The Role of Knowledge Management in Innovation: Spanish Evidence

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***Abstract*—**In the knowledge-based economy, innovation is considered essential in order to achieve survival and growth in organizations. On the other hand, knowledge management is currently understood as one of the keys to innovation process. Both factors are generally admitted as generators of competitive advantage in organizations. Specifically, activities on R&D&I and those that generate internal knowledge have a positive influence in innovation results. This paper examines this effect and if it is similar or not is what we aimed to quantify in this paper. We focus on the impact that proportion of knowledge workers, the R&D&I investment, the amounts destined for ICTs and training for innovation have on the variation of tangible and intangibles returns for the sector of high and medium technology in Spain. To do this, we have performed an empirical analysis on the results of questionnaires about innovation in enterprises in Spain, collected by the National Statistics Institute. First, using clusters methodology, the behavior of these enterprises regarding knowledge management is identified. Then, using SEM methodology, we performed, for each cluster, the study about cause-effect relationships among constructs defined through variables, setting its type and quantification. The cluster analysis results in four groups in which cluster number 1 and 3 presents the best performance in innovation with differentiating nuances among them, while clusters 2 and 4 obtained divergent results to a similar innovative effort. However, the results of SEM analysis for each cluster show that, in all cases, knowledge workers are those that affect innovation performance most, regardless of the level of investment, and that there is a strong correlation between knowledge workers and investment in knowledge generation. The main findings reached is that Spanish high and medium technology companies improve their innovation performance investing in internal knowledge generation measures, specially, in terms of R&D activities, and underinvest in external ones. This, and the strong correlation between knowledge workers and the set of activities that promote the knowledge generation, should be taken into account by managers of companies, when making decisions about their investments for innovation, since they are key for improving their opportunities in the global market.

***Keywords*—**High and medium technology sector, innovation, knowledge management, Spanish companies.

I. Introduction

THIS paper studies the impact of knowledge management on the innovation performance of high and medium-high technology firms in Spain. Its purpose is to create an analytical framework that will explain different innovating behaviours according to the investment made by companies in knowledge management practices and in their workers' capacities. To do so, it focuses on high and medium-high technology firms which, because they are classified as being technologically innovative, might be more sophisticated in the way they manage knowledge. The empirical analysis was performed using the "Encuesta sobre Innovación en las Empresas 2010" --Survey on Innovation in Business 2010- in Spain, developed by the INE (Instituto Nacional de Estadística) based on answers received from nearly 43,000 firms.

The paper goes on to propose different knowledge management constructs, depending on the origin of the innovation effort (internal and external) and the qualifications of the firm's personnel, as well as an innovation performance construct. Applying SEM methodology in each identified cluster, the cause and effect relationships between the defined constructs are studied, as well as the direct impact of the knowledge management constructs on the innovation performance construct.

The results for each cluster show that in all cases, knowledge workers (qualified personnel) have the greatest impact on innovation performance, regardless of the level of investment made. There is also a strong correlation between knowledge workers and investment in internal knowledge management, essentially represented by investment in R&D, whereas investment in external knowledge has scarcely any impact on innovation performance and is not internalised by the knowledge workers. The authors consider that this article essentially has two contributions to make to the literature. Firstly, it offers an analytical understanding of the innovation performance of companies according to their effort in creating and acquiring knowledge within the framework of cognitive generation and exploration. Secondly, it offers an empirical investigation of the quantitative impact of practices and measures of exploratory knowledge management on the innovation performance of high and medium-high technology Spanish companies.

II. Literature Review

The literature indicates that as well as being a firm's principal intellectual value, effective use of knowledge is of key importance to its competitiveness on the global market [1]-[4]. From the perspective of innovation, knowledge can be seen as the central and inherent element of innovation processes, from the generation, development, implementation and dissemination of new products, services, processes, technologies, organisational structures and business models [5]-[7]. Knowledge management can leverage innovation through the processes of generation, transfer and use of new

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ideas and their business exploitation [8]-[11]. Within this environment, the concept has taken hold of innovation performance, which is defined as being the innovation produced by an organisation, resulting from the generation and commercialisation of ideas in new products, new services and new or renovated organisational processes.

In order to identify patterns of behaviour vis-à-vis innovation performance, a number of sectorial studies have been conducted [12], [13] in different countries, all showing the positive effect of knowledge management on innovation.

III. Framework of Analysis and Hypothesis

The analysis is framed within the input-output model [14], which studies all organisational management processes in terms of the relationship between inputs and outputs. In this case, the inputs referred to are the measures and resources contained within processes of knowledge generation, including knowledge creation and acquisition [10]. The inputs analysed include both internal and external activities, such as investment in R&D activities, people and ICT (information and communication technology), devoted to transforming ideas and knowledge into new marketable products or services. The outputs consist of the commercial return on the innovation. They are quantified in terms of return on investment in innovation, reduction in costs, new patents, conversion of patents into products, increase in market share, etc. [14], [15].

The study focuses on two innovation performances, given their usefulness in explaining the impact on immediate business (return on investment) and their business potential (patent applications filed). Based on these and the inputs analysed, the following proposals are made:

Firstly, it is proposed that the effort in managing activities and subjects for knowledge generation contributes to the capacity to achieve better innovation performance. To examine this, the study will analyse how companies are managing their knowledge, specifically the phase of knowledge exploration and generation, which includes the processes of creation and acquisition of knowledge. In analysing the processes, the typology developed by Grant [16] is partly applied, since it helps to homogenise the set of activities and measures of knowledge management, making the analysis clearer.

- (H.1): The greater the effort in knowledge management activities for innovation in products and processes is, the better the innovation performance is.

Secondly, it is proposed that the practices and measures of knowledge management should be those of generation or exploration, in accordance with the input-output model for measuring innovation performance [14] including both internal and external creation and acquisition of knowledge. The cognitive practices and measures selected are those that: play a central role in the innovation processes; reflect the effort that the company is making for it to result in innovation; can be methodologically quantified and therefore compared *a posteriori*.

Knowledge creation activities oriented towards technological innovation are mainly R&D activities, internal and external ones. At the same time, the knowledge acquisition process includes activities that make it possible to identify, locate, acquire and assimilate the necessary knowledge that is not found in the company [16], [17], such as training and instruction, patents, licences, strategic partnerships [10]. The focus in this study is on training activities and on instruments that help assimilate knowledge such as ICT.

- (H.2): Internal knowledge creation and acquisition activities oriented towards innovation in products and processes contribute positively and significantly to innovation performance.
- (H.3): External knowledge creation and acquisition activities oriented towards innovation in products and processes contribute positively and significantly to innovation performance.

Thirdly, as knowledge subjects, knowledge workers represent a mediating stage between the knowledge management measures taken and the innovation performance obtained, because of their capacity for both knowledge creation and knowledge assimilation and absorption [18]. In this regard, we propose that training of employees is important, both in terms of intensity (educational level) and deployment in the organization (quantity of qualified workers).

- (H.4): The specialisation (qualification level) of knowledge workers contributes positively and significantly to innovation performance.

IV. Research Methodology

The study is essentially quantitative in nature, setting out and assessing [19] the impact that the proportion of knowledge workers and internal and external investment in knowledge for innovation has on innovation performance in the Spanish high and medium-high technology sector. Multivariate and quantitative techniques are applied, since these provide more exact and easily testable results, and offer a more reliable vision of the results by allowing the hypotheses to be tested [20]. These techniques are:

- An analysis of conglomerates to classify the companies into separate groups, in such a way that the components of each group are homogenous and the groups heterogeneous.
- A confirmatory factorial analysis, using the structural equations model (SEM), for each cluster obtained, to determine the nature of the relationship between the workers and the investment in knowledge and the variation in returns on innovation.

The data analysed have been taken from the items referring to the proposed constructs in the INE's innovation survey [21]. This survey has been conducted each year since 1994 among randomly-selected firms from all industries in the Centralised Companies Directory (Directorio Centralizado de Empresas - DIRCE).

Specifically, the survey includes findings on 5,074 Spanish companies from high and medium-high technology sectors (see Table I). For a confidence level of 99%, this sample offers a margin of error of 1.76%, and it is therefore feasible to apply the SEM (structural equations model) [22] to the resulting conglomerates.

TABLE I
HIGH AND MEDIUM-HIGH TECHNOLOGY ACTIVITIES AND SAMPLE DISTRIBUTION

CNAE[1]	Business Activity	%
20	Chemical industry	8.91
21	Manufacture of pharmaceuticals	6.86
26	Manufacture of computer, electronic and optical products	8.23
27	Manufacture of electrical material and equipment	9.14
28	Manufacture of machinery and equipment not elsewhere specified	16,46
29	Manufacture of motor vehicles, trailers and semi-trailers	4.80
302	Manufacture of locomotives and railway material	
303	Aero-space construction and its machinery	
304	Manufacture of military combat vehicles	2.06
309	Manufacture of other transport material not elsewhere specified	
58	Publishing	0.80
59	Cinematographic, video and TV programmes, sound recording and musical publication activities	0.46
61	Telecommunications	1.14
62	Programming, consultancy and other IT-related activities	10.29
63	Information services	0.46
72	Research and development	30.40

The explanatory items or variables selected from the survey are: cost of the internal RDI activities per employee (IDi); cost of the external RDI activities per employee (IDe); cost of training activities for innovation activities per employee (INVFORM); cost of acquisition of other external knowledge for innovation per employee (CEI); cost of activities of procurement of advanced hardware or software for innovation per employee (INVTIC); researchers as percentage of workforce (INVEST); researchers with higher education as a percentage of workforce (INVESU); percentage of workforce with higher education (EDSUP); number of patent applications filed in the two-year period 2008-2010 per employee (PATEN); percentage of turnover from innovation only for the company: (CNIE); and percentage of the turnover from innovation for the market (CNIM). These items have all been analysed according to the total number of employees (ratio per employee). They are reflective and quantitative, making it possible to apply the SEM. They have been handled in the survey in accordance with the procedure proposed by Williams and others [23] to reduce any implicit effect on the interviewee and mitigate the problem of common variance. Based on these items, the following constructs are proposed, on which the SEM modelling and analysis is performed for all clusters:

- Internal investment in knowledge for innovation (DIK), processes of knowledge management intended for acquisition, transmission and generation of knowledge for innovation within the firm (IDi; INVFORM).
- External investment in knowledge for innovation (IIK), acquisition of knowledge or processes and goods intended for subsequent generation of knowledge for innovation (IDe; CEI; INVTIC).
- Innovation performance (IP) includes the impact shown on the organisation's tangible and intangible performance arising from the creation of knowledge transformed into innovation.
- Worker qualification (WQ), as an indicator of the importance that training and specialisation of knowledge workers has on the innovation process.

[1] Clasificación Nacional de Actividades Económicas (Standard Industrial Classification)

A. Statistical Analysis

After a descriptive analysis was performed to provide a picture of the relevant characteristics of the sample, the participating companies were classified into groups using a hierarchical grouping technique [24]. The method used is that of cluster analysis, based on "classified objects" where each object is very similar to the others in the same group" [24, p. 492]. Within this method, the Ward methodology has been chosen because "it is designed to optimise the minimum variance within clusters. This objective function is also known as the within-groups sum of squares or the error sum of squares (ESS)". A SEM analysis was then run to check, firstly, the suitability of the selected variables to explain the proposed constructs, and then the existence of a causal relationship of significant interdependence between the proposed constructs. The selection of this methodology may be justified by the fact that as well as estimating the structural parameters and providing complete, coherent and exact information on their validity, it represents a theoretical relationship of cause and effect [25], specified in accordance with the underlying theory; such that, as states [26], its main advantage is to go from a verbally expressed theory to a mathematically-expressed model. For this reason, these are also called confirmatory analyses, since their chief interest lies in confirming the proposed relations through an analysis of the samples [27].

B. Results

The descriptive analysis of the sample offers information on its composition and distribution, which aids subsequent interpretation of the multivariate results (clusters and SEMs).

Most of the companies surveyed were founded before 2000 (55.9%) and only 26.3% were set up between 2005 and 2010. The group is dominated by SMEs (small and medium-sized enterprises); 60.5% were classified as small companies, 26.1% as medium-sized and 23.9% were large enterprises.

Having determined the characteristics of the sample, the hierarchical cluster analysis was performed and the following four company clusters obtained:

Cluster 1: Contains 623 Intensely Innovative (II) companies, mostly founded between 2005 and 2010 (55.8%), small in size (90.4%) and belonging to Sector 72 (71.5%); the cluster includes no large enterprise and

15.7% of companies were founded prior to 2000. It accounts for by far the largest number of patent applications filed (between 1 and 5 patents per employee), a very high percentage of researchers (more than 70%) and workers with higher education (more than 67%); companies in this group focus on internal and external knowledge creation, giving less importance to its acquisition. On average, over 32% of their turnover comes from innovations that are for the market and nearly 15% from those that are only innovative for the company.

Cluster 2: Makes up more than half of the total sample group. (2,804) They are Low Innovative (LI) and include practically all large companies and companies from CNAE Group 2, as well as most older companies (76.9% incorporated before 2000 and only 9.3% between 2005 and 2010). It is also the group with the lowest proportion of small companies (35%). They file scarcely any patent applications (0.05 on average per employee); less than half of the workforce has higher education (around 38%) and the percentage of research personnel is even smaller (just over 29%). Their investment, somewhat higher than the average for the other clusters, is focused more on internal creation and acquisition of knowledge. On average, around 18% of their turnover comes from innovations that are for the market and nearly 18% from innovations only for the company.

Cluster 3: Made up of 668 Medium Innovative (MI) companies, most are small (89.3%, with only one large company) and from Sector 72 (78.57%) of which 41.4% were incorporated between 2005 and 2010 and 28.6% prior to 2000; they all have one patent application filed per employee; have a high percentage of researchers (nearly 70%) and employees with higher education (about 60%); and acquire hardly any knowledge focusing on its internal and external creation. In these companies, as in the Highly Innovative cluster, somewhat over 32% of their turnover from innovations comes from innovations for the market and only 5.9% from innovations only for the company.

Cluster 4: With 979 companies, Somewhat Innovative (SI), these firms file less than one patent application per employee. Typically, they are small in size (81.7%), although the group also includes the large companies that are not included in Cluster 2. Almost 50% of the workforce is research staff and have higher education. Their level of investment is similar to that of the High and Medium Innovative clusters, although they focus somewhat more on internal generation than on external acquisition. Nearly 26% of their turnover comes from innovations that are for the market and about 15% from those that are only innovative for the company.

The confirmatory structural model proposed (Fig. 1) is to be validated for each of the clusters obtained, to determine whether it is feasible.

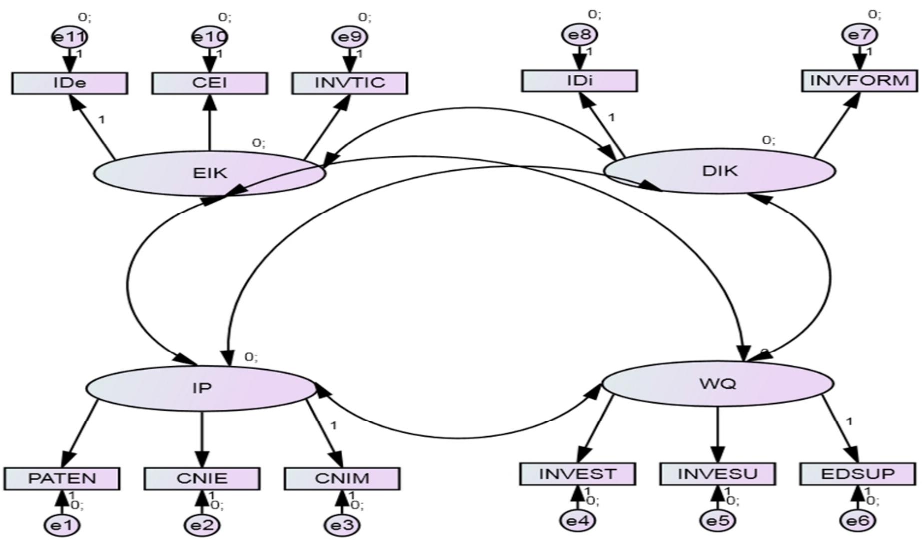

Fig. 1 Confirmatory model of factors of Knowledge Management for innovation –innovation performance

The confirmatory factorial analysis (CFA) offers valid and reliable results for all the variables used and therefore a causal model is proposed for measuring the impact that the constructs of knowledge management (WQ, DIK and EIK) have on the innovation performance construct (IP) (see Fig. 2).

A CFA is again performed to confirm that it has been identified; its indicators are valid and reliable; and the constructs proposed are reliable, valid and consistent.

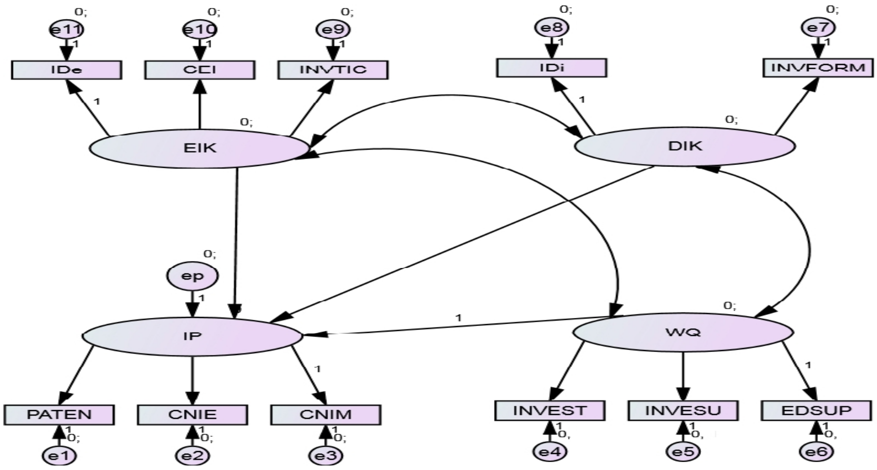

Fig. 2 Cause/effect model of factors of Knowledge Management for innovation –Innovation performance

TABLE II
VALIDITY AND RELIABILITY OF THE VARIABLES BY CLUSTER

	Standardized Regression Weights				C.R			
Variables	II	LI	MI	SI	II	LI	MI	SI
CNIE	0.58	0.36	0.47	0.46				
CNIM	0.71	0.56	0.68	0.75	13.58	14.02	14.23	13.87
PATEN	0.88	0.50	0.84	0.51	14.62	14.75	14.34	14.28
INVEST	0.94	0.93	0.94	0.94				
INVESU	0.96	0.97	0.94	0.95	12.15	12.42	12.81	12.77
EDSUP	0.91	0.91	0.93	0.93	11.66	11.74	11.85	12.00
IDi	0.97	0.98	0.95	0.98	12.29	18.59	12.19	11.71
INVFOR	0.73	0.81	0.81	0.72	15.90	18.13	17.74	15.81
INVTIC	0.86	0.77	0.86	0.87	18.08	17.27	19.03	18.93
CEI	0.39	0.30	0.38	0.33	13.09	15.98	16.36	16.13
IDe	0.94	0.89	0.91	0.88	12.98	16.36	16.27	16.45

The standardised weights are in most cases greater than 0.40; dispensing with weights of less than 0.40 does not provide better results and the variables are sufficiently significant to be maintained in the model. Moreover, all critical coefficients (C.R.) are over 1.96 (Table II), and are therefore valid [24].

TABLE III
RELIABILITY AND CONSISTENCY OF THE CONSTRUCTS

	Composite reliability				AVE			
Constructs	II	LI	MI	SI	II	LI	MI	SI
DIK	0.93	0.94	0.94	0.92	0.89	0.91	0.86	0.85
EIK	0.90	0.75	0.87	0.89	0.76	0.64	0.72	0.67
WQ	0.98	0.96	0.97	0.99	0.77	0.72	0.82	0.77
IP	0.92	0.91	0.93	0.90	0.72	0.76	0.71	0.77

The reliability of indicators and constructs has been measured using the coefficients of composite reliability, because it does not depend on the number of attributes associated with each concept, and with the variance extracted (AVE) which provides information on the consistency of the constructs (Table III).

The coefficients of composite reliability score over 0.70 and the AVE are, for all constructs, higher than 0.50 [24], [28], and the CFA model is therefore acceptable, making it possible to pass on to an analysis of the structural model.

The goodness of fit of the model is now analysed using the Chi-square statistic. However, because this index is very sensitive to the sample size, other absolute indices are taken into account such as the RMR (average value of all the standardised residues or errors), and the RMSEA (discrepancy of the model by degrees of freedom). The CFI relative index proposed by [29] is also applied, since it takes into account the sample size; its threshold value for judging the proposed model to be a good fit is 0.95 [30].

As can be seen in Table IV, the statistics indicate that this model shows a good goodness of fit, except the Chi-square because of its sensitivity to the sample size. Moreover, factor IKM significantly influences innovation performance (IP) for all clusters and explains, except in the case of low innovative organisations, more than 25% of their variance (see Table V).

TABLE IV
OVERALL FITS OF THE STRUCTURAL MODEL

Fit	II	LI	MI	SI
χChi-square	136.62	139.28	139.98	187.27
df	39	39	39	39
RMR	0.04	0.04	0.03	0.04
RMSEA	0.03	0.03	0.03	0.04
CFI	0.92	0.98	0.98	0.97

TABLE V
IMPACT OF THE FACTORS ON THE RESULTS AND PERCENTAGE OF THE VARIANCE EXPLAINED

	Impact of EIK, DIK Y WQ on IP				Percentage variance explained			
	II	LI	MI	SI	II	LI	MI	SI
EIK	0.06	0.03	0.05	0.01				
DIK	0.68	0.16	0.66	0.29	0.76	0.21	0.38	0.26
WQ	0.76	0.63	0.74	0.66				

TABLE VI
CORRELATION BETWEEN CONSTRUCTS OF KNOWLEDGE MANAGEMENT

	II	LI	MI	SI
EIK ⟷ WQ	0.12	0.22	0.35	0.13
DIK ⟷ WQ	0.58	0.54	0.69	0.68
DIK ⟷ EIK	0.26	0.25	0.42	0.20

As for the interdependence between the constructs of knowledge management, it is significant in all cases, with a particularly important correlation between DIK and WQ (see Table VI). Therefore, the validity of the model to explain the impact of knowledge management for innovation on innovation performance and the interdependence between the different activities of knowledge management is confirmed.

C. Interpretation of Results

The clusters obtained indicate that the companies that obtain the best innovation performance in terms of both patents and income from innovation are those that have a larger percentage of qualified employees and which devote their efforts more towards the creation of knowledge for innovation, thus confirming H.1, since the level of acquisition of knowledge is similar in all of them. This is ratified by the causal model, where it can be seen that the direct impact on results of the constructs of knowledge management is greater the more innovative the organisations are; significantly 76% of variance in innovation performance is explained by these constructs.

The variables in the internal investment in knowledge construct show very high variable loads. It should be noted that in all cases, values of over 0.9 were reached by the variable of knowledge creation (IDi), making it the most explanatory variable of this construct. This and the fact that its impact on innovation performance is positive, significant and higher the more intensely innovating the set of companies is makes it possible to confirm H.2, except in the case of the low innovating companies, where although the impact is significant, it is very low.

As regards external investment in knowledge, the fundamentally explanatory variable is external knowledge creation (external R&D), with knowledge acquisition having very little weight (less than 0.4). Likewise, its impact on innovation performance is insignificant in all cases (except in the case of medium innovative companies where it is below 0.07) and therefore H.3 must be rejected.

The qualification level of workers –researchers and non-researchers– is the most significant construct for all clusters; its variables have a very high explanatory power (greater than 0.9 in all cases), and its impact on innovation performance is the highest and most significant of all the proposed constructs (over 0.6 in all cases) and therefore H.4 is confirmed.

V. Discussion and Conclusions

The results set out in the Section III.B indicate that, in the case of Spanish High and Medium-High technology companies, knowledge management through staff qualification and the creation and acquisition of knowledge for innovation has a positive levering effect on business exploitation, measured through their innovation performance.

Highly-qualified personnel are the elements that generate the most important positive effects on innovation performance. This is because as knowledge subjects, they convert tacit knowledge into explicit knowledge, in a process of continuous feedback [7] which generates learning environments that favour processes of knowledge creation for innovation [31]. In turn, they focus innovation on internal knowledge creation for the generation, development, implementation and dissemination of new products, services, processes, technologies, organisational structures and business models [6], [7], opting to a lesser extent for external knowledge creation and to a very small degree for acquisition of knowledge.

All of the foregoing contributes to an analytical understanding of the innovation performance of the sector according to the effort made in personnel qualification, and in the creation and acquisition of internal and external knowledge.

Based on the foregoing, it is concluded that Spanish high and medium-high technology firms are clustered around the volume of intangible outputs (patents per employee) and the percentage of research staff and qualified personnel, independently of their internal R&D activities. This suggests that the hiring of research staff and personnel with higher education has an impact on ensuring the success of knowledge management for innovation. In this regard, full consistency can be seen between these staff-based variables and the variables on internal investment in knowledge, since the personnel variable with the greatest weight is that related to research personnel while the variable of internal investment with the greatest weight is that related to internal R&D processes. On the contrary, expenditure in acquisition of internal knowledge (training) and external knowledge (knowledge and ICT) is very low, as well as the investment in knowledge creation and external knowledge (external R&D). As a consequence, the weight of external investment in knowledge is minimal, as it is its correlation with the other constructs of knowledge management and their impact on innovation performance. At the same time, the strong correlation between knowledge workers (qualified personnel) and the set of activities that promote the creation and acquisition of internal knowledge should be taken into account by company managers when making decisions on investment for innovation, given that a lack of investment in training activities that promote the transfer, generation and improvement of knowledge is reducing their opportunities for improvement on the market.

To conclude, this work makes a new contribution on the patterns of behaviour with regard to innovation performance, complementing other sector studies carried out in Spain [32] and elsewhere [12], [13], and gives further proof of the positive effect of innovation knowledge management.

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