3	100
Performance and productivity evaluations, etc.	4.7	14.2	26.8	39.4	15	100

Source: "Knowledge-intensive Mexican SMEs" project.

Unlike collaborative relationships with customers and suppliers, relationships with other agents in the RIS seem to be less important in shaping the links that promote learning and innovation. Table 7 shows that approximately a quarter of companies are affiliated with a chamber of commerce or a cluster-type association, while only 12.6% have had access to government funds through an innovation stimulus program.

Table 7. Relations with the Regional Innovation System (RIS)

<i>Type of relationship</i>	<i>Percentage</i>
Government support was provided for the creation of the company	3.9
In the last five years, the company had access to government program funds.	12.6
The company obtained financing for the acquisition of machinery and equipment.	3.1
The company obtained financing for the acquisition of advanced technology or software.	2.4
The company is affiliated with a chamber of commerce.	26.8
The company is affiliated with a cluster.	23.6

Source: "Knowledge-intensive Mexican SMEs" project.

Regarding innovation processes in the main product or service, 58.3% of SMEs introduced at least some type of innovation in the last three years, with the metropolitan areas of Tijuana and Juárez standing out, with 77.1% and 63.3% of innovative SMEs, respectively (see Table 8).

Table 8. Knowledge-intensive SMEs, introduction of innovations to the main product or service, by metropolitan area (percentage)

Innovations to the main product or service	Metropolitan Area				Total
	Tijuana	Juárez	Hermosillo	Monterrey	
No	22.9	36.7	50.0	59.4	41.7
Yes	77.1	63.3	50.0	40.6	58.3
Total	100.0	100.0	100.0	100.0	100.0

Source: "Knowledge-intensive Mexican SMEs" project.

Analysis of results

The statistical tests are based on two models: an exponential model, which seeks to capture changes in innovation due to increases in independent variables, and a logistic model, whose purpose is to determine the probability that a company will be innovative in the presence of independent variables.

Exponential model

Table 9 shows the results of the exponential model. According to the usual statistical tests, it can be seen in Table 9 that this is a statistically robust model. The multiple regression coefficient, R^2 , indicates that the design and the selected variables account for 27.4% of the explanation of the innovation behavior of knowledge-intensive companies. Of the four explanatory variables, according to the t -test, only X_1 (the company's relationships with customers and suppliers) and X_3 (endogenous learning actions) contribute significantly to innovation behavior.

Table 9. Results of the exponential model

Variables					
Regression model	$\ln Y_i = -0.624 + 0.373 \ln X_1 + 0.249 \ln X_2 + 0.384 \ln X_3 + 0.049 \ln X_4 + e_i$				
t test	-1.444	2.097	1.606	2.738	0.189
Determination coefficient	$R^2 = 0.274$				
F test	$F = 10.95$				
Durbin-Watson statistic:	$DW = 1.8$				
Park test					
$e_i^2 =$	0.818 -	0.161 $\ln X_1 -$	0.200 $\ln X_2 +$	0.310 $\ln X_3 -$	0.228 $\ln X_4 + v_i$
t test	3.637	-1.74	-0.248	0.421	-1.69

Source: prepared by the authors.

Regarding the robustness of the model, it can be stated that there are no crucial violations of assumptions. First, there is no autocorrelation (the errors do not depend on each other) since, according to the Durbin-Watson test, it is equal to 1.8 and, with the upper and lower limits defined by the sample size, the level of statistical significance and the number of independent variables, there is no positive or negative autocorrelation. Second, it is a homoscedastic model (the variance is constant) according to Park's test. The model for detecting heteroscedasticity is not significant in terms of the F test or, according to the t -test, in the regression coefficients, which shows that the model has constant variance. Finally, the correlation matrix of the four independent variables does not show multicollinearity (the X_i do not depend on each other).

Logistic model

With the aim of measuring the probability that a knowledge-intensive SME will be innovative, a logistic model was tested using the same independent variables. The model successively eliminates the variables that contribute least to the probability specified in the dependent variable and stops when the variables included make a significant contribution.

The logistic model selected variables X_1 and X_3 , as did the exponential model. The presence of relationships with customers, suppliers, and other companies, as well as endogenous learning actions, increase the probability that a company will be innovative (see Table 10).

Table 10. Results of logistic regression analysis

Variable	B	Standard error	Wald test	Degrees of freedom	sig.	exp (B)
X_1	0.4325	0.2029	4.545	1	0.0330	1.5541
X_3	0.3334	0.155	4.6162	1	0.0315	1.3958
CTE	-3.3074	0.9985	10.9722	1	0.0009	0.0366

Source: prepared by the authors.

Conclusions from statistical models

Given the above results, a logistic model was adjusted with the two selected variables: the company's relationships with customers and suppliers and endogenous learning actions (see Table 11).

Table 11. Results of the adjusted exponential model

$\ln Y = 0.154 \ln X_1 + 0.397 \ln X_3 + e_t$		
Ee	(0.070)	(0.129)
t	2.200	3.072
$R^2 = 0.827$		
$F = 283.565$		

Source: prepared by the authors.

According to the Kolmogorov-Smirnov test, this adjusted model maintains normality in errors, which is an essential assumption for the conclusions obtained.

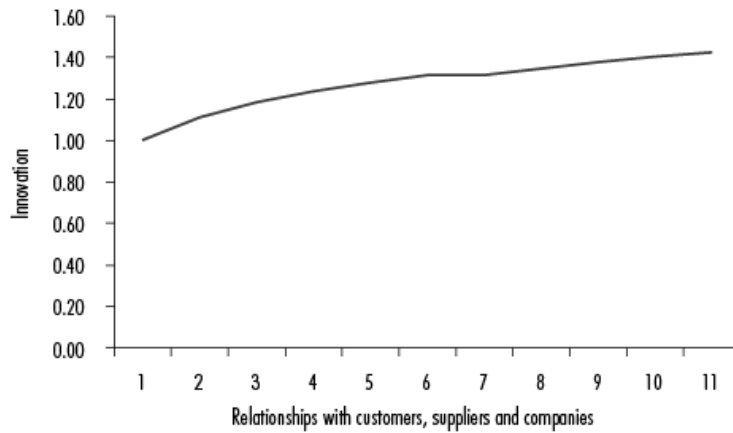
Taking the antilogarithms of this model, we find that innovation depends on the following two variables:

$$Y_i = X_1^{0.154} X_3^{0.397}$$

According to the statistical criteria mentioned above, the explanation of innovation using these two variables is high and robust, and both variables individually provide a statistically significant explanation for innovation.

With this conclusion established, the influence of each variable was investigated separately, assuming that the other remained constant. Figure 2 shows how a company's relationships with customers, suppliers and other companies

Figure 2. Influence of relationships with customers, suppliers and other companies on the innovation index

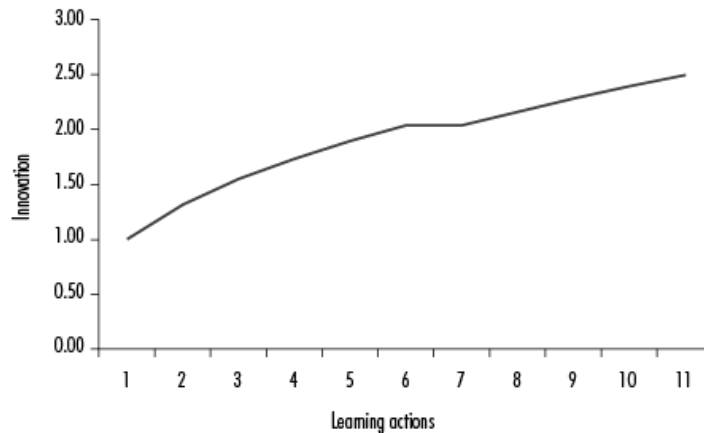


Source: prepared by the authors.

Figure 3 shows the influence of endogenous learning actions on innovation. When analyzing the figures, the isolated influence of both variables (relationships with customers and suppliers, and learning actions) follows a decreasing pattern. This means that, although innovation increases with the greater intensity of these variables, the rate of increase progressively decreases.

This behavior is explained by the model's regression coefficients, which are greater than 0 and less than 1. These coefficients indicate that any increase in independent variables produces a positive increase in innovation, but at a decreasing rate. Thus, by intensifying learning activities or business relationships, innovation continues to grow, albeit with an increasingly smaller additional impact.

Figure 3. Influence of learning actions on the innovation index



Source: prepared by the authors.

6. CONCLUSIONS

For local SMEs operating in contexts with a high density of MNEs, innovation capabilities are fundamental for their consolidation and upgrading in highly competitive and constantly changing environments.

This study analyzed some determinants of innovation in knowledge-intensive SMEs, showing that it depends both on internal resources and processes and on the characteristics and intensity of their interaction with the environment.

In terms of external links, relationships with customers and suppliers are the main source of information and knowledge for innovation. These relationships provide access to new technologies and best practices but also function as channels for learning and innovation. From the perspective of knowledge flows inside the GVC, these are knowledge spillovers that, in addition to strengthening the capacities of SMEs, are functional for MNEs due to their need for nearby, competent suppliers that allow them to outsource services and replace distant suppliers.

Furthermore, although knowledge spillovers are essential for improving innovative capabilities, the incorporation of this knowledge is achieved through a deliberate effort to appropriate it through endogenous learning actions carried out by the companies themselves.

It should be noted that, according to the statistical models applied, the variable that has the greatest influence on innovation is "learning activities," which are crucial for translating external knowledge into internal innovations. This is the most relevant finding of the study and has implications for both future studies on innovative processes in SMEs and sectoral policies.

According to conventional theory, institutions and agents of the RIS constitute another important source of knowledge for local businesses. However, the results of this study show that the RIS makes an insignificant contribution to the innovative capabilities of knowledge-intensive SMEs, which probably indicates a deficit in industrial policy. However, this statement should be taken with caution because the indicators used to measure links with the RIS only capture formal links, omitting informal relationships that in some contexts may be relevant for learning and innovation.

Another more general reason for caution concerns the limitations of the statistical models used, which assume the exogeneity of the independent variables, excluding possible bidirectional causality between innovation capabilities and learning mechanisms.

These limitations underscore the importance of future research on the topic, which could delve deeper into the influence of RIS on the innovative capabilities of SMEs, as well as explore the possible endogeneity between innovation and learning variables.

INFORMED CONSENT

The participation of the interviewees was with their informed and voluntary consent, maintaining their anonymity during the presented analyses.

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¹ In Table 1, the column "Metropolitan Region" refers to the Mexico City Metropolitan Area, which consists of Mexico City and some municipalities in the states of Mexico and Hidalgo. Throughout the rest of the document, Metropolitan Area refers to the various urban areas defined by the INEGI, which include a central city and its surrounding areas, characterized by a high concentration of economic activity and population. Four of these areas were selected for this study.

² Normalization, as is usual, was carried out using the formula: $X_n = (X - X_{min}) / (X_{max} - X_{min})$ This expression yields only positive values, which makes it compatible with the linearization process in logarithms.