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THE MEDIATING EFFECT OF FIRM'S R&D COLLABORATIONS ON THEIR INNOVATIVE PERFORMANCE

There is the need for firms to engage in R&D collaborations with different partners because these collaborations enable them to acquire new knowledge and technologies thereby increasing their innovation capabilities. These innovative collaborations are known to increase firm's innovative performance, but the extent of the increase is not known. The main objective of this paper is to empirically examine the mediating role of firm's R&D collaborations and its influence on their innovative performance. To fulfil this objective, we used the Structural Equation Model and firm-level data from the Eurostat Community Innovation Survey (2010-2012). Our results have demonstrated that firms R&D collaborations was a statistically significant determinant that played a full mediating role in contributing to increase firm's innovation performance by 27%. Our results have demonstrated that firm's innovation collaborations rather had a weaker effect on their innovation performance. Additionally, knowledge sources also influenced firm's collaborations, it had a stronger effect. Conversely, knowledge sources were not statistically significant in influencing firm's innovation performance, it rather had an unsubstantial effect on innovation performance.

Keywords: *Innovation, innovation performance, knowledge, R&D collaborations, Spain*

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1. Introduction

These days, firms have come to the realization that they cannot innovate single-handedly, this has made them to establish and deepen their formal networks with partners such as clients and customers, market rivals, universities and other government research institutions (Amara & Landry, 2005). These innovative interactions are paramount in helping them remain competitive as well as boosting both the regional and national innovation systems. Knowledge and innovation have become the big push for firms as this drives their competitiveness and improved innovation performance. It is therefore not surprising that the contribution of knowledge to the productivity of firms has gained lofty attention in the knowledge-based economy due to knowledge spill overs and its impact on economic and firm growth (Fischer & Varga, 2003; Bellucci & Pennacchio, 2016). The investment in human capital and the accumulation of knowledge has become a vital factor of production that increasingly contributes to firm's productivity and growth (Odei & Stejskal, 2018).

Firms can acquire knowledge and innovations from internal sources (within the firm's own confinements) or from other external sources (collaborations with other entities) (Grigoriou & Rothaermel, 2017). Internally, firms can acquire knowledge mainly through constant in-house R&D activities such as training and upgrading of employees' skills. Developing employee skills represent a vital source of novel knowledge for firms, and they put in lots of internal measures such as internal training and education programs aimed at developing and recuperating the internal knowledge foundations.

Firms' innovation collaboration has also become very imperative because it is one of the key sources of external knowledge (Stejskal et al., 2018). Collaborations within the market (inter-firm) and firm' collaborations with institutions such as universities and other private and public research organizations has ballooned in recent decades. These institutions are the birthplaces and hubs of knowledge and information, so firms stand to benefit when they form synergies with them (Anderson & Odei, 2018). The national innovations systems lay emphasis on the regular interactions among different collaborators such as firms in the enterprise group, universities and governments as this can boost competitiveness and innovations in firms (Wu et al., 2017).

In this paper we focused on the manufacturing sector in Spain which is the most important sector accounting for about 82 percent of total production, with the automobile industry playing a kernel contribution to GDP. Numerous studies have shown that the Spanish manufacturing firms collaborate with other partners for their innovations (Vega-Jurado et al., 2009; Nieto & Santamaría, 2010; Soto-

Acosta et al., 2016; Martinez-Conesa et al., 2017). We therefore aim to examine whether firms in the manufacturing sector's innovations collaborations have an impact on their innovations performance which we measured using the proportion of sales coming from new products. We chose the manufacturing sector because this sector is known to consist of diverse companies such as knowledge and technology intensive firms that require new knowledge to thrive and are therefore likely to collaborate with other partners and institutions like universities, research organizations among others.

The rest of our paper is structured into five sections. The next section is on theoretical background on firm's collaborations and their sources of knowledge and information. Section 3 elaborates on the methodology describing the source of data and method used for our empirical analysis. Section 4 focuses on the empirical results, while section 5 contains discussions and conclusion with some policy implications.

2. THEORETICAL BACKGROUND

Endogenous theories of economic growth rose to prominence based on its focus on the role played by knowledge in countries and firms growth process (Aghion et al., 1998). The increasing attention given to knowledge spill overs has drifted scholarly attention to the sources of knowledge and innovation. Firms collaborations are now seen as new ways for them to gain, absorb and assimilate knowledge a vital input for innovation. Firms cooperate with other social entities for knowledge, information and innovation. These innovative collaborators are the sources of knowledge for firms and these collaborations allow them access to this vital economic resource (knowledge). From the innovation standpoint, novel knowledge is churned out of the interactive learning process, when firms engage in R&D collaborations with other economic entities (Henttonen et al., 2016).

Firms enter into R&D cooperation for their internal and external knowledge and information vital to sustain them in the intense market competition they face from their rivals. For external knowledge, firms can enter into innovative synergies with higher educational and research institutions (universities, private and public research centres), as well as partners from the market such as suppliers, clients and customers as well as with their market rivals. A study by Belderbos et al. (2015) concluded that firms need to incessantly cooperate with other external partners such as competitors, customers, suppliers and other private as well as public research institutions to better their innovative performance. Universities (other public and private research institutes) are the innovations and learning hubs producing

and diffusing knowledge in the domestic and global research network. Universities produce and make scientific insight available to firms for further adoption and development. A study by Prokop et al. (2018) concluded that firms valued their cooperation with universities as indispensable and beneficial for their general innovation performance.

Suppliers of equipment, materials, components, or software have also become an all-important collaborating partner which firms can partner for their innovations (Un & Asakawa, 2015) and they can bring important insight into the organization of production, logistics and other functions. Their role is increasingly metamorphosed from supplying firms with heavy machinery and equipment to providers of advanced technologies, knowledge and innovation. They assist firms to modify their product characteristics and this helps firms to improve their production processes. Suppliers disseminate knowledge in harmony with firm modus operandi (Robson & Haigh, 2008). When a new and sophisticated technology is introduced by manufacturers, suppliers offer training for firms on how to use these technologies and machines (Lager, 2016).

Clients and customers from both the public and private sectors also provide knowledge on their choices and preferences and this informs firms' production decisions. User-producer intercommunication is pivotal to collaborative learning within innovation development (Baldassarre et al., 2017). Customers' interactions with producers accelerate the production of improved products and services that can have towering commercial success and worth (Poetz & Schreier, 2012). They can voice out their likes or otherwise of product designs and the listening producer will have no option than to meet their (customer) demands. This makes them reliable sources of knowledge for firms. Producers can in the end incorporate customers' needs and preference in their production, design and packaging of their products.

Firms can also collaborate with their competitors for their knowledge. Firms have the incentives to be innovative when they are in a very competitive environment. Intense market competitions from other market rivals pushes them to adopt modern methods of production to stay ahead of their competitors and expand and lead the market (Lau & Lo, 2015). Competition is therefore one of the main drivers of firm's innovation (Plummer & Acs, 2014). In highly competitive and open markets, firms are compelled to espouse efficient production techniques that will make them offer improved products and services to their customers. According to Carlin et al. (2004), competition (competitors) have a positive impact on innovations, as this is akin to believe that firms are inherently less probable to innovate if they are not spurred by their competitors.

Firms collaborations with external management consultants who offer them with expert advice has also become a reliable conduit of innovation within the firm-level (Back et al., 2014). Consultants and consultancy firms are instrumental

in expediting innovations because they act as channels for external knowledge by providing firms with information about clients' taste and preferences (Thrift, 2005). Additionally, they aid firms to improve their branding and design to make them more appealing to their customers. They also provide firms with market research on how to produce new products and services that can satisfy customers' needs and demands. A study conducted by Bruhn et al. (2018) concluded that external consultants can help to improve innovations and productivity in small and medium-scale enterprises.

The main objective of this paper is to examine the influence of mediating role of firm's collaborations for knowledge and their effect on their innovation performances. We are convinced that knowledge sources are important assets for firms, but less is known about how they can influence firm's innovation performance. This paper seeks to fill this gap, and also contribute to the increasing literature on firms-level innovations.

3. SOURCES OF DATA AND METHODOLOGY

For our empirical analysis, we used secondary data from the Eurostat Community Innovation Survey (CIS) conducted between 2010 and 2012. We resorted to using the old instead of the new data sets because, the current data has no information on firm's sources of knowledge for innovations and so was not beneficial for our analysis. The CIS is a harmonised survey of innovation activities in enterprises conducted every two years. The harmonised survey provides detailed data and information on businesses innovativeness and the various activities that influence these innovations such as types of innovation they carry out, sources of knowledge and information, firm's collaborations with other actors, their sources of innovation funding and expenditures. The CIS has increasingly become the source data for studying and analysing firm level innovation.

To achieve our objective, we included in our empirical analysis all firms in the manufacturing sector, both large firms and Small and Medium Enterprises (SMEs). We considered 12,178 innovative enterprises in the manufacturing sector in Spain that had carried out innovation activities during the period 2010-2012. For this study, we considered firms in our target population all enterprises in the core NACE categories 10-33 that had at least 10 or more employees. Our target group also consisted of enterprises that had on-going and abandoned innovation activities. Many studies have used the CIS data to measure firm-level innovation (see Grillitsch et al., 2017; Bocquet et al., 2017).

3.1 Partial least squares structural equation model

The partial least squares structural equation modelling (PLS-SEM) was used for our analysis to explore the conceptual relationship among the theoretical constructs. We performed the modelling by using the Adanco software. The PLS-SEM is an iterative estimation method that combines multiple regression with principal components analysis (Wold et al., 1984). The PLS-SEM is able to model latent variables, to consider various forms of measurement errors, and to test entire theories makes it useful for our research (Henseler & Dijkstra, 2015). The PLS is a covariance-based structural model that uses regression or path coefficients to examine the relationships amongst observed theoretical constructs (Reinartz et al., 2009). The structural equation model is often depicted and visualized graphical with path diagrams. It is the method of choice when dealing with hypothesized models consisting of multiple exogenous and endogenous latent variables in a solitary structural model (Kock, 2014).

Additionally, we used the bootstrapping algorithm to evaluate the model's parameter estimates and standard errors with 5,000 bootstrap samples in 6 iterations (Streukens & Leroi-Werelds, 2016; Nitzl et al., 2016). The latent variable scores of our model was computed to ensure that our indicators reliability estimates and r-square of the latent variable were fully maximized (Fornell & cha, 1994). The PLS model was preferred for our analysis because of the explanatory nature of this study. Explanatory studies help to establish the relationship that exist between constructs, therefore they can be used for studies that intend to find the relationship between variables.

3.2 Model Evaluation

We measured the model's internal consistency and reliability using the composite reliability which is the recommended technique to deal with reflective measurements (Hair et al., 2009). Researchers and scholars are now increasingly resorting to the use of the composite reliability method of Dillon-Goldstein's rho (Jöreskog's rho (ϱc), with values equal to or more than 0.70 indicating acceptable reliability, with the maximum threshold of 1 (Werts et al., 1974; Chin, 1998). Unlike the Cronbach's alpha, Dillon-Goldstein's rho does not presuppose that each items scale constituent is of proportionate significance, because its assumptions are modelled on factor loadings in lieu of the correlations amongst items, this therefore makes it a more accurate reliability measure (Vinzi et al., 2010). From table 1 below, all our constructs achieved values greater than the acceptable 0.7 threshold.

Table 1

EXPLANATION OF LATENT VARIABLES

Latent variables	Indicators	Jöreskog's rho (ϱ_c)
Sources of knowledge (SK)	Within the enterprise or enterprise group (SENTG) Suppliers of equipment, materials, components, or software (SSUP) Clients or customers from the private sector (SCLPR) Competitors or other enterprises in your industry (SCOM) Consultants and commercial labs (SINS) Universities or other higher education institutions (SUNI) Government, public or private research institutes (SGMT) Conferences, trade fairs, exhibitions (SCON) Scientific journals and trade/technical publications (SJOU) Professional and industry associations (SPRO)	0.946
R&D collaborations (R&D COLL)	Other enterprises within the enterprise group (CO11) Suppliers of equipment (CO21) Clients or customers from the private sector (CO311) Clients or customers from the public sector (CO321) Competitors or other enterprises (CO41) Consultants and commercial laboratories (CO51) Universities (CO61) Government, public or private research institutes (CO71)	0.845
Innovation performance (INN_P)	Proportion of growth of total turnover between the years 2010 – 2012	1.000

Source: Author's calculations

Also, for the discriminant validity, the Fornell-Larcker criterion was used (Fornell & Larcker, 1981; Hair et al., 2006). The Fornell-Larcker criterion assumes that all the construct's average variance extracted (AVE) needs to be higher than the squared inter-construct correlations of all the model' constructs. As can be seen from table 2 all our latent variables have values surpassing the highest correlation coefficients indicating that our variables had no issues with multicollinearity.

Table 2

INTER-CONSTRUCT CORRELATIONS OF LATENT VARIABLES AND SQUARE ROOT OF AVES

Constructs	**SK**	**R&D COL**	**INN_P**
SK	0.6353		
R&D COLL	0.2687***	**0.4109**	
INN_P	0.0062***	0.0206***	**1.0000**

Source: Author's calculation, Significance at *** p<0.001.

Note: Squared correlations; AVE are shown in the diagonal.

Table 3 also shows information about the cross loadings matrix which provides information about the correlations among indicators and their corresponding constructs. Authors such as Gorsuch (1974) have suggested that loading values of equal to or greater than 0.40 are acceptable, but values less than this threshold need to be eliminated from the model. From table 3, it is also evident that all loadings are higher than 0.5 demonstrating acceptable convergent validity of all latent variables (Hair et al., 2009)

Table 3

COMBINED CROSS LOADINGS

Indicator	SK	R&D COL	INN_P
SENTG	**0.7792**		
SSUP	**0.7910**		
SCLPR	**0.8192**		
SCOM	**0.8056**		
SINS	**0.7954**		
SUNI	**0.7389**		
SGMT	**0.7787**		
SCON	**0.8287**		
SJOU	**0.8338**		
SPRO	**0.7959**		
CO11		**0.5205**	
CO21		**0.6743**	
CO311		**0.6753**	
CO321		**0.4856**	
CO41		**0.5594**	
CO51		**0.6997**	
CO61		**0.7202**	
CO71		**0.7408**	
INN_P			**1.0000**

Source: Author's calculations

3.3 Descriptive statistics

Table 4 present the basic statistics of the variables used in our empirical analysis. The descriptive statistics show that manufacturing firms in Spain mainly acquire their knowledge from the enterprise group. Furthermore, when it comes to innovation collaborations, our results have shown that they are at low levels, but for firms that opt to collaborate are more probable to do so with scientific institutions such as government or private research institutes. Our results cognate with that found by other authors (Castro & Fernández, 2006; Vega-Jurado et al., 2008). Our results have also shown that on average, the turnover made by these firms is 31, 221 Euros.

Table 4

DESCRIPTIVE STATISTICS

	Variables	Mean	Standard deviation
Knowledge sources	SENTG	2.27	0.995
	SSUP	1.57	1.08
	SCLPR	1.54	1.16
	SCOM	1.15	1.05
	SINS	1.02	1.04
	SUNI	0.703	0.971
	SGMT	0.910	1.07
	SCON	1.06	1.01
	SJOU	0.896	0.927
	SPRO	0.788	0.898
R&D collaborators	CO11	0.040	0.197
	CO21	0.068	0.252
	CO311	0.049	0.217
	CO321	0.010	0.101
	CO41	0.030	0.172
	CO51	0.048	0.213
	CO61	0.060	0.236
	CO71	0.083	0.276
Innovation performance	Turnover (average)	31,221 €	

Source: own calculations

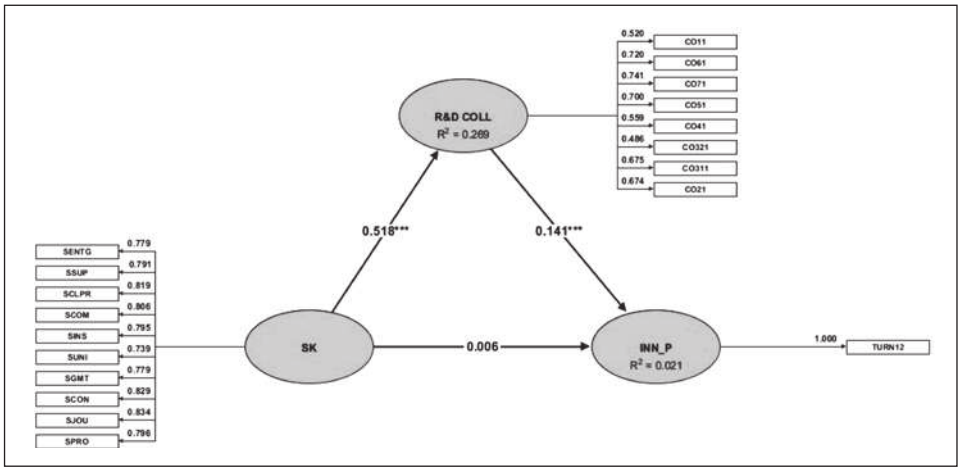
4. RESULTS AND DISCUSSIONS

Our study is founded on the assumption that when firms engage and form alliances with other partners, it can help soar their innovation performance as seen from the literature. With this assumption in mind, we used the structural equation model as the analytical tool to test this assumption. Table 5 and Figure 1 below represents the structural model showing the path coefficients, R-squares, effects size and the p-values of the model estimates. First, the coefficient of determination (R^2) which quantifies the percentage of variance between the endogenous variable and the independent variables is 0.27. This implies that Spanish manufacturing firm's collaborations with other entities and institutions significantly influenced their innovation performance. Over all it accounted for 27% of the gross variation in the collaborations latent variable, it had the strongest effect among all the latent variables (0.37). Additionally, the dependent variable also had a low coefficient of determination of 0.02 demonstrating a low explanatory propensity.

Firms collaborations was statistically significant in influencing their innovation performance. Notably, the positive and significant total effect of 0.141 ($p < 0.001$) for R&D Coll as a mediator variable means that it really played a full mediating role between sources of knowledge (SK) and innovation performance (INN_P). However, this effect is relatively weak. The weakness can be attributed to the fact that the levels of R&D collaborations in Spain is low and not all firms have fully embraced forming synergies with other partners (see Guisado-González et al., 2018). Our results show that cooperation is an essential determinant for Spanish manufacturing industries innovation performance. This suggest that firms can improve their innovation performance and competitiveness when they form synergies with knowledge and research institutions such as universities and other public or private outfits in their locality or even from abroad. This affirms the claim that industries cannot innovate in isolation but need the aid of other entities. Our result is akin to other studies which have proven that firms R&D collaborations boost their innovation performances (Kang & Park, 2012; Un & Asakawa, 2015; Chesbrough, 2017). Firms' collaborations with universities and other public research centres can provide them with vital feedback, knowledge and information that can help them to improve upon their current production, designs and marketing.

Figure 1

STRUCTURAL MODEL



Source: Author's calculations, Note: significant at *** p<0.001.

Additionally, firms' sources of knowledge and innovation influenced their collaborations and their choice of collaborators. The numerous sources of knowledge and information available to firms have all demonstrated to have a positive and statistically significant relationship or influence on firm's R&D collaboration ($\beta = 0.518$, $p < 0.01$). It can also be seen that it has the highest coefficient of 0.518. Knowledge sources produced the strongest effect among all the latent variables under consideration with an f^2 of 0.367 according to the Cohen's criterion.

Conversely, knowledge sources were found to be positive and statistically significant in influencing firm's innovation performance directly. Among all the latent variables under consideration. As shown in table 5, it can be evidenced that knowledge sources had the lowest beta ($\beta = 0.006$, $p < 0.001$), yet it had a positive influence on innovation performance. It rather had an indirect effect on innovation performance with an indirect effect of (0.073), as well as total effect of (0.078). Knowledge sources had an unsubstantial or practically zero effect on innovation performance $f^2 = 0.000$. The reason for the weak effect between knowledge sources and firm's innovation can be attributed to firms having low or weak absorptive capacity, they are unable to recognize novel external knowledge and information, hence they are not able to assimilate, transform and appropriate such internal and external knowledge in their processes and products production (Cohen

& Levinthal, 1990). Our result is akin to other studies on the Spanish manufacturing firms (Vega-Jurado et al., 2009; Duysters & Lokshin, 2011). Similarly, in a related study of Italian manufacturing firms, Paula and Silva (2017) came to the same conclusion which is akin to ours: knowledge sources weakly contributed to Italian manufacturing firm's innovation performance.

Table 5

PATH COEFFICIENTS FOR LATENT VARIABLES

Effect	**Beta**	**Indirect effects**	**Total effect**	**Cohen's f^2**	**Interpretations**
SK -> R&D COLL	**0.518*** (0.007)**	N/A	0.518	0.367	strong effect
SK -> INN_P	0.006 (0.026)	0.0729	0.078	0.000	unsubstantial effect
R&D COLL -> INN_P	**0.141*** (0.021)**	N/A	0.141	0.015	weak effect

Source: Author's calculations

Note: significant at*; p<0.05, **; p<0.10, ***; P<0.001. Robust standard errors in parenthesis.

5. CONCLUSION

The results of our empirical analysis have revealed that Spanish manufacturing firm's collaborations with other firms and institutions can increase their likelihood of having heightened innovation performance. As seen from the analysis, R&D collaborations played a full mediating effect in influencing firms innovation performance. The implication here is that when firms engage in collaboration with any possible collaborator, it is likely that they will increase their innovation performance by 27%, although this is a statistically significant, and positive, its influence can be said to be not so huge. Firms search for knowledge and innovation influenced them to collaborate in this regard to meet this all-important objective. This is visible in the positive and significant relationship between knowledge sources and collaboration. Without collaborations this would have been non-existent. With regards to the relationship between knowledge sources and firm's innovation performance, this study showed that it rather influenced it positively, but the linkage is

weak ($\beta = 0.006$). The weaker bridge between knowledge sources and innovation performance can be attributed to weaker absorptive capacity among firms.

Furthermore, it can also be seen from the empirical analysis that sources of knowledge (SK) had the strongest effect on firms R&D collaborations with an effect size f^2 of 0.367. This implies that knowledge sources had the greatest magnitude of influencing firm's collaborations. Similarly, sources of knowledge and innovation available to firms rather had an unsubstantial effect on their innovation, with this magnitude, it can be said that sources of knowledge were not so important determinant influencing Spanish manufacturing firm's innovation performance ($f^2 = 0.000$). Lastly also, R&D collaborations also had a weak effect on firm's innovation performance ($f^2 = 0.015$). This can be inferred as the innovation performance also depends on other factors that were not considered in this study.

This study warrants both theoretical and practical policy implications for innovation managers, government and the businesses. Theoretically, this article contributes to closing the gap in the existing literature on explaining the mediating role of firm's collaborations with different collaborative partners and how they influence firm's innovative performance. Majority of research within this area narrowly focused on just university-industry partnerships while almost ignoring the other most important collaborators available for firms to cooperate with. By focusing on all the most important collaborating partners available for firms, this paper has been able to demonstrate that firms can chose to partner not only universities for their innovations but the other partners especially those from the market environment also matter for their innovation performance. This article highlights that firms can improve their innovation performance by having diverse collaborative arrangements. This finding is quite interesting because it shed more light on the relevance of firm's collaborations with knowledge institutions as well as with market partners, therefore its forthright to present in theoretical terms.

From the practical perspective, our study calls for innovation policies to be drawn towards incentivising firms to interact with other collaborators in the market as well as with institutions such as universities and other public research institutions if they want to achieve sustainable innovation performances. This can be materialized if the Spanish government could provide industrial R&D subsidise and innovation funding to invigorate and spur innovation. Tax holidays can also be provided to industries that have the potential to innovate to enable them grow and remain operational. Additionally, from the firm's perspective, to have a higher absorptive capacity, they will need to engage highly skilled human capital in the activities of the organization. They can therefore partner with higher educational institutions and other innovations hubs to meet their skilled manpower needs. The government can also play an instrumental role in this regard by constantly reforming educational policies to suit the interest of industries.

Admittedly, this research is constrained by certain potential limitations that could limit its use for absolute generalisation due to its sole focus on just the manufacturing industries in Spain. Again, we admit that our data set is not current, and our results might not provide a true reflection of the current situation about Spanish manufacturing firm's collaborations and its influence on their innovation performance. We therefore recommend further studies using new datasets and fully incorporate all sectors of the Spanish economy to point out the variations in collaborations and innovation performances that will exist.

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POSREDNI UČINAK SURADNJE NA ISTRAŽIVANJU I RAZVOJU NA INOVATIVNE PERFORMANSE PODUZEĆA

Sažetak

Važno je da poduzeća uspostave suradnju u istraživanju i razvoju s različitim partnerima jer im ta suradnja omogućuje stjecanje novih znanja i tehnologija, čime povećavaju svoje inovacijske sposobnosti. Poznato je da ovakve suradnje povećavaju inovativne učinke tvrtke, ali opseg povećanja nije poznat. Glavni cilj ovog rada je empirijski ispitati posredničku ulogu istraživačke i razvojne suradnje tvrtke i njezin utjecaj na njihovu inovativne učinke. Kako bismo ispunili ovaj cilj, koristili smo model strukturnih jednadžbi te podatke na razini poduzeća iz Eurostatove ankete o inovacijama u zajednici (2010.-2012.). Naši rezultati pokazali su da je suradnja poduzeća u području istraživanja i razvoja bila statistički značajna odrednica koja je imala punu posredničku ulogu pridonoseći povećanju inovacijskih učinaka tvrtke za 27%.Naši rezultati pokazali su da je inovacijska suradnja poduzeća prilično slabije utjecala na njihovu inovacijsku učinkovitost. Uz to, izvori znanja također su također utjecali na suradnju poduzeća, što je imalo jak utjecaj. Suprotno tome, izvori znanja nisu bili statistički značajni na utjecaj na inovacijske performanse poduzeća, točnije imali su nebitan učinak na inovacijske performanse.

Ključne riječi: Inovacije, inovacijske performance, znanje, I&R suradnja, Španjolska