Combinations of knowledge sources for product innovation based on the degree of novelty: Evidence from Peru

Combinaciones de fuentes de conocimiento para la innovación de productos en función del grado de novedad: evidencia de Perú

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Abstract: This research aims to unveil the combinations of knowledge sources that influence the degree of innovation novelty or radicalness (products new-to-firm and new-to-market). Exploratory and confirmatory factor models and bivariate probit regression are applied on a sample of Peruvian manufacturing companies made available by the Peruvian National Innovation Survey. The results show two combinations. Firstly, the combination of internal sources (within the firm or business group) with the knowledge of customers, suppliers, and competitors, which are related to the new-to-firm and new-to-market product innovations. Secondly, the combination of knowledge from universities, public research institutes, and consultants/private R&D institutes, which are related to new-to-market product innovations. This study contributes to the literature by revealing the combinations that influence the degree of novelty or radicalness of innovation in Peru, which represents the search strategies and knowledge combinations to achieve innovation at firm level. The study also provides evidence of how knowledge generated by other companies in the business group or consultants/private R&D institutes contributes to the firm innovative. The practical implications of this research rely on understanding how strategy makers can promote the management of different knowledge sources in companies and their combinations to achieve product innovations based on the degree of novelty.

Keywords: Open innovation, product innovation, knowledge sources, knowledge recombination, knowledge integration.

Resumen: Esta investigación tiene como objetivo revelar las combinaciones de fuentes de conocimiento que influyen en el grado de novedad o radicalidad de la innovación (productos nuevos para la empresa y nuevos para el mercado). Se aplican modelos factoriales exploratorios y confirmatorios y regresión probit bivariante en una muestra de empresas manufactureras peruanas proporcionada por la Encuesta Nacional de Innovación del Perú. Los resultados muestran dos combinaciones. En primer lugar, la combinación de fuentes internas (dentro de la empresa o grupo empresarial) con el conocimiento de clientes, proveedores y competidores, que se relacionan con las innovaciones de productos nuevos para la empresa y nuevos para el mercado. En segundo lugar, la combinación de conocimiento de universidades, institutos públicos de investigación y consultores/institutos privados de I+D, que se relacionan con las innovaciones de productos nuevos para el mercado. Este estudio contribuye a la literatura al revelar las combinaciones que influyen en el grado de novedad o radicalidad de la innovación en Perú, que representa las estrategias de búsqueda y las combinaciones de conocimiento para lograr la innovación a nivel de empresa. El estudio también proporciona evidencia de cómo el conocimiento generado por otras empresas del grupo empresarial o por consultores/institutos privados de I+D contribuye a la innovación de la empresa. Las implicaciones prácticas de esta investigación se basan en comprender cómo los responsables de la estrategia pueden promover la gestión de las diferentes fuentes de conocimiento en las empresas y su combinación para lograr innovaciones de producto basadas en el grado de novedad.

Palabras clave: Innovación abierta, innovación de producto, fuentes de conocimiento, recombinación de conocimientos, integración de conocimiento.

1. Introduction

This study addresses the research question: what combinations of knowledge sources influence the degree of novelty or radicalness of innovation (new-to-market and new-to-firm product innovations)? The research is conducted in industrial companies in Peru, an emerging country.

The study examines the sources of knowledge: internal (within the company or business group), and knowledge that comes from customers, suppliers, competitors, consultants or private R&D institutes, universities and public research institutes that constitute the main actors that exchange knowledge and add value to the innovation of companies in a national innovation system.

To date, it is known that, due to the heterogeneity of knowledge sources, firms employ strategies that seek external knowledge from different sources, producing a combination effect. The sources of knowledge used in the combinations are different, varying depending on the type of innovation, the complexity of knowledge in the industry, and the firm's internal capabilities. Previous studies have focused primarily on product and process innovations in developed countries and little is known about the combinations that influence the degree of novelty or radicalness of innovation (new-to-market and new-to-firm product innovations), especially in emerging countries.

Product innovations includes innovation of new or substantially improved products. It includes radical and incremental innovations, while new-to-market (national or international market) product innovation refers to radical innovations and innovations for the national market that imitate innovations present in other markets, so they have a higher level of complexity, are more elaborate, and require a higher level of knowledge and greater internal capacity of the company.

The industries of Peru correspond mainly to low-technology industries and medium-low-technology industries, so they are industries that have different levels of knowledge; furthermore, the level of complexity of the innovations is different from companies in developed countries, where the evidence of combinations of sources of knowledge is concentrated.

The combinations found in developed countries can only be generalized to high-tech manufacturing firms from developed countries: there is a gap in the literature regarding the combinations that influence the degree of novelty or radicalness of innovation (new-to-market and new-to-firm product innovation) and in emerging country contexts.

This study pertains to Peruvian companies and contributes to the scarce evidence that exists on the combinations of knowledge sources in emerging countries. Understanding these combinations is of interest both to companies that need to design and implement knowledge search strategies from different sources and manage this knowledge to achieve new-to-market product innovations, and to public agencies that develop support policies for businesses.

2. Literature review

2.1 Innovation and Sources of Knowledge

According to the resource-based view (RBV) of a firm (Wernerfelt, 1984), the resources and capabilities available in a company determine its ability to innovate, and knowledge is the most fundamental resource to achieve innovation (Farooq, 2018). With the open innovation paradigm (Chesbrough & Bogers, 2014) the company can increase its knowledge for innovation through the knowledge flows it can receive from other companies and organizations.

Sources of knowledge are the flows of knowledge that come from actors who share resources and create value for innovation in companies, such as customers, suppliers, competitors, consultants, universities and other R&D institutions that are part of a national innovation system (Freeman, 2004; Lundvall, 1992).

Internal sources comprise the internal knowledge that the company has for innovation: they collect the knowledge acquired in R&D and the knowledge available to the company's departments, being the most important knowledge for innovation (Gu et al., 2016; Ruiz-Pava & Forero-Pineda, 2018). When a company is part of a business group, it can receive flows of knowledge and technology from other companies in the business group, and these flows increase the internal knowledge of the company that the company has available for innovation (Kim & Lui, 2015).

Business groups play a particularly important role in the R&D of their subsidiaries because they provide knowledge to adapt new products to the local market, especially for products that are in other markets, or because they contribute to the creation and acquisition of globally relevant technology for the group (Zhang et al., 2015).

Customers contribute to innovation with market needs and experience of the use of products, and this knowledge is the input for the development of new products. It is the most important knowledge to develop innovations because it guides the company to innovation based on what the market needs (Cui & Wu, 2018; Melander, 2020).

Suppliers contribute with technologies in the supply chain that are used in product parts (Kumar et al., 2016), including embedded technology such as machinery and equipment, and non-embedded technology such as patents and licences (Dosi et al., 2021; Moreira et al., 2020).

Competitors provide market knowledge, product technology (Ozkaya et al., 2015) and critical information about the market, technologies and patents (Wang & Gao, 2021). Consultants provide ideas to increase innovation capacity (Doloreux & Turkina, 2017) and help companies receive technology transfers (Bianchi et al., 2016).

Universities contribute to the production of scientific knowledge and technological development, which is especially useful for large companies with high technological knowledge (Bellucci & Pennacchio, 2016; Neves et al., 2021), but the company needs to have internal absorptive capacity to receive this transfer of knowledge and technology (Østergaard & Drejer, 2022).

Public research institutes are the government's support for business innovation. They provide specialized knowledge for specific clusters or sectors of companies, but companies must also have internal absorptive capacity to receive this transfer of knowledge (Cheah & Ho, 2020; Jung et al., 2021).

Internal sources are the most important and are positively related to the company's innovative performance. The knowledge flows for innovation obtained from external sources such as customers, suppliers, competitors, universities and public research institutes increase the company's innovative potential (Laursen & Salter, 2006).

Several studies have examined the individual effect of each source on product innovation: internal sources, customers, competitors and university (Gómez et al., 2016); customer and supplier sources (Moon et al., 2018); consultants who help transfer knowledge from universities and public research institutes (Bianchi et al., 2016); universities that impact product innovation mainly in radical innovations and with large companies (Neves et al., 2021; Pittayasophon & Intarakumnerd, 2017); and public research institutes that develop knowledge for business sectors and impact product innovation (Cheah & Ho, 2020).

In their study in Peru, Moya-Fernández & Seclen-Luna (2024) studied the impact of each source of knowledge and found that internal sources, customers and consultants are positively related to product innovation, while Arenas & Gonzalez (2019) found that consultants are related to product innovation in Peru.

Each source of knowledge has an impact of different intensity depending on the characteristics of the industrial sector in which the company operates and the competitiveness of each country (Gómez et al., 2016; Pejić et al., 2015). Likewise, the impact of each source of knowledge has a different intensity depending on the technological level of the sector and the complexity of the knowledge managed by the company (Doloreux & Turkina, 2017; Gu et al., 2016).

2.2 Knowledge Source Combinations for Innovation

Knowledge sources are heterogeneous—that is, each provides companies with a different type of knowledge. The company needs to access different sources, and makes the selection and combination based on the type of innovation it wants to carry out and the internal knowledge it has; it needs to select external knowledge that is complementary and can be integrated with the company's internal knowledge (Chen et al., 2016; Criscuolo et al., 2018; Rodríguez et al., 2016).

The firm has knowledge components, each of which is associated with a technological or scientific concept, and the recombination of the various knowledge components gives rise to new meanings or functions that are the basis for achieving innovation (Xiao et al., 2022). Knowledge recombination in the firm can generate new knowledge or the reuse of existing knowledge, leading to innovation (Appio et al., 2017).

The firm prioritizes its open innovation strategy, selecting the different sources it can access to obtain knowledge based on learning from past collaborations, its absorptive capacity, and the heterogeneity of the external knowledge it can access (Kesidou et al., 2022). Knowledge combination is more advantageous in firms in high-tech sectors (Wu & Wang, 2017). A firm's knowledge-creating capacity is positively associated with its absorptive capacity (Khraishi et al., 2022).

Obtaining knowledge for innovation, which comes from the integration of internal knowledge with external knowledge obtained from different sources, is achieved through joint action of the company's internal capabilities, especially R&D capacity and the knowledge available for innovation (Criscuolo et al., 2018; Ma & Yu, 2021).

Table 1 shows studies that have examined the relationship between combinations of knowledge sources and different types of innovation. A first research trend was to examine the impact of external sources of knowledge (customers, suppliers, competitors, universities, public research institutes, etc.) on different types of innovation such as product and process innovation, and service innovation. The evidence indicates that using different knowledge sources creates a combination effect that is distinct from the effect of each knowledge source separately (Rodríguez et al., 2017).

The studies carried out showed various combinations—customers and competitors, or customers and suppliers, or universities and research institutes—can increase the innovative potential of the company, and this external knowledge is complementary to the internal knowledge of the company (e.g. Chen et al., 2011, 2016; Cruz-González et al., 2014; Laursen & Salter, 2004; Leiponen, 2005; Tödtling & Grillitsch, 2015; Rodríguez et al., 2016).

A second research trend was to examine combinations of internal sources with external sources of knowledge where internal sources have an important role and the company's internal capabilities. These combinations are: internal with suppliers, customers and competitors; internal with suppliers, competitors and universities; internal with customers, competitors and universities (e.g. Criscuolo et al., 2018).

The impact of external sources was also examined according to the degree of innovation novelty (new-to-firm and new-to-market product innovations), Köhler et al. (2012) found differences between the combinations appropriate for new-to-market product innovations and those appropriate for new-to-firm product innovations; the combination of suppliers with professional associations and the combination of universities and public research institutes are more appropriate for new-to-market product innovations, and the combinations of customers and competitors are more appropriate for new-to-firm product innovations.

Sarpong & Teirlinck (2018) found that collaboration with customers or competitors, is appropriate for new-to-market and new-to-firm product innovations, and collaboration with universities or consultants or private/public research institutes and collaboration with suppliers are appropriate for new-to-market product innovations.

Other combinations that have been found appropriate for new-to-market product innovations are: combination of customer and suppliers, and combination of universities and research institutes (Duodu & Rowlinson, 2021) combination of internal sources with customers (Duran et al., 2022), combination of customers, competitors, suppliers, and firms from different industries; combination of universities and research centres (Ruiz-Pava & Forero-Pineda, 2018).

Table 1: Studies of combinations of knowledge sources by type of innovation

Type of Innovation	Industry type	Combination of knowledge sources	Country	Reference
Product innovation	Manufacturing	- Customers, suppliers and competitors - Consultants, commercial laboratories/ R&D enterprises, government research organizations, government office and private research institutes	United Kingdom	Laursen & Salter (2004)
Services innovation	Services	- Internal - Customers and competitor Finland - Universities	Finland	Leiponen (2005)
Product innovation	Manufacturing	- Customers and suppliers - Competitor and firms in other industries - Universities and research institutes, and governments	China	Chen et al. (2011)
Product innovation: new-to-firm and new-to-market	Manufacturing	- Customers and competitors - Suppliers, professional exchanges, and exhibitions/ fairs - Universities and public research institutes	Belgium, Germany, Greece, Portugal, Spain	Köhler et al. (2012)
Product innovation	Manufacturing	- Government research organizations, private research institutes, universities or other higher education institutions, commercial laboratories/R&D enterprises and experts/consultants - Conferences, meetings, scientific journals and trade/ technical publications - Fairs, exhibitions, professional and industry/trade associations - Clients, customers and competitors	Spain	Cruz-González et al.(2014)
Product innovation	Manufacturing	- Supplier - Universities, technical institutes and related sectors from firm - Universities and related sectors from firm - Related sectors from firm	Austria	Tödtling & Grillitsch (2015)

Type of Innovation	Industry type	Combination of knowledge sources	Country	Reference
Product and process innovation	Manufacturing	- Customers and suppliers - Competitors and companies from other industries - Universities and public research institutes	China	Chen et al. (2016)
Services Innovation	Services	- Consultants, clients, supplier, universities, research centers, competitors - R&D internal & external - External knowledge, market intro, preparations - Machinery, training	Spain	Rodríguez et al. (2016)
Product and process innovation	Manufacturing	- Internal and customers - Internal, suppliers and customers - Internal, customers and competitors - Internal, customers and universities - Internal, suppliers, customers and competitors - Internal, suppliers, competitors and universities - Internal, customers, competitors and universities	United Kingdom	Criscuolo et al. (2018)
New to local market and new to international markets product innovation	Manufacturing	- Internal - Customers, competitors, suppliers, and firms from different industries - Technological developments center, research centers, universities and training centers	Colombia	Ruiz-Pava & Forero-Pineda (2018)
New-to-firm and New-to-market product innovation	Manufacturing	- Collaboration with customers or competitors - Collaboration with universities or consultants or private/ public research institutes	Belgium	Sarpong & Teirlinck (2018)
New to market product innovation	Manufacturing	- Collaboration with suppliers - Collaboration with suppliers and customers. - Collaboration with universities, research institutes and consultancy firms	Norway	Haus-Reve et al. (2019)
New-to-market Product innovation	Manufacturing	- Customer and suppliers - Universities and research institutes	Hong Kong -China	Duodu & Rowlinson (2021)
Product innovation	Manufacturing	- Customers, suppliers, and competitors - Universities and research centers - Conferences, scholarly journals, and associations	Peru	Del Carpio Gallegos & Seclen-Luna (2022)

Type of Innovation	Industry type	Combination of knowledge sources	Country	Reference
Product innovation	Manufacturing	- Internal - Market (customers, suppliers, companies from other sectors and associations) - Science (universities, research and productivity centers, business incubators, technology parks and specialized consultant) Free access source (fairs, seminars and conference, scientific and technological database)	Colombia	Escorcia-Caballero et al. (2022)
New-to-market product innovation	Manufacturing	- Internal and customers	Turkey	Duran et al. (2022)
Product and process innovation	Manufacturing	- Collaboration with suppliers, customer and external knowledge sourcing	China	Zhang (2024)
New to market product innovation	Manufacturing	- Internal - Collaboration with suppliers, customers, and competitors - Universities - Conferences, trade fairs, or exhibitions professional and industry associations; technical, industry, or service standards; scientific journals and trade/technical publication	United Kingdom	Audretsch et al. (2025)

Most of the investigations in Table 1 focus on product and process innovation, and in developed countries. Differences are shown between the combinations of one country and another country, and between industrial companies and service companies. Evidence of combinations of knowledge sources in emerging countries is limited.

Product innovation includes both incremental innovation and radical innovation, but radical innovation is more elaborate; it requires more specialized knowledge than incremental innovation, which is to improve products, and requires a lower level of knowledge in the company (Gui et al., 2022).

New-to-market product innovation (national or international market) includes both radical new product innovations and new products for the national market that are imitations of other products that exist in other markets. It is more complex than new-to-firm product innovation (Ritala et al., 2018). New-to-market product innovation is more elaborate; it requires greater efforts to integrate internal and external knowledge to achieve innovation (Doloreux et al., 2018; Jugend et al., 2018), and to be successful in combining knowledge sources requires strong capabilities and cooperation with internal sources (Hervas-Oliver et al., 2022; Plechero & Grillitsch, 2023; Rodríguez et al., 2017).

The industries of Peru, using the classification of manufacturing industries based on technology (OECD, 2007), correspond mainly to low-technology industries and medium-low-technology industries. They are different from companies in developed countries, where there is generally evidence of the aspects that influence the combinations in terms of the level of complexity of the knowledge that the industry handles and the complexity of the innovations (Kesidou et al., 2022; Wu & Wang, 2017).

The conclusions of combinations found in developed countries can only be generalized to high-tech manufacturing firms from developed countries, since they have been obtained in other contexts of technology companies, other industrial sectors and with greater knowledge complexity (Cruz-González et al., 2014).

There is little knowledge about the combinations of knowledge sources that influence the degree of novelty or radicalness of innovations (Criscuolo et al., 2018). It is necessary to expand knowledge of how companies combine the knowledge components they have to achieve innovation (Xiao et al., 2022).

Therefore, there is a gap in the literature about the combinations that influence the degree of novelty or radicalness of innovations (new-to-firm and new-to-market product innovation), especially in emerging countries. In order to contribute to this gap in the literature, this research raises the following hypotheses.

Considering that companies can combine sources that include knowledge from internal sources (within the company or business group) that provide ideas and internal R&D knowledge, knowledge from companies in their business group (De Beule & Van Beveren, 2019), knowledge provided by customers about product needs (Cui & Wu, 2018; Melander, 2020), and knowledge provided by suppliers about technologies (Kumar et al., 2016), and that previous studies have found a positive relationship in manufacturing between the combination of internal sources, suppliers and customers and product innovation (Criscuolo et al., 2018), the following hypotheses are argued.

H1a: The combination of internal sources of knowledge (within the company or business group), customers and suppliers is positively related to new-to-firm product innovation.

H1b: The combination of internal sources of knowledge (within the company or business group), customers and suppliers is positively related to new-to-market product innovation.

Considering that firms' innovations may require a higher level of knowledge complexity, which requires knowledge from a greater number of sources, knowledge that suppliers provide about technologies (Kumar et al., 2016) and knowledge of competitors about the market and product technology (Ozkaya et al., 2015; Wang & Gao, 2021) and that previous studies have found a positive relationship in manufacturing between the combination of sources customers, suppliers and competitors, and product innovation (Criscuolo et al., 2018; Del Carpio Gallegos & Seclen-Luna, 2022), the following hypotheses are argued.

H2a: The combination of internal sources of knowledge (within the firm or business group), customers, suppliers and competitors is positively related to new-to-firm product innovation.

H2b: The combination of internal sources of knowledge (within the company or business group), customers, suppliers and competitors is positively related to new-to-market product innovation.

Considering that previous studies in Peru have found a positive relationship in manufacturing companies between consultants and product innovation (Moya-Fernández & Seclen-Luna, 2024) and between the combination of universities and research centres with product innovation (Del Carpio Gallegos & Seclen-Luna, 2022), and that previous studies have identified combinations of universities, research institutes and consultants/R&D laboratories with product innovation (Cruz-González et al.,2014; Haus-Reve et al., 2019), the following hypotheses are argued.

H3a: The combination of knowledge sources from universities, public research institutes and consultants/private R&D institutes is positively related to new-to-firm product innovation.

H3b: The combination of knowledge sources from universities, public research institutes and consultants/private R&D institutes is positively related to new-to-market product innovation.

3. Methodology

3.1 Data and Sample

The method is quantitative, non-experimental and cross-sectional. Data used are from the National Survey of Innovation in the Manufacturing Industry and Knowledge-Intensive Service Companies 2018 of Peru, the latest innovation survey in Peru, implemented by the Instituto Nacional de Estadísticas e Informática del Perú (INEI) in 2019. The survey is aligned to the Oslo Manual (OECD/Eurostat, 2018), which contains the most widely accepted international guidelines on country innovation surveys. For the survey design, the INEI considered a sampling frame of 16,636 companies from the central directory of companies in Peru. The sample is probabilistic, stratified, single-stage, and independent at the level of division of the International Standard Industrial Classification (ISIC). The survey was made up of 2,084 companies. The sample for this research was 833 manufacturing companies that carried out innovative activities during the period under review. The rest of the companies were excluded. Table 2 shows the companies that participated in the sample by type of industry using the ISIC classification. It shows that the categories with the highest percentage are mainly food, textile, chemical, and plastic companies.

Table 2: Classification of companies according to the international standard industrial classification (ISIC)

ISIC code/description	Frequency	Percentage (%)
C10-C11 Food products- Beverages	164	19.69
C13-C14 Textiles - Wearing apparel	99	11.88
C15 Leather	27	3.24
C16 Wood products	26	3.12
C17- C18 Paper products - Printing and reproduction	57	6.84
C19-C20 Refined petroleum products - Chemical products	80	9.60
C21-Pharmaceuticals	24	2.88
C22- C23 Plastic products - Non-metallic mineral products	110	13.21
C24-C25 Basic metals - Fabricated metal products	92	11.04
C26- C27 Computer, electronic - Electrical equipment	31	3.72
C28-C33 Machinery - Repair of machinery	50	6.00
C29-C30 Motor vehicles - Other transport equipment	26	3.12
C31-Furniture	25	3.00
C32- Other manufacturing	22	2.64
Total	833	100

3.2 Variables

There are two dependent variables: (1) innovation of new-to-firm products, measured as a binary variable, with the value of one if the company carried out new-to-firm product innovation; and (2) innovation of new-to-market products (national or international markets), measured as a binary variable, which takes the value of one if the company carried out new-to-market product innovation. The Peruvian survey, following the Oslo Manual, uses variables that are binary to record innovations—i.e. whether or not the company carried out innovation in the period examined. Other studies that use this measure include Criscuolo et al. (2018).

The independent variables in this study are: (1) internal sources (within the firm or business group), (2) customers, (3) suppliers, (4) competitors, (5) consultants or private R&D institutes, (6) universities, and (7) research institutes. The sources of knowledge are registered in the Peruvian survey on a descending scale from one to four (1 = high, 2 = medium, 3 = low, 4 = not used) according to the degree of importance of each source of knowledge for innovation activities. These variables were converted from a descending scale to an ascending scale of one to four according to the importance of the source for innovation activities (1 = not used, 2 = low, 3 = medium, 4 = high). Other studies that use the knowledge sources scale ranging from "not used" to "high" include Köhler et al. (2012) and Wu and Wang (2017).

There are three control variables in this study: company size, seniority of the company, and R&D intensity. Company size can influence a company's innovative potential, because larger companies can concentrate a greater number of workers and resources for R&D, so they can expand their knowledge and capacity to innovate more compared to smaller companies. Company size is measured by the number of employees in the company (Díaz-Díaz & De Saá Pérez, 2014; Gu et al., 2016).

The seniority of the company may have an influence, since older companies may have more experience in previous R&D and have accumulated a greater amount of knowledge for innovation and may have developed capabilities for innovation. As a result, they may become more innovative. The seniority of the company is measured by the number of years the company has been in business (Lefebvre et al., 2015).

R&D intensity is measured by R&D expenditure/sales (Laursen & Salter, 2006). Companies with larger R&D budgets develop more intense R&D activities, can link up with other market players, can develop more knowledge and have greater potential capacity to innovate (Gómez et al., 2016; Gu et al., 2016).

Table 3 shows data for the independent variables and the control variables. Some sources of knowledge have low and medium levels of importance for innovation activities (scale 1 = non-use, 2 = low, 3 = medium, and 4 = high). Low values are observed in R&D intensity (R&D expenditure/sales) (mean = 0.0016). In Peru, there is low investment in R&D: only 0.17 per cent of GDP was invested in R&D in 2018, which is a small amount compared to R&D investments in developed countries (World Bank, 2019). This means fewer resources to develop R&D and less development of internal capabilities (Zawislak et al., 2018). The R&D intensity variable is related to the company's capacity to generate knowledge and technologies in R&D (Gu et al., 2016; Laursen & Salter, 2006). R&D expenses/sales are also a measure of a company's absorptive capacity (Cohen & Levinthal, 1990; Laursen & Salter, 2006).

Table 3: Variable's values

Variable	Min	Max	Mean	Standard deviation
Internal source (within firm or business group)	1	4	3.22	1.03
Customers	1	4	2.55	1.25
Suppliers	1	4	2.61	1.18
Competitors	1	4	2.22	1.15
Consultants or private R&D institutes	1	4	1.68	1.00
Universities	1	4	1.47	0.83
Public research institutes	1	4	1.33	0.71
Size of company (number of workers)	1	15,686	303.49	807.70
Seniority of company (year)	3	110	23.89	16.45
R&D intensity (R&D expenditure/sales)	0	0.49	0.0016	0.018

3.3 Data Analysis

Exploratory factor analysis (EFA) was applied to determine the factors that group the independent variables. Later, confirmatory factor analysis (CFA) was applied to verify that the factors obtained in the EFA have an adequate level of confidence. The factor analysis technique to group variables from sources of knowledge for innovation has been used by several authors for EFA (e.g. Chen et al., 2016; Rodríguez et al., 2016; Ruiz-Pava & Forero-Pineda, 2018) and CFA (e.g. Ruiz-Pava & Forero-Pineda, 2018).

The sample adequacy test was performed and the Kaiser-Meyer-Olkin (KMO) index was calculated which is greater than 0.60, while the Bartlett sphericity test was less than 0.05 (Kim & Mueller, 1978). To extract factors, the principal components method was used, the magnitude of the factor loadings of each variable was considered to be greater than 0.5 (Fabrigar et al., 1999).

CFA was carried out to verify that the factors obtained in the EFA have an adequate level of confidence. Reliability and convergent validity are examined by verifying that the factor loadings exceed 0.50, and the average variance extracted (AVE) exceeds 0.50. Cronbach's alpha will be applied to each construct as a measure of reliability.

Absolute fit indices are applied that indicate the degree to which the model observed in the covariance matrix matches the covariance matrix of the implicit model. The indices used are root mean squared error of approximation (RMSEA), which refers to the amount of variance not explained by the model, and standardized root mean squared residual (SRMR). For RMSEA, a value between 0.05 and 0.08 is acceptable (Lai, 2020), and for the SRMR index, a value <0.05 is considered adequate (Cho et al., 2020). The chi-square index was not considered because in relatively large samples it tends to increase the differences between the variance-covariance matrix of the sample and the matrix of the proposed model (Lewis, 2017). If the RMSEA value is between 0.05 and 0.08 and SRMR <0.05, there is adequate fit of the model.

A Probit bivariate model will be used for regression. This selection was made due to the binary characteristics of the dependent variable that takes the value of one when the company has carried out innovation and the value of zero when the company has not carried out innovation. In addition, considering that this is a non-random independent variable, it takes censored values of one and zero. Therefore, it is considered that linear ordinary least squares (OLS) models are not appropriate in this case, since they are inefficient and inferences cannot be made. Probit has been used in previous studies for regressions on innovation with a binary dependent variable (e.g. Criscuolo et al., 2018; Gómez et al., 2016; Ruiz-Pava & Forero-Pineda, 2018).

The model was examined for endogeneity, multicollinearity and heteroscedasticity problems. To examine multicollinearity, a strong non-multicollinearity test was used using the variance inflation factor (VIF) test, considering that VIF values lower than 3 rule out multicollinearity problems. To examine endogeneity, the correlations between the variables were analysed to verify that all correlations were lower than 0.8—that is, that there was no high correlation between the independent variables. To examine whether there was heteroscedasticity in the regression, which occurs when the variance of the errors is not constant in all samples, robust standard errors were used, which allow an unbiased and efficient estimate in the presence of heteroscedasticity.

4. Results

EFA was carried out to group variables into factors. The KMO index of sampling adequacy had a value of 0.715, values greater than 0.60 considered appropriate (Kim & Mueller, 1978), and the Bartlett's sphericity test had a significance level of 0.000, being less than 0.05 (Kim & Mueller, 1978). The extraction method used was the principal components rotation method: varimax with Kaiser normalization. Factors with an eigenvalue greater than one were extracted (Fabrigar et al., 1999; Hair et al., 2010). The communalities obtained were >0.60, and the factor loading of each variable was greater than 0.5, which are appropriate values (Fabrigar et al., 1999). In addition, each factor is composed of at least three variables (Fabrigar et al., 1999). The variables that make up each factor can be seen in Table 4. The second column shows the number of firms using the variable.

Two factors were obtained from the factorial analysis: the first was made up of internal sources (within the firm or business group), customers, suppliers and competitors, called internal and market sources; the second factor was made up of university sources, research institutes and consultants/private R&D institutes, called science source and consultants.

CFA was carried out to verify that the factors obtained in the EFA have an adequate level of confidence. It was verified that the factor loadings were greater than 0.50. In addition, the average variance extracted (AVE) was obtained: it was greater than 0.50. For the construct internal and market sources, Cronbach's alpha of 0.71 was obtained, and for the construct science source and consultants, Cronbach's alpha of 0.75 was obtained, which are considered appropriate measures of reliability.

Absolute fit indices are applied that indicate the degree to which the model observed in the covariance matrix matches the covariance matrix of the implicit model. Values of RMSEA = 0.056 and SRMR = 0.04 were obtained, indicating an adequate fit of the model.

Table 4: Factor analysis results: principal component analysis

Source of knowledge	Count of firms using it	%	Factor: Internal and market sources	Factor: Science sources and consultants
Internal (within firm or business group)	723	81.87	0.559	
Customers	553	60.36	0.760	
Suppliers	594	67.27	0.575	
Competitors	500	56.62	0.695	
Consultants/Private R&D Institutes	311	35.22		0.638
Universities	238	26.95		0.853
Public research institutes	181	20.49		0.853

In this way, CFA confirms the relationship between the internal and market sources factor and the observed variables—internal sources (within the firm or business group), customers, suppliers and competitors—and the science source and consultants factor and the observed variables—university, research institutes, and consultants/ private R&D institute, which were found in the EFA.

The model was examined for endogeneity, multicollinearity and heteroscedasticity problems. A strong test for non-multicollinearity was used, where VIF values less than 3 were obtained. Pearson correlations between the variables were examined as shown in Table 5: as can be observed, the correlations are very low, less than 0.5. Table 6 shows the results for the bivariate probit regression, where robust errors were used.

Table 5: Pearson correlation between variables

	New-to-firm product innovation	New-to-market product innovation	Internal and market sources	Science sources and consultants	Size of company	Seniority of company	R&D intensity
New-to-firm product innovation	1						
New-to-market product innovation	-0.391	1					
Internal and market sources	0.242	0.048	1				
Science sources and consultants	0.217	0.034	0.363	1			
Size of company	0.117	-0.66	0.090	0.124	1		
Seniority of company	0.144	-0.031	0.039	0.114	0.159	1	
R&D intensity	0.020	-0.028	0.001	0.006	0.013	-0.017	1

4.1 Bivariate Probit Regression

The Bivariate probit regression was performed and the results are shown in Table 6 for both new-to-firm and new-to-market product innovation.

Hypotheses H2b and H3b were accepted. The results indicate that there are two combinations that relate to new-to-market and new-to firm product innovation. The first is internal sources (within the firm or business group) with customers, suppliers and competitors being positively related to new-to-market product innovations. The second is the combination of universities, research institutes and consultants/private R&D institutes that relate to new-to-market product innovation.

Table 6: Bivariate probit regression result

Variables	New-to-firm product innovation (coefficient / robust error)	New-to-market product innovation (coefficient / robust error)
Internal and market sources	0.0338269 * (0.0296087)	0.1380447 *** (0.0290937)
Science sources and consultants	0.0136005 (0.0388761	0.1223177 *** (0.0387637)
Size of company	-0.0002134 * (0.0001136)	0.0001191 *** (0.0000497)
Seniority of company	-0.0021276 (0.0030079)	0.0082319 *** (.0027483)
R&D intensity	-2.245669 * (0.8227837)	1.713224 (2.334411)
Constant	-0.8165912 *** (0.1587103)	-1.759286 *** (0.1642856)
Number of observations	833	
Wald chi2	119.04	
Prob> chi2	0.0000	

*Note: *** p value <0.01, ** p value <0.05, * p value <0.10*

In the first combination, customers play an important role in providing knowledge about their needs that is useful for innovations in product adaptations to the local market; suppliers contribute with technology in the supply chain; and competitors provide market knowledge that they have obtained from their own clients and with product technology. Companies that are part of a business group contribute with knowledge such as R&D results for products in other markets and know-how; they can provide technology and contribute to the company's internal capabilities to develop R&D.

In the second combination, companies combine the knowledge of universities, public research institutes and private R&D consultants or institutes. Universities and public research institutes generate knowledge and technologies. However, companies require consultants/private R&D institutes to help compensate for the company's weaker internal capabilities and help transfer knowledge from universities and public research institutes, while private R&D institutes contribute to the development of R&D activities.

Regarding the control variables, the size of company and the seniority of the company are related to new-to-market product innovation, which is the more elaborate type of innovation, requiring a higher level of knowledge and strong internal capabilities. Larger companies can rely on a greater number of employees who can contribute innovation skills and resources for R&D, affording the company greater innovation capabilities. Meanwhile, older or more established companies have greater internal R&D experience, allowing them to develop greater capabilities and knowledge. They can accumulate knowledge from past R&D projects, thus having greater potential to develop innovations.

There is a negative relationship between the variable size of company and new-to-firm product innovations, implying that smaller firms have a greater capacity to develop this type of innovation than larger firms. This is explained due to large firms could have more complex processes, and could require more complex R&D activities to achieve this type of innovation.

R&D intensity is negatively related to new-to-the-firm product innovation This is explained due to this innovation can be achieved by imitating/adopting products already in another market/country, and through knowledge obtained from competitors, suppliers, or other companies in the business group. In these cases, many R&D activities are simplified and have lower R&D expenses. This negative relationship is interpreted that companies with lower R&D activities/expenses, have a greater capacity to achieve this innovation than other companies that require more R&D for this innovation and that may have higher R&D expenses.

5. Discussion

The objective of this research was to examine the combinations of knowledge sources that influence the degree of novelty or radicalness of innovation in Peru. In line with this objective, the relationship between the sources of knowledge used by the company and new-to-market and new-to-firm product innovation is examined.

The results show two combinations. Firstly, the combination of internal sources (within the company or business group) with the knowledge of customers, suppliers and competitors is related to new-to-firm and new-to-market product innovation. Secondly, the combination of knowledge from universities, public research institutes and consultants/private R&D institutes is related to new-to-market product innovation.

In the first combination, the internal knowledge source (within the company or business group) can contribute with knowledge, know-how and even R&D results from other companies in the group (Hsu et al., 2015; Zhang et al., 2015). Of the companies examined in Peru, 22.3 per cent are part of a business group. Competitors are important as they have knowledge of the market and product technologies, while customers contribute with their needs and their experience with the products. This is complemented by the knowledge of competitors in the market, which is very important, especially for innovations that adapt products for the local market from products that already exist in other markets. Suppliers contribute with knowledge of part technologies.

Regarding the first combination, the results are found to be different from the combinations generally found in developed countries for product innovations and processes innovation, such: internal sources with customers and suppliers (e.g. Chen et al., 2016; Criscuolo et al., 2018; Köhler et al., 2012), internal sources with competitors (e.g. Criscuolo et al., 2018; Rodríguez et al., 2017).

This first combination is similar to the combination of internal sources, customers, suppliers and competitors for product innovation presented by Criscuolo et al. (2018) in the UK, whose authors found other combinations, such as internal with suppliers, competitors and universities; internal with customers, competitors and universities.

Regarding the second combination, the results found are shown to be different from the combinations of knowledge that include universities and research institutes (e.g. Chen et al., 2016; Ruiz-Pava & Forero-Pineda, 2018), since the combinations found include universities, public research institutes and consultants/private R&D institutes. The consultants help compensate for the internal capabilities of the companies, such as absorptive capacity, while private R&D institutes help develop R&D activities.

This research differs from others developed in emerging countries for product innovation, Del Carpio Gallegos & Seclen-Luna (2022) in Peru found the combination of customers, suppliers and competitors, and the combination of universities and research centres. Escorcia-Caballero et al. (2022) in Colombia found combinations of customers, suppliers, companies from other sectors and associations, and the combination of universities, research and productivity centres, business incubators, technology parks and specialized consultants. However, these combinations focus on examining external sources only and are for product innovation (radical and incremental).

The current study also differs from the research by Ruiz-Pava & Forero-Pineda (2018) in Colombia that found an exclusive combination with internal sources; a second composed of customers, competitors, suppliers and firms from different industries; and a third composed of technological development centres, research centres, universities and training centres. However, the research focuses on studying combinations for innovation by type of market, national or international, which is different from the combinations for new-to-firm and new-to-market product innovation. Also, these combinations do not include consultants.

This research contributes in the following ways. Firstly, it provides insights into the combinations that influence the degree of novelty or radicalness (new-to-firm and new-to-market product innovation) for Peru, an emerging country.

Existing theory on knowledge source combinations indicates that companies make combinations influenced by the type of innovation and the firm's internal capabilities (Criscuolo et al., 2018), new-to-market product innovations includes radical innovations that are more complex than those found for product innovations, in addition the companies examined have particular characteristics, correspond mainly to low-technology industries and medium-low-technology industries and have an average of 0.0016 in R&D intensity (R&D expenditure/sales) which implies that they have lower internal capabilities to generate knowledge through R&D.

The existing combinations generally obtained in developed countries can only be generalized to high-tech manufacturing firms from developed countries (Cruz-González et al., 2014) and the combinations found contributes because knowledge about the combinations that influence the degree of novelty or radicalness (new-to-firm and new-to-market product innovation), especially in emerging countries, is still scarce.

Secondly, this research contributes evidence by including in combinations knowledge from other firms in the business group of which the firm is part. Evidence from emerging countries on combinations has generally considered knowledge from internal sources without considering that the company may receive knowledge from other companies in the business group. The Peruvian survey is aligned with the Oslo Manual (OECD/Eurostat, 2018), so it already records internal sources as knowledge within the firm or business group.

Thirdly, the study provides evidence on the role of consultants/private R&D institutes in combinations in emerging countries. In Peru, consultants/private R&D institutes play an important role in new-to-market product innovations: universities and public research institutes generate knowledge, and the role of consultants/private R&D institutes is to contribute to the implementation of knowledge from universities and public research institutes.

The evidence that exists from developed countries has rarely included consultants/ private R&D institutes in combinations for new-to-market product innovations. This is because universities in developed countries play an important role, especially in developing technologies used in radical innovations in high-tech companies. Universities and public research institutes have greater capabilities for technological development, while companies have greater capabilities and resources for directly implementing this knowledge.

Finally, the research contributes because the combinations found represent the external knowledge search strategies employed by these companies and the sources of knowledge they combine to achieve new-to-firm and new-to-market product innovations, which is of practical use to companies and public policymaking bodies.

6. Conclusions

6.1 Theoretical Implications

This research contributes with two combinations of knowledge sources that influence the degree of novelty or radicalness of innovation. The first is the combination of internal sources (within the firm or business group) with customers, suppliers and competitors for new-to-market and new-to-firm product innovation. The second is the combination of universities, public research institutes and consultants/private R&D institutes for new-to-firm product innovation.

The study demonstrates that innovation patterns for new-to-market and new-to-firm product innovation are strongly influenced by firms' characteristics, such as their internal capabilities and their relationships with customers, suppliers, competitors, consultants/ private R&D institutes, and business support institutions such as universities and public research institutes.

Due to their accumulated knowledge and accumulated experience in carrying out R&D, older companies are positively related to new-to-market product innovation. Similarly, larger companies that have the capacity for more resources, such as a greater number of collaborators, and have the skill for innovation are positively related to new-to-market product innovation. This is because new-to-market (national or international) product innovations are more complex, more elaborate, and require a greater amount of knowledge, since they include radical innovations and innovative imitations of products existing in other markets developed for the Peruvian market.

6.2 Practical Implications

This study has practical implications for business administrators and managers that can encourage companies to develop search strategies for external sources—customers, suppliers, competitors, universities and public research institutes, and consultants—in combinations that influence the degree of novelty or radicalness of innovations. Companies can also be motivated to implement key competencies to manage this knowledge to achieve the knowledge required to develop new-to-market and new-to-firm product innovations. The study further encourages companies to increase their investment in R&D development as an important source of internal knowledge and R&D intensity.

The study has practical implications for public policy planners, who can design policies that stimulate universities and public research institutes to improve the generation of industry-specific knowledge and encourage companies to utilize knowledge from universities and public research institutes to increase the generation and use of knowledge that adds value to innovation.

6.3 Limitations and Future Research

The research has limitations due to the temporality of the data. It is suggested that further research be conducted in other contexts and emerging countries to provide evidence of the combinations of knowledge sources that lead to new-to-market and new-to-firm product innovation. It is also recommended that further studies be conducted that examine combinations of knowledge sources over time and their relationship with new-to-market and new-to-firm product innovation. In addition, it is suggested that new studies be developed that expand knowledge on the internal capabilities that influence the company's combinations of knowledge sources.

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