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Influence of technological attributes on subsidiary technology sourcing: A case study in Ibero-America

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Abstract
This paper empirically investigates the influence of technological attributes on the sourcing of relevant production technologies by subsidiaries based in the Ibero-American region. We draw on the concept of strategic roles, internal embeddedness, capacity, and organizational learning. We gained rich insights into the topic through a focus on case studies of German Multinational Companies and their production subsidiaries based in Peru, Brazil, Colombia and Spain. Semi-structural interviews, observation of the sourced technology and other data collection techniques were applied, and a cross-case analysis was implemented to obtain the results. This paper suggests that across Ibero-American production subsidiaries, production technology with certain complexity related to their strategic roles is internally sourced. Finally, the strategic role of the subsidiary and technology familiarity is low; external sources will be chosen regardless of the complexity of the technology. The findings have important implications for technology managers of Ibero-American based subsidiaries, who are decision makers in the sourcing of production technologies and offer empirical evidence to understand the positioning of some Ibero-American markets in the global innovation map.
Keywords: Ibero-American region; production technology; subsidiary technology sourcing.

Influencia de los atributos tecnológicos en la adquisición de tecnología por las subsidiarias: Un estudio de caso en Iberoamérica

Resumen
Este documento investiga empíricamente la influencia de los atributos tecnológicos en la tercerización de tecnologías de producción relevantes por parte de filiales con sede en la región iberoamericana basándonos en los conceptos de roles estratégicos, integración interna, capacidad y aprendizaje organizacional. Obtuvimos información sobre el tema a través de un enfoque en estudios de casos de empresas multinacionales alemanas y sus subsidiarias de producción con sede en Perú, Brasil, Colombia y España. Se aplicaron entrevistas semiestructurales, observación de la tecnología de origen y otras técnicas de recopilación de datos, y se implementó un análisis de casos cruzados para obtener los resultados. Este documento sugiere que, en todas las filiales de producción iberoamericanas, las tecnologías de producción con cierta complejidad relacionada con roles estratégicos se obtienen internamente. Finalmente, el papel estratégico de la subsidiaria y la familiaridad con la tecnología es bajo; se elegirán fuentes externas independientemente de la complejidad de la tecnología. Los hallazgos tienen implicaciones importantes para los gerentes de tecnología de las subsidiarias con sede en Iberoamérica, quienes toman decisiones respecto a la tercerización de tecnologías de producción, y ofrecen evidencia empírica para comprender el posicionamiento de algunos mercados iberoamericanos en el mapa de innovación global.
Palabras clave: región iberoamericana; tecnología de producción; abastecimiento de tecnología subsidiaria.

Influência dos atributos tecnológicos na aquisição de tecnologia por subsidiárias: Um estudo de caso na Ibero-América

Resumo
Este documento investiga empiricamente a influência dos atributos tecnológicos na terceirização de tecnologias de produção relevantes por subsidiárias situadas na região ibero-americana, com base nos conceitos de papéis estratégicos, integração interna, capacidade e aprendizagem organizacional. As informações sobre o tema foram obtidas por meio de um estudo de caso de empresas multinacionais alemãs e suas subsidiárias de produção localizadas no Peru, Brasil, Colômbia e Espanha. Foram aplicadas entrevistas semiestruturadas, observação da tecnologia de origem e outras técnicas de coleta de dados, e realizou-se uma análise cruzada dos casos para a obtenção dos resultados. O estudo sugere que, em todas as subsidiárias de produção ibero-americanas, as tecnologias de produção com certo grau de complexidade relacionado aos papéis estratégicos são adquiridas internamente. Por fim, quando o papel estratégico da subsidiária e a familiaridade com a tecnologia são baixos, opta-se por fontes externas, independentemente da complexidade da tecnologia. Os achados têm implicações importantes para os gerentes de tecnologia das subsidiárias sediadas na Ibero-América, que tomam decisões sobre a terceirização de tecnologias de produção, e oferecem evidências empíricas para compreender o posicionamento de alguns mercados ibero-americanos no mapa global de inovação.
Palavras-chave: região ibero-americana; tecnologia de produção; fornecimento de tecnologia por subsidiárias.

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1. Introduction

Technology sourcing reflects the technology strategy of every firm. In the case of a multinational company (MNC), internationalization enables access to a wider variety of sources. Effective sourcing strategies have become critical to MNC performance as core technologies may lead to the development of unique capabilities, which may induce and facilitate the introduction of foreign markets (Demirbag, Apaydin, & Sahadev, 2021).

Also, technology sourcing highlights the real intricacies of subsidiaries because it must consider both inter- and intra-firm issues on knowledge transfer in an international setting. Furthermore, subsidiary sourcing capability ensures the availability of new technology and allows subsidiaries to increase the scale and quality of innovation (Shekarchian & Albadvi, 2019).

The sourcing mode selection by a subsidiary has been explained and researched due to the strategic role it plays within the MNC. This stream of research started with Marina Anastasiou and Robert Pearce's research works in the United Kingdom (Papanastassiou, 1999; Papanastasslou & Pearce, 1997), then in Greece (Manolopoulos et al., 2009; Manolopoulos et al., 2005), and lastly in China (Zhang & Pearce, 2010; Zhang et al., 2018). This stream of research empirically tested the relationship between sources of technology and different subsidiaries strategically motivated and the impact on their performance. This research framework was used by other authors to evaluate complementarity or substantiality of the internal and outsourcing modes (Andersson et al., 2016; Athreye et al., 2016; Cantwell et al., 2019).

Currently, there is an increasing number of studies on different contingency factors that affect subsidiary technology sourcing. For example, Ferraris et al. (2020) describe the influence of internal embeddedness in the use of external sources by subsidiaries; Deminbarg et al. (2021) explore the relationship between micro-foundational dimensions of firm internationalization and subsidiary technology sourcing; and Oki et al. (2022) study how regulatory/normative institutional distance moderate the role of local outsourcing. Although these studies contribute to the understanding of the topic by considering geographic and intra-organizational attributes, they do not contemplate the characteristics of the technology that is intended to be sourced by the subsidiary.

This leaves a gap in literature concerning how technological attributes affect subsidiary technology sourcing. Some researchers justify the inclusion of this type of factor to better understand the phenomenon. For example, Hsu et al. (2016, p. 96) outlined important insights about how leverage and protection mechanisms are related to subsidiary technology sourcing; however, they argued that one of the limitations of their research was the consideration of a parsimonious approach assuming that the nature of technology sourced across all their sample was similar. For these reasons, the authors recommended future research that include the effect of the nature of technology into sourcing decisions to obtain refined findings. Furthermore, Thakur-Wernz et al. (2020, p. 15) used a research model with factors such as project complexity, uncertainty, and prior experience as antecedents of the subsidiary sourcing choice, they also called for future research that considers the same factors but in development activities in order to reveal differences with the research activities they studied. Additionally, Murphree et al. (2022, p. 14) indicate that understanding subsidiary sourcing strategies requires "opening the black box of their industries to consider the specific technology challenges they face". They reported on where and from whom a subsidiary decides to source in accordance with the geographic scope and scale of the technology challenges being faced and call for future research in other institutional contexts.

Admittedly the power of explanation of subsidiary roles in technology sourcing is still insightful; however, linking it with technological attributes will enrich our understanding of why and how subsidiaries decide their technology sourcing mode. In this sense, the aim of our study is to broaden current knowledge on subsidiary technology sourcing by considering both strategic roles and technological attributes. We selected two subsidiaries with different roles based on the strategic importance of the host market.

Also, we will follow the recommendation of Zhang et al. (2018, p. 640): "future research should then focus on how subsidiary roles and technology sourcing interact within emerging economies." Therefore, we consider subsidiaries based in Ibero-America as our empirical context as most research in the literature on subsidiary technology sourcing were implemented in developed markets. As far as we know, no previous research on the topic has investigated this region.

The Ibero-American region is mainly characterized by emerging and developing countries with vulnerable institutions, weak market infrastructures, high levels of corruption and volatility, populism, low-skilled labor, and reduced R&D infrastructure. Studies in non-advanced countries are also important as they are a mean to exhibit host innovation system relationship with internationalization and as a base to propose better mechanisms to strengthen local technological and scientific infrastructure.

This study is focused on the Manufacturing sector, as is one of the main industries in which MNC invest and because it is a tool of modernization for non-developed countries (El-Khasawneh, 2012). As manufacturing in the Ibero-America region tends to be mature, competition shifts towards processes rather than products (Allred & Swan, 2014). Therefore, relevant production technologies will be studied. We refer to 'production technology' as all machines introduced into the factory to manufacture products. This type of technology have attributes like 'technology complexity' and 'technology familiarity.' The term "technology complexity" is defined here as the degree in which technology components have multiple interactions

and develop a no decomposable whole. Several studies have been conducted on how technology complexity is related to technology sourcing (Bonesso, Comacchio, & Pizzi, 2011; Cabrera & González, 2019; Ivarsson & Alvstam, 2017; Murphree et al., 2022; Thakur-Wernz et al., 2020). In turn, the term "technology familiarity" is defined here as the extent to which a subsidiary recognizes a technology to be compatible with the MNC's core business." Similarly, a growing body of literature has examined this factor in studies of technology sourcing (Haro-Domínguez, Ortega-Egea, & Tamayo-Torres, 2010; Purdy, Eslami, Eshghi, & Rod, 2023; Thakur-Wernz et al., 2020).

Therefore, we propose the following research question *'How do technological attributes influence the sourcing of production technology in subsidiaries with different roles based in Ibero-America?'*

2. Theoretical Framework

Our study considers the literature on technology sources that subsidiaries can access, connecting with the proposition that theorizes how technological attributes influence the selection between internal and external sources in subsidiaries with major and minor strategic role based in Ibero-American countries.

2.1 Sources of technology for foreign subsidiaries.

Literature has divided sources of technology for foreign subsidiaries into six. Each of them can be drawn considering the organizational boundary perspective, that is, whether the technology source originates inside the MNC or not. From the boundary MNC faces, internal and external sources of technology are separated. Internal sourcing are intra-unit sources (i.e., within the subsidiary limit) and intra-MNC source (i.e., sourcing from the headquarters or sister units). The three external sources are organizations in the host country, home country, and third-countries. Some studies have considered the traditional division of internal and external sources in their analysis of subsidiary technology sourcing (Hsu et al., 2016; Swan & Allred, 2009). As this study is explorative in nature, it will separate the sources into internal and external.

2.2 Internal technology sources for subsidiaries with different strategic roles.

Literature has argued that internal sourcing affords the greatest control, more tacit knowledge can be shared, facilitates a tighter degree of coupling between MNC stakeholders, and provides learning benefits and cost-saving in resource transfer (Allred & Swan, 2014). However, the selection of internal sources (i.e., intra-MNC or intra-unit source) varies according to the role of the subsidiary.

2.2.1 Major-role subsidiaries select intra-MNC source

Sourcing technology from the headquarters or a sister subsidiary (i.e., intra-MNC source) is related to a strategic role because they have better internal embeddedness and internal capacity.

Internal embeddedness enhances the use of the MNC resources because of the closeness with MNC stakeholders, more closeness could mean information exchange and the possibility to become an internal source of production technology. It is generally argued that knowledge flows increase with internal embeddedness (Cantwell et al., 2019). This has been called "internal knowledge embeddedness" in the literature on MNC parenting advantage and internal embeddedness (e.g. Asakawa, Park, Song, & Kim, 2018; Nell, Kappen, & Laamanen, 2017). This term refers to interdependencies between headquarters and subsidiaries in their product development and production processes such as the exchange of technology that subsequently can increase subsidiary performance (Wang & Zhang, 2023).

However, selecting MNC stakeholders as a source of technology is also related to the internal capacity the unit must have to receive technology from a more knowledgeable stakeholder. It has been argued that the ability of a headquarter to transfer knowledge from its home base to its foreign subsidiaries depends on the extent to which those are engaged in knowledge development (Meyer, Li, & Schotter, 2020; Miao, Choe, & Song, 2011). Along the same line, Murphee (2022) suggests that greater absorptive capacity can better source knowledge from great distances (such as headquarters and sister subsidiaries) since they require less frequent and direct interaction to internalize and utilize it. Therefore, subsidiaries with strategic roles throughout their internal embeddedness and internal capacity can internally source production technology from headquarters or sister subsidiaries.

2.2.2 Minor-role subsidiaries select intra-unit source

Subsidiaries with a minor strategic role are those with limited product and functional scope. Small-sized operation may generate weak relationships with the MNC network in technology production concerns and, subsequently, reduced valuable knowledge stock (Miao et al., 2011). They are more likely to embark purely on internal sourcing by using their own resources (i.e., intra-unit source). The technological complexity of these developments are expected to be low.

2.3 External technology sources for subsidiaries with different roles.

External sources enforce international competitiveness as this is strictly connected to the dispersed knowledge of the market for technology. Studies concentrate on the distinction between home, host, and third-country external sources.

Host technology sources, specifically, can support the subsidiary in the creation process to develop new goods for the local market because these technologies are more aligned with local tastes and conditions (Zhang & Pearce, 2010). However, researchers assert that their application depends on the extent to which a subsidiary has developed a close relationship with local stakeholders, a rich local stock of knowledge (Berry, 2018), and operation experience in the host country (Miao et al., 2011; Zhang et al., 2018). In non-developed context, such as the Ibero-American region, it is rarely treated as potential knowledge resource of technology with a deep trust in local partners (Du & Williams, 2017). Therefore, we argue that home and third-country external sources are more often preferred than local sources for relevant production technologies.

As it is difficult to predict what outsourcing mode is preferred for a specific subsidiary strategic role, this can be better approached by the novelty of the external sources, whether it is known or new for the organization. Applying the concepts of the organizational learning literature of exploration and exploitation to outsourcing, we can draw on exploration of external sources (the use of new external sources) and exploitation of external sources (the use of known external sources (Rothaermel & Alexandre, 2009)). Outsourcing strategy in production technology acquisition varies according to the strategic role of the subsidiary.

2.3.1 Major-role subsidiaries select new external sources

Major-role units, as their ability to focus on generating those sources of technology that can underpin their upgraded status, need to dedicate enough energy to exploration to ensure their future viability. In this line, they may benefit from the high frequency of interaction with MNC stakeholders to keep up with external sources that build on the new knowledge. This knowledge would lead to the acquisition of new technology to manufacture distinctive additional production processes. Thus, if successful, it can alter the trajectory of the MNC and may spill over or influence operations in other subsidiaries (Pearce, 1999). In this sense, major-role units' external technology strategy consists of pursuing exploration related to production-technology suppliers of the group.

2.3.2 Minor-role subsidiaries select known external sources

Minor-role subsidiaries tend to establish weak links with the technology market and mainly depend on headquarters' knowledge of technology suppliers. In addition, the headquarter dominance limits knowledge search from more diverse knowledge domains (Berry, 2018, p. 857). We argue that less strategic subsidiaries will be dictated by the headquarters to choose their external production-technology sources. In this sense, headquarters can good knowledge about possible suppliers share with the subsidiary as well as the typical terms and conditions under which production technology can be bought. In minor-role units, the process improvement has a limited scope because the focus is to manufacture established MNC products, which is sufficient to use external sources that build on knowledge that is familiar to the MNC. In this sense, minor-role units' external technology strategy consists of pursuing exploitation related to technology suppliers.

2.4 Technological attributes influencing internal sourcing and outsourcing.

The decision to internally source or outsource a production technology also depends on technological attributes, whether knowledge embedded in the technology is familiar with the MNC's core business or not, and its technological complexity.

Subsidiarity role is made effectively and benefits the group, when its operations are also defined interactively through an understanding of the technological trajectory of the parent-MNC network (Zhang et al., 2018). In this sense, the selection of internal sourcing in the subsidiary level must be related with a high familiarity with the technology so that the final creation would be in balance with the existing corporate technological knowledge. Additionally, internal personnel and resources can be more efficiently utilized when the production technology required is closely related to a group's core technology. Recent research on sourcing supports this (Cabrera & González, 2019). Alternatively, when subsidiaries recognize that production technology is not compatible with the MNC core business, it is more likely to be outsourced.

Regarding technology complexity, we establish that subsidiaries can source production technology with a varied level of complexity using external sources. However, internal sourcing is intended for a certain complexity compatible to the subsidiary's internal capacity (Murphree et al., 2022; Thakur-Wernz et al., 2020). Production technologies are often designed and developed around special resources such as skilled employees, machine tools, and CAD/CAM/CAE software. This may constrain design on a more complex production technology or to a simpler one. As the allocation of these resources depends on the strategic roles of the subsidiary, higher complexity of technology is internally developed by major-role subsidiaries than minor-role units.

Our research builds upon the work of the abovementioned authors. The following proposition describes an empirically testable model depicted in Figure 1. Technological attributes combined with strategic roles are important in the selection of the mode in production technology sourcing by subsidiaries based in Ibero-America. We argue that technology familiarity determines the selection between internal and external sources and technology complexity divide internal sourcing modes when subsidiary roles are considered. Various technology complexities can be sourced by external sources, but their novelty is used differently by a subsidiary role. Then, we express the following proposition:

P. *Ibero-American production subsidiaries internally source a production technology with certain technology complexity related to their strategic roles. However, when the technology familiarity is low, they will choose external sources, regardless of their roles and complexity of the technology.*

3. Methodology

A case study methodology is used to understand the phenomenon within real-life context (Yin, 2018). A theory-testing approach is selected to test explanatory theories of subsidiary technology sourcing by evaluating it in an unstudied context, i.e., the Ibero-American region. In theory-testing case studies, propositions are selected from theory and articulated beforehand; then, they are compared to observations, or data, in the case. The standpoint taken in this research is a positivist paradigm. Ontologically, it is assumed that there is a real world existing independently of our attempts to know it. Thus, organizations are real, and we can study them. The epistemological position is, the researcher and the phenomena being investigated are assumed to be independent, and the researcher remains detached, neutral, and objective. Our research designcan be found in Dekkers (2011) research on technology sourcing.

We believe we can gain rich insights into the topic through a focus on multiple case studies, as the evidence is often considered more compelling and robust. The selected empirical research design is a single-home country to two-host countries. We focus on three cases of MNC in the manufacturing industry seeking literal replication. Within each case, we search for two subsidiaries with different roles. This is akin to a multiple-embedded case study design (Yin, 2018). The unit of analysis is the relevant internal and external production-technology sourcing project of each subsidiary. We consider 'relevant technology' the one that subsidiary spent a lot of money in its acquisition. Notably, a project level of analysis can reveal more complex and fine-grained technology sourcing effects. Scholars encourage the use of projects in sourcing choice studies (Bonesso et al., 2011; Purdy et al., 2023; Thakur-Wernz et al., 2020).

3.1 Sampling Strategy.

3.1.1 For MNCs.

MNCs headquartered in Germany were chosen because of their well-developed market of machinery suppliers that may influence foreign operations in the adoption of home knowledge related to this type of technology (Ribeiro, Junior, Silva, Silva, & Sellitto, 2022). Personal relationships and professional networks were used in the sampling process. This route to identify potential cases on the basis of ease of access is referred by Easterby-Smith et al. (2008) as convenience sampling. We initially selected four German MNCs that fulfill the following criteria: 1) they belonged to the manufacturing industry; 2) they had more than one production subsidiary based in the Ibero-American region. Those MNCs had different industrial backgrounds: pencil,

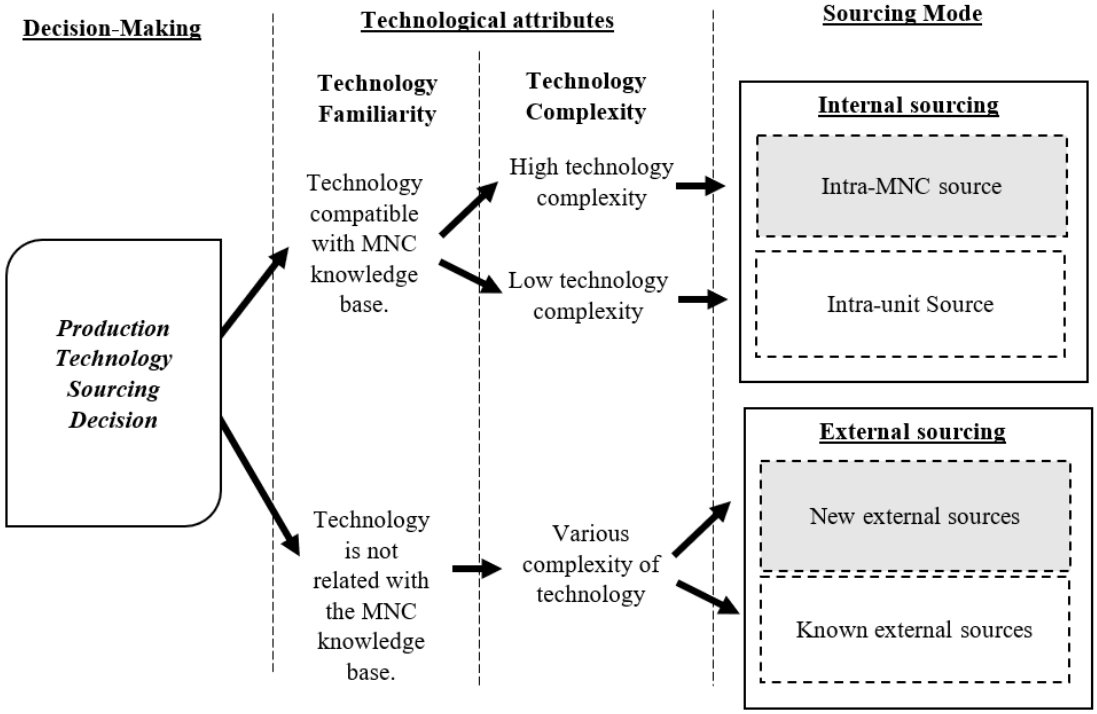

Figure 1. A model of production technology sourcing in subsidiaries based in Ibero-American countries.
Notes: the gray area are sourcing modes selected by subsidiaries with major strategic roles. While sourcing modes in white are selected by subsidiaries with a minor strategic role.

home-appliances, pumps, and industrial-automation technology. Invitations to participate in the research were first sent to the general managers of their Peruvian subsidiaries. Of the invitations sent, only one did not accept to participate due to company privacy policy and sensibility of data requested. The researchers of this study believe that a sample of 3 MNCs is sufficient to achieve literal replication and draw viable conclusions regarding the analysis and discussion of results. Table 1 gives an overview of the selected MNCs.

3.1.2 Subsidiaries.

We interviewed the general manager of the Peruvian subsidiary for each MNC to ask them about the market importance, roles and mandates of the production subsidiaries based in Ibero-America. With this information, we were able to identify the subsidiary with the major and minor strategic role. Then, we contacted production managers of the selected subsidiaries to present the research and to request an interview in which confidentiality and anonymity were promised. Relying on one respondent is justified by the fact that they are the most knowledgeable managers on production concerns, e.g., sourcing of production technologies. Table 2 gives an overview of the selected subsidiaries.

Major-role subsidiaries were based in Brazil and Spain. They had R&D laboratories co-located with the production plant. Apart from having the role of serving customer needs in the host market, they had a global mandate about a particular product, component, or technology within the MNC. While minor-role subsidiaries were based in Peru and Colombia (developing countries), which only had one production plant to attend local needs.

3.2 Data Collection.

We used semi-structural interviews to capture projects on internal and external production technology sourcing. Data collection was carried out on field trips between late 2017 and early 2019, spending a complete day at each subsidiary. We relied on previous research to prepare the questions and adapt them to our context (e.g. Zhang et al. (2018)). As such, we pilot-tested the question list on a group of three subsidiary managers from the manufacturing industry based in Peru. The interviews with sample subsidiaries were done in three phases. We first started with introductory questions about the subsidiary role, functional scope, host market characteristics, intra-MNC communication, and strategic independence in production technology sourcing. Second, we asked the respondents to think about internal production technology with which they had spent a lot of money. Third, we asked them to tell the story about the decision (*How was this decision made in the first place?*') and the factors that affected decision-making (*What was the factor that influenced the selection of this sourcing option?*'). Next, we asked respondents to consider external production technology that required a significant investment from them. Finally, we asked them to tell the story and factors about the decision to use external sources. See the Appendix for the questionnaire.

These data were complemented by technology observation, file notes collected in guided tours of production, and secondary data from innovation surveys and publicly available information such as news and web pages. The interviews and technology observation were led by the corresponding author, who is a mechatronic engineer with a more technological vision. Table 3 shows the summary of the different collection techniques applied in this study.

Table 1. Selected MNCs.

MNC (Identifier)	Pencil manufacturer (A)	Home-appliance manufacturer (B)	Automation technology Manufacturer (C)
Product Portfolio	Pencil, crayons, markers, pens, and other office supplies.	Cooking, refrigerators, washing, and other home appliances.	Electrical and pneumatic technology, sensors, controllers and others.
Start of Operation	1761	1967	1925
Subsidiaries in the world	29	75	83
Production Subsidiaries in the world	17	38	8
Production subsidiaries in Ibero-America	4	2	2

Souce: own elaboration.

Table 2. Subsidiaries selected.

MNC	Pencil manufacturer (A)		Home-appliance manufacturer (B)		Automation-tech. Manufacturer (C)	
Role	Major	Minor	Major	Minor	Major	Minor
Identifier	A1	A2	B1	B2	C1	C2
Host Country	Brazil	Colombia	Spain	Peru	Brazil	Peru
City	Sao Carlos	Bogota	Navarra	Lima	Sao Paulo	Lima
Start of Operation	1930	1976	1988	1996	1968	2003

Souce: own elaboration.

3.3 Analysis.

Qualitative data from interviews and file notes were transcribed. Data were coded with DEDOOSE, a qualitative data analysis software. Deductive analysis of the data guided by the theoretical model of the research was considered. Concepts suggested by the theoretical model create sub-categories and categories that were constantly compared with the data collected. The corresponding author coded the data independently and systematically. Subsequently, in a joint session, the classification of codes into the established categories were discussed by the research team until a consensus was reached. Throughout the research process, we used the memo-writing technique to keep us involved in the analysis. Table 4 shows the general categories and subcategories with example quotations from the interviewees.

We analyzed the technologies collected during the interviews by observation to evaluate their technological attributes. Twelve observations were carried out during the guided tour of the production plant at each subsidiary. We evaluated "technology familiarity" dichotomously. We labeled 'familiar' if the researcher observed that the

Table 3. Data collection

Type	City, Country	Date (month-year)	Duration (minutes)	Respondent
Pilot interviews	Lima, Peru	Aug-17	25 23 28	General Manager
Pencil MNC Interviews	Lima, Peru	Jun-18	30	General Manager
	Bogotá, Colombia	Jul-18	62	Production Manager
	Sao Carlos, Brazil	Dic-18	68	Production Manager
Home-Appliance MNC Interviews	Lima, Peru	Sep-17	64	General Manager
	Lima, Peru	Oct-17	64	Production Manager
	Navarra, Spain	May-18	30	Production Manager
Automation Technology MNC Interviews	Lima, Peru	Nov-18	42	General Manager
	Sao Paulo, Brazil	Dic-18	87	Production Manager
	Lima, Peru	Feb-19	42	Production Manager
Summary				
Interviews	12			
General Managers	6			
Production Managers	6			
Technology Observation	12			
Internally Sourced	6			
Outsourced	6			

Souce: own elaboration.

Table 4. General categories and subcategories on the sourcing of production technology by Ibero-American subsidiaries.

General Categories	Subcategories	Relevant quote examples from the Interviewees	
		Major-role subsidiaries	Minor-role subsidiaries
Subsidiary attributes for sourcing	Internal capability	"We use the same resources as the headquarters. When it comes to development in Brazil, the parent company does not worry much because we have a large internal development capacity."	"We in the group have a system for managing the factory, but the way it's done here is very different from how it's done in Europe. Here, we work with very basic technologies, simple technologies. In other parts of the world, you may work with a lot of automation and robots."
	Internal embeddedness	"We actively participate in the group technology network, where we share knowledge with the goal of standardizing production technologies and processes."	"Our geographical position could be very important, but for the company, an international company that has factories around the world, there are managers who don't even know that the group has a factory in Colombia."
Subsidiary Sourcing Modes	Internal Sourcing Modes	"There is a special machine that has been developed by the parent company, but it is very expensive because it is intended for mass production. I proposed making new equipment in Brazil for lower production volume, but I had to collaborate with them to develop it."	"Our only in-house development was a small machine that our maintenance staff developed with basic resources from our factory, but it was useful because we created several replicas"
	Types of External Sources	"We approved to import this line from Germany. Not from the headquarters, but from a new supplier that works with the headquarters" (new external source)	"Some machines have been bought on the recommendation of the headquarter, German brands were bought, of the machines we have, to say a percentage, I think 90% have been bought on their recommendation" (known external source)

Souce: own elaboration.

knowledge underlying the technology was related to the core business of the MNC, and 'non-familiar' otherwise. Furthermore, technology complexity was measured by the complexity coding system method proposed by ElMaraghy (2005) and also used in technology sourcing studies (e.g. Cabrera & González, 2019). It captures the variety and amount of information in each technology and its components. The overall index is the sum of the structural, control, programming, and operation complex indexes. Therefore, the complex index that ranges from zero to six comprises low complex production technologies. Medium complexity with a range from 7 to 17. Finally, scores above 18 are described as high and advanced production technologies.

The next step was to perform cross-case analysis, in which we compared single cases and looked for similarities, differences, and patterns. Table 5 summarizes the data on the collected cases and details the sourced technology name, sourcing mode, a brief of the decision-making, technology familiarity, and complexity index.

3.4 Ensuring trustworthiness.

To ensure that Yin's (2018) trustworthiness criteria have been met, we used four separate techniques. The first one was data triangulation through four different collection techniques: interviews to general managers of the Peruvian subsidiaries that supported us to find the relevant production subsidiaries, interviews to the production managers of the sample subsidiaries to collect the projects, data from technology observation, and secondary data.

The second technique was peer examination, in such a way that we asked two of our colleagues that were not part of the research team to examine the interpretation process of the data. We also applied audit trail as another trustworthiness strategy, data collection strategies, analytic choices, core reflections, and decisions were entered in many memo-writings. Finally, we spent a complete day at the subsidiary to fulfill the 'Prolonged engagement' technique. It allowed for sufficient time to observe the technology and build trust with the informants and correct

Table 5. Cross-c

MNC	**Pencil Manufacturer MNC (A)**		**Home-Appliance Manufacturer MNC (B)**		**Automation-Tech. Manufacturer MNC (C)**	
Sub. Role	**Major (A1)**	**Minor (A2)**	**Major (B1)**	**Minor (B2)**	**Major (C1)**	**Minor (C2)**
Internal Sourcing Cases						
Technology	Pencil production line	Automatic module for modelling clays	Testing machine for home-appliances	Curing oven for refrigerators parts	Pneumatic-valve production line	Testing bench for products
Familiarity	Familiar	Familiar	Familiar	Familiar	Familiar	Familiar
Complexity	18.11 (high)	5.79 (low)	18.68 (high)	2.3 (low)	18.52 (high)	2.8 (low)
Internal source	Intra-MNC source	Intra-unit source	Intra-MNC source	Intra-unit source	Intra-MNC source	Intra-unit source
Decision-making	Special-purpose technology is not available in the market and that was co-developed with the headquarters and a sister subsidiary.	Technology is not available in the market. Availability of internal resources and low technological level of the asset.	Special-purpose technology not available in the market that was co-developed with the headquarters.	Low technological level of the asset and availability of internal resources.	High cost of technology importation led to internalization and co-developed with the headquarters.	Low technological level of the asset and availability of internal resources.
Outsourcing Cases						
Technology	Pencil Shaping Machine	Injector	Laser Cutting for plastic pieces	Painting oven	Pneumatic valve production line	CNC lathe
Familiarity	Familiar	Non-Familiar	Non-Familiar	Non-Familiar	Familiar	Non-Familiar
Complexity	19.5 (high)	15.32 (medium)	9.89 (medium)	9 (medium)	19.10 (high)	18.58 (high)
External source type	New home-country supplier.	Known home-country Supplier.	New third-country supplier.	Known third-country Supplier.	New home-country supplier.	Known home-country Supplier.
Decision-making	Headquarters supported the supplier procurement. They chose a home supplier that is not used to working with wood. That's why technology had to be co-developed.	Use of the headquarters' list of home suppliers. Technology is available in the market.	Headquarters supported the supplier procurement. Technology is available in the market but requires co-development for minor technical changes.	Use of the headquarters' list of international suppliers. Technology is available in the market.	Headquarters share a supplier that worked in the home factory. However, the technology needed to be co-developed between the unit and the supplier to adapt it to the unit host market.	Use of the headquarters' list of home suppliers. Technology is available in the market.

some misinterpretations.

4. Results

In this section, we report our findings. We compared data across cases to find similarities, differences, and patterns. The region's relative homogeneity of institutional and economic conditions across countries reduced confounding effects and increased comparability.

4.1 Results for each MNC

4.1.1 Pencil manufacturer MNC subsidiarie.

A1 unit, based in Brazil, played a role in the MNC group's supply network by producing and exporting the core product (pencils) to 70 countries around the world. The host location offered comparative advantages because they could extract wood to manufacture pencils faster than any other in the group. In this sense, this subsidiary allowed the MNC network to implement economies of scale and share relevant knowledge about production concerns.

A2 unit, based in Colombia, manufactured for their host market products that were already established in the MNC group's product range such as crayons and modeling clays. The size of the factory was the smallest in the Ibero-American region. Only 18% of the revenues came from products developed locally and the rest came from the sales of products that they import from peer subsidiaries. Sister subsidiaries in the region had a higher production volume than the Colombian subsidiary. Managers informed us that they were starting to feel isolated from the MNC network and considering their local production as not strategic.

Moreover, both subsidiaries evidenced different source behavior of production technology. While the A1 unit interacted with a new home-country supplier and MNC stakeholders (both headquarters and sister subsidiary) to internally source new product developments, the A2 unit focused on production improvement using known home-country suppliers and embarked alone on internal technology development.

4.1.2 Home-appliance manufacturer MNC subsidiaries

B1 unit, based in Spain, developed and produced new products (refrigerators) to supply the European market. The unit was a center of excellence on Heat Pumps technology. Also, they had global responsibilities beyond the production charter such as IT corporate service, repair consulting, and customer service.

B2 unit, based in Peru, produced the MNC group's established product range (cookers, refrigerators, and freezers) for the South American market with minor adaptations of products and production processes to suit regional demand and conditions. The informant argued the use of basic technologies in comparison to other factories in the group. As it was the unique production subsidiary within the Latin-American region, it was responsible of controlling small regional subsidiaries in sales, marketing, finance, and customer services.

Also, both subsidiaries evidenced a different source behavior of production technology. While the B1 unit interacted with the headquarters to internally source and utilize new third-country suppliers for production improvement reasons, the B2 unit focused on production improvement but used known home-country suppliers and embarked alone on internal technology development.

4.1.3 Automation-technology manufacturer MNC subsidiaries

C1 unit, based in Brazil, produced the MNC group's established product range for the Center and South American markets, with major adaptation of products and production processes to suit regional demand and conditions. Some of the products they adapted ended up being part of the MNC portfolio. Also, the unit had responsibilities to control subsidiaries based in South America regarding product-adaptation projects, operations, and customer services. The informant argued that there was a strong internal capacity comparable with the level of the headquarters.

C2 unit, based in Peru, produced one type of product (pneumatic cylinder) of MNC group's established product range for their host market only. At the time of the interview, the group was in a restructuring process that involved grouping regional subsidiaries based on smaller markets. The respondent explained that this was causing a depletion of the production load, as it would be transferred to another sister unit in the region.

Again, both subsidiaries evidenced a different source behavior of production technology. While the C1 unit embarked on new product development by co-creating production technology with new home-country suppliers and internally developing jointly with the headquarters, the C2 unit focused on production improvement and services using known home-country suppliers and embarked alone on technology development.

4.2 Results for strategic role influencing subsidiary technology sourcing

Findings suggest that the headquarters recognized the importance of major role units by supporting their internal sourcing projects. The three internal sourcing projects for A1, B1 and C1 showed that they pursued internal exploration by co-developing production technologies with the headquarters and sister subsidiaries (i.e., intra-MNC source). In turn, minor-role subsidiaries embarked solely on internal development using their own internal resources (i.e., intra-unit source).

In the cases of outsourcing, both types of subsidiaries requested support to the MNC about production-technology suppliers. However, there were differences.

Regarding major-role units, home and third-country suppliers were used. Headquarters supported the unit in the supplier procurement. Data showed that headquarters shared new suppliers with the unit that were not part of the

stablished staff of suppliers. This suggests that the head office recognized the capacity of the unit to interact with new suppliers and expand the MNC supplier network. This excerpt from A1 evidenced it:

"We approved to import this line from Germany. Not from the headquarters, but from the suppliers that supply the headquarters. They are the same guys, the same guys that source the headquarters, but to Brazil. The headquarters knew what was happening".

Minor-role units used home and third-country suppliers as external sources. They sourced technology to improve performance indicators such as production volume, flexibility, and customization. The minor-role unit had short relationships with the supplier because the technology was readily available in the market to be purchased and installed in the factory without any modifications. Furthermore, minor-role units were supported by the headquarters in the procurement of the supplier. The unit received not only the supplier's name but also the model and characteristics of the technology, indicating that suppliers were known. The manager of C2 described it as follows:

"Germany is very, very standardized in the processes, what machines, what models are already standardized. If I want to leave, probably and Germany won't find me out, cool, but if they find me out, they will bother. Everything is very standardized, no, no, I can't start inventing things".

4.3 Results for Technology Familiarity influencing the subsidiary technology sourcing

Subsidiaries decide to internalize when the knowledge underlaying the technology is related to the MNC's core business, regardless of the strategic role. Although, major-role subsidiaries use the knowledge from MNC repositories for internal exploration by co-developing production technologies with the headquarters and sister subsidiaries. This excerpt showed the involvement of the headquarters in the internal sourcing project of the C1 unit:

"There is a special machine that has been developed by the parent company, but it is very expensive because it is intended for mass production. I proposed making new equipment in Brazil for lower production volume, but I had to collaborate with them to develop it."

Additionally, it is observed that these minor-role subsidiaries use resources as part of the subsidiary's heritage that was transferred by the MNC from the beginning of operations and used to run the business in the host market. These resources were readily available in the unit rather than emerging from a formal R&D. One instance was expressed by the respondent of C2 about his internal project:

"We had the components and the knowledge to make the technology because this is our business, we knew what we needed":

On the contrary, when production technology was not familiar, minor-role subsidiaries chose outsourcing. However, contrary to our expectation, two major-role subsidiaries did not follow this reasoning. Outsourcing by major roles was different in comparison to minor role units because the technologies were not readily available in the market to purchase them directly. Then major-role units needed to co-develop special-purpose technologies with the suppliers. In this sense, technology familiarity was a prerequisite to the knowledge transfer to the suppliers to accomplish the goal of adapting the technical features to production demands.

4.4 Results for Technology Complexity influencing the subsidiary technology sourcing.

Subsidiaries internally sourced production technology with certain technology complexity related to their strategic roles. Major roles units internally developed entire lines of production. Again, regarding internal sourcing, MNC stakeholders such as the sister and headquarters were used as a source of production technology. Sourcing knowledge from the headquarters and sister units were useful in the development of complex lines of production.

By contrast, minor-role units did not receive any attention from the headquarters in their internal sourcing projects. Furthermore, their projects were the first and the only ones within their factories as opposed to major-role units where projects triggered subsequent developments, and the continued accumulation of knowledge related to production technologies. The three internal cases in A2, B2, and C2 subsidiaries were small applications characterized as low technological developments carried out less formally by members of the engineering unit and production personnel.

In cases of outsourcing, both types of subsidiaries sourced production technologies with different levels of complexity. Hence, the pattern was not identified.

5. Discussion

We find support for the theoretical proposition that across Ibero-American production subsidiaries, internally sources a relevant production technology with certain technology complexity related to their strategic roles. However, when it comes to results arising from major-role subsidiaries, it might be doubted whether external sources are selected when technology familiarity is low. Apart from this slight discordance, these results extend our knowledge of subsidiary technology sourcing by using a contingency view, considering technological attributes in an unexplored empirical context.

Firstly, in all cases, a high technology familiarity influenced in the selection of internal over outsourcing. This agrees with Cabrera et al. (2019) finding that Peruvian subsidiaries chose internal development when the manufacturing technology were highly compatible with MNC's knowledge base. Although, outsourcing in their study was related to cost reduction, which was not the scope of this particular study.

Secondly, technology complexity influenced the decision to select the internal sourcing (i.e., intra-MNC and intra-unit source) that varied regarded the strategic role of the subsidiary. Our results have several similarities with Murphree et al. (2022)'s findings the internal sources varied systematically with the complexity of the technology. They found that for low and high technology complexity, subsidiaries sourced technology from their own internal capability and the headquarters, respectively. Similarly, Thakur-Wernz et al. (2020), using data on clinical trials in the global biopharmaceutical industry, showed that greater complexity leads subsidiaries to choose MNC stakeholders more often than intra-unit sourcing.

Moreover, headquarters supported both major and minor roles subsidiaries in looking externally for new and well-known sources of production technology, respectively. That is, relevant production technologies could not be sourced locally. This finding significantly differs from previous results reported in the literature. For example, Zhang et al. (2018) found that production subsidiaries extensively reported the use of local sourcing of technology driven by the need to adapt and develop products for the Chinese market. Murphree (2022), who conducted research in Canada, found that subsidiaries from the oil and gas industry avoid MNC stakeholders to source locally when the technology was complex. Furthermore, it appears that local knowledge sourcing may not assist subsidiaries in economically disadvantaged regions such as Ibero-America.

Finally, firm-level data from German manufacturing MNC showed that subsidiaries based in emerging markets of the Ibero-American region internally sourced and outsourced new and high-complex production technologies rather than adapting existing parent technology, hence playing a more important strategic role than was previously assumed. This is similar to a research that analyzed new technology development by Swedish MNCs in emerging markets (Ivarsson & Alvstam, 2017). Similarly, Wang (2023)'s findings evidenced the importance of internal knowledge embeddedness that shaped the subsidiary's ability to produce technical knowledge. This result matches well with our result that the above-mentioned subsidiaries used the group network to source while constructing knowledge-intensive long-term relationships with headquarters and sister subsidiaries.

These findings are consistent with the theoretical claims from organization learning, internal capability, strategic roles, and network-based perspectives for the theoretical concept of internal embeddedness. Our aim was to find cases that were theoretically salient, not cases from which to generalize to a population.

Since we based our findings on a limited number of cases, we should treat the results from such analyses with considerable caution. The findings are only valid within the narrowly defined scope of the sourcing of production technology and limited to German MNC's subsidiaries operating in the manufacturing industry in the Ibero-American context, specifically in Peru, Colombia, Brazil, and Spain.

6. Conclusions

To better understand by considering technology attributes, this study has responded to the call for additional empirical studies on subsidiary technology sourcing. Inspired by the International Business and Technology Management literature, the study describes differences in production-technology sourcing across subsidiaries with different roles. This study found that across Ibero-American production subsidiaries, production technology with certain technology complexity related to their strategic roles is internally sourced. For subsidiaries with less strategic roles, when the technology familiarity is low, they will choose external sources, regardless of the complexity of the technology.

Conducting this study in the Ibero-American region allowed us to challenge implicit assumptions presented in research from more advanced regions. Ibero-America has relative homogeneity in institutional conditions and shares common languages (i.e. Spanish and Portuguese) across countries, which reduces confounding effects and increases comparability (Aguinis et al., 2020). The results of this study suggest that Ibero-America may not be viewed as a host context for international companies to tap on local production technology; however, there is international transfer of this type of technology that often comes from the home country.

Firm-level data from German manufacturing MNC show that their production subsidiaries in advanced countries of the Ibero-American region are extending the MNC knowledge base on production technology. While subsidiaries based in developing countries are still using standardized technology procedures.

This study has several implications for practice. First, management at headquarters must ensure that they generate and provide their small-country subsidiaries with a constant flow of technological knowledge so that the subsidiaries can develop a knowledge base that allows them to effectively decide between internal and external sources of technology. Second, managers at subsidiaries need to closely monitor technology sources within multinational corporations, encourage technology transfers to their operations by building strong network relationships, and embark on explorative technology projects.

The current study was limited by data from retrospective interviews, technology observations, and secondary data, which created a risk of important facts being forgotten. To address this, subsidiaries were consistently advised to propose the relevant and costliest production technology projects and focus on the knowledgeable participants involved in those projects. However, data allow us to offer insights that are not available from quantitative studies.

Finally, future research could explore the extent to which the findings of this study translate to the experiences of other subsidiaries that source production technology. All the multinational corporations investigated are based

in Germany, and their host markets are located in Ibero-American countries. Future research could apply a similar research approach in a different environment (e.g., emerging multinational corporations, different industries, and other host countries). Also, future studies could include the perspective of headquarters managers, customers or suppliers in the process of technology sourcing by foreign subsidiaries. It is also suggested to analyze the subsidiary technology sourcing in the coming years. Finally, future studies could explore the impact of a wider variety of technology sources, focusing on more specific models than the dual internal and outsourcing model considered here.

Conflict of interest

The authors declare no conflict of interest.

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Annexes

Table A1. Questionnaire

PHASE I: Introduction and Firm History
Q1.1: As part of the introduction, could you please tell me about your company and your position there?
Subsidiary Role
Q1.2: What do you think about the unit role and responsibilities in the global operation of multinational firms?
Q1.3: Tell me about how the subsidiary role and responsibilities have evolved or changed over time?
Subsidiary Mandate Now
Q1.4: Please explain if your business unit has the following functional scope:
(1) Sales and service.
(2) Assembly.
(3) Manufacturing.
(4) Product development.
(5) International strategy development.
Q1.5: Has the functional scope changed overtime? If yes, please explain how.
Control Mechanism
Q1.6: In production-technology acquisition decisions, what is the role of headquarters?
Subsidiary-Subsidiary Communication
Q1.7: How do you locate the relevant subsidiary to speak about production technologies?
Q1.8: Does your business unit help other subsidiaries with production technologies problems?
PHASE II: Local Market
Q1.9: Is the location strategically important to your company?
PHASE II: Internal sourcing Case
Q2.1: Think about an INTERNAL production technology that have been developed inside your multinational corporation, in which you have spent a lot of money.
Q2.2: How did you get that technology? Did you develop it in-house? Did you acquire it from a sister subsidiary? Or did headquarters transfer it?
Q2.3: What was the reason for acquiring the technology? (example: Cost reduction, Lack of Production Capacity, Increase Product Quality, New Product Introduction or Need to upgrade Configurations, etc.).
Q2.4: What factors influenced in the decision? (example: Developing cost, internal capabilities, intellectual properties, experience, etc.).
PHASE III: Outsourcing Case
Q3.1: Think about EXTERNAL production technology with which you have spent a lot of money.
Q3.2: How did you get that technology? Did you acquire it from a host supplier? Did you acquire it from a home supplier? or Did you acquire it from other source?
Q3.3: What was the reason for acquiring the technology? (example: Cost reduction, Lack of Production Capacity, Increase Product Quality, New Product Introduction or Need to upgrade Configurations, etc.).
Q3.4: What factors influenced in the decision? (example: Developing cost, internal capabilities, intellectual properties, experience, etc.).