Relatedness in the adoption of different innovation types: product, process, organizational and commercial innovations

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Abstract:

The paper analyses the relatedness or interrelations in the joint adoption of different types of innovation (product, process, organizational, and commercial). We study the relatedness in the adoption of two innovation types and how it could be conditioned by the presence/absence of the remaining innovation types. In order to do this we develop a new methodological approach for testing conditional relatedness. The empirical study uses the Spanish Community Innovation Survey (2008-2014). Our results show that, contrary to the traditional approach that suggests a strong relatedness between product and process innovations, this is the less intense link found. Our empirical approach also allows us to confirm that product innovation emerges as a fundamental axis in the innovation strategy because the more intensively used innovation strategies are those combining product innovation with any other innovation type in absence of the rest and those combining any of the other three innovation types in presence of product innovation. These results provide implications for further research, top management and innovation strategy development.

Key words:

Product innovation; process innovation; organizational innovation; commercial innovation; adoption; relatedness

JEL codes: M20; O31

1. Introduction

Within the innovation management literature, recent theoretical (Hullova et al. 2016) and empirical (Carboni and Russu 2018) research has increasingly recognized that firms usually adopt different innovation types simultaneously rather than in isolation. This simultaneous adoption can be justified by different reasons (Battisti and Iona 2009; Ballot et al. 2015): First, it may be due to the search for efficiency in the use and exploitation of resources through the acquisition of synergies (Battisti and Stoneman 2010). Second, it could respond to motivations such as imitation or fashion (Damanpour 2014). Third, it could simply be driven by the characteristics of top managers and the presence of favourable conditions in the financial and economic spheres (Battisti and Iona 2009). Consequently, studies that focus on the adoption of only one innovation type, which are the most frequently explored in the literature, can be misleading (Battisti and Iona 2009).

Although several papers have confirmed the relatedness or interrelations in the joint adoption of different innovation types -in what some authors have also called complementarities in use (Ballot et al. 2015, Hullova et al. 2016), while others speak of coexistence in the adoption of innovations (Vega-Jurado et al. 2009)- previous research represents an incomplete picture of this issue (Battisti and Iona 2009; Damanpour 2014; Ballot et al. 2015), by several reasons.

First, previous research reveals a main focus on the joint adoption of more traditional forms of innovation, in particular product and process innovations (i.e. Damanpour and Gopalakrishnan 2001; Reichstein and Salter 2006; Martinez-Ros and Labeaga 2009; Barge-Gil et al., 2011; Hervas-Oliver et al., 2015). Studies that analyze relatedness between the remaining innovation types defined in the Oslo Manual (OECD 1997; 2005), namely organizational and commercial innovation, are scarcer (i.e.: Hervas-Oliver et al. 2017; Carboni and Russu 2018), a fact that may overlook important relationships between the different innovation types. Thus, organizational and marketing innovations facilitate the emergence of both product and process innovations (Bharadwaj and Menon 2000; Lokshin et al. 2008) as they make possible the changes in the structure that supports the innovations (Pisano 1990). Also, product innovations may demand new forms of marketing, or new production technologies may require new marketing approaches to market them (Schmidt and Rammer 2007). This scarcity of works exploring these relationships constitutes a research gap, suggesting the need of more research about this issue.

Second, most of previous literature has focused on the relatedness between two, or three, innovation types (Carboni and Russu 2018) but, to the best of our knowledge, no previous works have analysed relatedness between all the four innovation types identified in the Oslo

Manual. As consequence of this research gap, although previous literature has confirmed the existence of relatedness between different innovation types, it has not been able to deepen the analysis of the intensity of these relationships, nor has been possible to stablish whether the relatedness between two innovation types could be dependent on the adoption of the other innovation types. This knowledge would be interesting to identify what innovation types are more intensively related, or whether the intensity of this relatedness could be dependent on the adoption of the remaining innovation types.

Third, although pairwise correlation has been broadly supported by previous research (i.e.: Gomez and Vargas 2009; Guisado et al. 2013) as the more appropriate empirical approach for the study of relatedness, it does not allow to analyze if there are indirect feedback effects influencing through other practices (Catozzella and Vivarelli 2004). In other words, it does not allow to test whether the relatedness in the adoption of different types only exists when simultaneously another innovation is already carried out.

The aim of the paper is to investigate the relatedness in the adoption of all the innovation types included in the Oslo Manual. In particular, we will study the relatedness in the adoption of two innovation types and whether this relatedness could be influenced by the presence/absence of the remaining innovation types. The empirical study uses data from the Spanish Community Innovation Survey (CIS) (2008-2014). The study makes several contributions to previous literature. First, it offers a more complete view of relatedness in the adoption of innovation types considering, for the first time, the four innovation types of the Oslo Manual simultaneously. The inclusion of innovation types that have received less attention in previous research - organizational and commercial- constitutes a relevant contribution to previous research because, as different authors suggest (Damanpour and Evan 1984; Karlsson and Tavassoli 2016; Carboni and Russu 2018) the competitiveness of firms increasingly seems to depend not only on product and process innnovations but also on marketing and organizational innovations.

Second, the consideration of the four innovation types will allow us to obtaine a deeper view of the degree of intensity in relatedness in the joint adoption of different innovation types, providing relevant information about innovation strategies of companies.

Third, since pairwise correlation, traditionally used in relatedness literature, can be inadequate for testing whether relatedness in adoption of innovations is dependent on other innovation types we implement a new procedure, conditional relatedness. To the best of our knowledge this is the first paper analysing conditional relatedness in this field. This methodological approach allows us to analyze the existence of variations in the intensity of the relatedness

between two innovation types conditioned to the absence or presence to the other two types of innovations considered.

Section 2 presents the literature review. Section 3 develops the empirical methodology to be applied. Section 4 presents the data sources and variables. Section 5 shows the findings, and Section 6 concludes.

2. Literature review

From the seminal work by Schumpeter (1934), it is widely recognised that innovative activities can involve different aspects (i.e. products, process technologies, customer and supplier relationships or organizational practices and management structures) (Pisano 1990; Drejer 2002; Garcia and Calantone 2002; Battisti and Stoneman 2010; Doran 2012) which simultaneously implemented (Li et al. 2007; Guisado-González et al. 2017) could be mutually reinforced (Reichstein and Salter 2006; Martínez-Ros and Labeaga 2009). Several different theoretical approaches, including the Transaction Cost Economics (TCE) Theory, the Resource Based View (RBV), the Knowledge Based View (KBV) and the Systemic Approach (SA), have been used interchangeably to sustain this mayor emphasis on mutual interaction of innovation activity (IA) following different arguments. A synthesis of them are detailed below.

2.1. Transaction Cost Economics Theory

The argument that the value of firm resources is exerted only in presence of other factors (Ennen and Richter 2010) is consistent with Teece´s (1986) proposal about "complementary assets" in innovation. Drawing on TCE, Teece argued that ensuring a market introduction of an innovation often requires complementary resources (Hill and Rothaermel 2003) related to manufacturing or after sales assistance. These assets can be integrated by companies in a unique way which confers them competitive advantage. Otherwise, the company must assume that its external suppliers could appropriate a considerable portion of the rents derived from innovation, as a result of its position vis-à-vis the innovating company (Ennen and Richter 2010). This is a key issue in presence of appropriability problems, imitators or tacit or partly codified innovations (Carboni and Russu 2018).

2.2. The Resource Based View Approach

The RBV suggests that firms could get competitive advantages from their ability to combine many heterogeneous resources in unique ways (Adegbesan 2009). Thus, IA focused in all areas can foster interchanges with key constituencies, enabling firms to manage resource dependencies with the external units, and maintaining the flow of resources to the organization (Pfeffer and Salancik 2003; Scott 1992). The synergy from developing different IA improves

the firm's capability to introduce and deliver services to its clients, on the one hand, as well as reach its main goals, on the other (Damanpour et al. 2009). The joint adoption of innovation practices within the firm assumes that strong interdependencies among internal organizational assets resulting from these activities exists and are key factors to achieving organizational effectiveness over time. Moreover, it facilitates protection against imitation which fosters firm's competitive advantage (Rivkin 2000; Wischnevsky and Damanpour 2006).

2.3. The Knowledge-Based View approach

The KBV approach also offers arguments in favour of relatedness between innovation types. From this theoretical perspective, innovation is a process in which firms develop knowledge to solve problems (Nonaka 1994). In doing so, individuals and firms need different sources of competences -skilled personnel, scientific competence, market knowledge, organisational linkages- (Galia and Legros 2004), to transform knowledge into new products, processes or services (Nonaka and Takeuchi 1995). This fact would suggest a need of implementing different innovation management practices at the same time and sharing experiences, which would improve the creation and exploitation of knowledge.

2.4. The Systemic Approach

Finally, the SA emphasizes the systemic nature of IA (Kurkkio et al. 2011; Carboni and Russu 2018). Thus, existing research reveals firms that introduce product and/or process innovation must often reorganize their production (Kraft 1990), workforce, sales divisions, knowledge management and/or distribution systems (Schmidt and Rammer, 2007; Mothe et al., 2014; 2015), and new production processes may result in new organizational practices and models (Schmidt and Rammer 2007), or in the possesion of fundamental capabilities to introduce novel products (Lewandowska et al. 2016). In addition, both product and process innovation may imply changes related to marketing and deliver methods or geographical scope of production activities (Ballot et al. 2015), on the one hand. On the other hand, new technologies may increase production capacities or improve the quality of products and require new marketing strategies (Schmidt and Rammer 2007). Such integrative view suggests that in order to get all the benefits of innovation adoption is necessary to integrate and coordinate different activities (Galia and Legros 2004). In other words, it seems to exist synergies from adopting different types of innovation (Battisti and Stoneman 2010). However, these interactions may also entail perverse effects raising barriers to organizational change (Gopalakrishnan et al. 1999; Milgrom and Roberts 1995).

Based on those arguments, our a priori expectation is that the relatedness in the adoption of different types of innovation exist and might be significant. We also expect that some

combinations or innovation strategies could be more intensively used than others, signalling the preferred company´s innovation strategies.

3. Econometric method: new methodological approach for testing conditional relatedness

As presented in previous section, it seems to exist convergence from different theoretical frameworks in favor of the existence of relatedness, however, from an empirical perspective the same convergence is not found. Although the more appropriate empirical strategy for studying relatedness in the adoption of different innovation types seems to be correlation analysis, it has been scarcely used by previous research (Damanpour and Gopalakrishnan 2001; Reichstein and Salter 2006; Carboni and Russu 2018). The adequacy of the method seems to be broadly supported by previous research in other fields (i.e.: Gomez and Vargas 2009; Guisado et al. 2013). The method is based on the proposal developed by Arora and Gambardella (1990), in which the correlation coefficients are determined from the residues resulting from a series of regressions in which the dependent variable is, successively, the innovation type to be adopted. This procedure avoids the influence of observable exogenous variables on the correlations obtained by the normal system, achieving more reliable results (Guisado et al. 2013). Thus, Arora and Gambardella (1994) propose to regress separately each innovation type on a set of exogenous variables and positive correlation between errors suggests relatedness in the adoption of different innovation types.

However, this method does not takes into account the indirect feedbacks that could be acting through other practice (Catozzella and Vivarelli 2004) making that relatedness in the adoption of different innovation types only exists when simultaneously another innovation is already carried out.

In order to overcome this limitation, we use a novelty approach not previously used in this field for studying the relatedness in the adoption of two innovation types. More precisely, this methodological approach consists on analyzing pair correlations between residuals conditioned to the presence/absence of the third and/or four innovation type.

In doing so the empirical study is structured in two steps:

1. We first regress each innovation type on determining innovation variables taken from previous literature. The econometric strategy consists of estimating various specifications of the model depending on the innovation type. However, despite the careful revision of previous papers analyzing the determining factors of innovation types, firm characteristics can be also determining the adoption of innovations. Therefore, estimations with pooled regression analyses would be biased. Estimating a random effects

probit allows to avoid this problem. This method considers the existence (if any) of unobserved factors that may influence simultaneously the adoption of all four innovation types. This allows to contrast to whether extent the adoption of different innovation types is related (Gomez and Vargas 2009). Furthermore, the estimation of a random effects probit model as suggested by Arvanitis et al. (2015), Badillo and Moreno (2016) and Damanpour et al. (2009) has several advantages regarding to a fixed effect probit estimations, allowing to control for individual heterogeneity rather than a fixed effect procedure. First, it allows to maintain in the sample firms with one observation. Second, unlike the fixed effects regressions, it keeps time invariant variables, reducing the potential problems for within panel autocorrelation. Third, it does not suffer from the incidental parameters problem (Hsiao 2003; Wooldridge 2010). Finally, The theoretical foundations suggest that the random effects works better than the fixed one when a sample of the entire population is considered such as is our case (Baltagi 2005). Our specification is as follows:

$$y_{it}^{*} = \alpha + \beta_1 X_{it} + Z_t + \mu_i + \varepsilon_{it} \quad (1)$$

where i= 1, …, N indicate the firms and t=1, …, T indicates the time periods.

y_{it}^{*} is the latent dependent variable that depends on the observable vector of explanatory variables X_{it}, a time vector of dummies Z_t, unobservable time invariant characterisitcs of the firm μ_i and other unobservable attributes that vary over time and are captured by the idiosyncratic error ε_{it}. If the latent variable is y_{it}^{*} is positive it seems that the company has introduced an innovation (product, process, organizational or commercial), and y_{it}= 1, and 0 otherwise.

2. Second, after regressing determining factors on innovation types, we get the residuals of these estimations and proceed to analyze the correlations between them. A significant positive correlation between the error terms, after controlling for explanatory variables, suggest that the adoption of different innovation types is related. We first test for unconditional relatedness by analyzing the correlations between these four residuals, and then we proceed with the analysis of conditional relatedness. In doing so we analyze the pair correlation between residuals conditional to the presence or absence of the other two innovation types.

4. Data set and variables

4.1. Data set

The data is taken from seven waves of the Spanish Survey of Innovation in Companies for the years 2008 to 2014. This data is part of the CIS surveys based upon the methodological guidelines of the Oslo Manual (OECD 1997). The CIS 2008 covers the periods 2006-2008, and so on. Therefore, the seven waves used are providing information over a nine years period (2006-2014).

After cleaning the data (i.e. dropping observations of firms reporting mergers, total split, acquisitions, closures, confidentiality issues, or firms wrongly included or unreachable) there are 68,190 observations in total.

4.2. Variables

Dependent Variables

The dependent variables measure whether a company (i) introduce a product ($Product_{it}$), process ($Process_{it}$), organizational innovation ($Organizational_{it}$), or a marketing innovation ($Commercial_{it}$) over the previous two years, taking value 1 in this case and 0 otherwise.

Independent Variables

These second group of variables are selected based upon previous papers that have studied the determinants of innovation adoption (see table 1).

These variables are Internal R&D expenditures ($Irdex_{it}$), External R&D expenditures ($Erdex_{it}$), Machinery acquisition expenditures ($Machex_{it}$), Training expenditures ($Trainex_{it}$), External knowledge acquisition expenditures ($Eknowex_{it}$), Market introduction expenditures ($Markiex_{it}$), Governement funding ($Goverfun_{it}$) and Cooperation dummies ($Coopfirm_{it}$, $Coopsu_{it}$, $Coopucli_{it}$, $Cooprcli_{it}$, $Coopcom_{it}$, $Coopcon_{it}$, $Coopuni_{it}$, and $Coopins_{it}$).

Control variables

Based on previous literature (i.e.: Cassiman and Veugelers, 2006; Serrano-Bedia et al., 2018 several“general firm characteristics” like Size ($Size_{it}$), Sector-dummies, Export ($Export_{it}$) and Group ($Group_{it}$) are considered in the analysis.

Table 1: Definition of the variables

Variables	Description	Antecedents
$Product_{it}$	1 when the firm i introduced a product innovation over the two previous years; 0 otherwise.	Martinez Ros (1999); Martinez Ros and Labeaga (2009); (2009); Tavassoli and Karlsson (2015); Karlsson and Tavassoli (2016); Criscuolo et al. (2017); Serrano-Bedia et al. (2018)
$Process_{it}$	1 when the firm i introduced a process innovation over the two previous years; 0 otherwise.	Martinez Ros (1999); Martinez Ros and Labeaga (2009); (2009); Tavassoli and Karlsson (2015); Karlsson and Tavassoli (2016); Criscuolo et al. (2017); Serrano-Bedia et al. (2018)
$Organizational_{it}$	1 when the firm i introduced an organizational innovation over the two previous years; 0 otherwise.	Tavassoli and Karlsson (2015); Karlsson and Tavassoli (2016); Serrano-Bedia et al. (2018)
$Commercial_{it}$	1 when the firm i introduced a commercial innovation over the two previous years; 0 otherwise.	Tavassoli and Karlsson (2015); Karlsson and Tavassoli (2016); Serrano-Bedia et al. (2018)
$Irdex_{it}$	1when the firm i has engaged in internal R&D expenditures in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Erdex_{it}$	1when the firm i has engaged in external R&D expenditures in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Machex_{it}$	1when the firm i has engaged in expenditures for the acquisition of machinery, equipment or software in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Trainex_{it}$	1 when the firm i has engaged in expenditures for employees´ training in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Eknowex_{it}$	1 when the firm i has engaged in expenditures for external knowledge in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Markiex_{it}$	1 when the firm i has engaged in expenditures for the introduction of innovation in the market in period t; 0 otherwise	Karlsson and Tavassoli (2016)
$Goverfun_{it}$	1 when the firm i received public financial support for innovation from a regional, national or European source, including the Sixth European Framework, over the two previous years; 0 otherwise	Peters (2009); Criscuolo et al. (2017)
$Coopuni_{it}$	1 when the firm i cooperates on IA with other firms; suppliers; public clients; private clients; competitors; consultants; universities; research centres; respectively in period t; 0 otherwise	Fritsch and Meschede (2001); Reichstein and Salter (2006); Karlsson and Tavassoli (2016); Criscuolo et al. (2017)
$Coopins_{it}$		
$Coopfirm_{it}$		
$Coopsu_{it}$		
$Coopucli_{it}$		
$Cooprcli_{it}$		
$Coopcom_{it}$		
$Coopcon_{it}$		
$Size_{it}$	Log of firm's i employees in period t	
$Export_{it}$	The percentage of the turnover from exportations as percentage of the total turnover for firm i in period t	Guisado-Gonzalez et al. (2017); Serrano-Bedia et al. (2018)
$Group_{it}$	1 if the firm i belongs to a group in period t; 0 otherwise	Catozzella and Vivarelli (2014); Criscuolo et al. (2017); Serrano-Bedia et al. (2018)
Sector dummies	Forty three sector specific industry dummies based upon NACE 2009 two digit-level classification.	
Time dummies	Seven time specific dummy variables	

The main description of the variables along with the construction and previous papers that have used the same variables is presented in table 1.

5. Results and discussion

Table 2 summarizes the frequency of the combinations of innovation types in Spanish firms. Product and process is the most frequent combination of innovation types from years 2008 to 2010, whereas the combination between process and organizational innovation is the most frequent in the years 2011 and 2012. The third more frequent option is the combination of product and organizational innovation for all years. Finally, the less frequent combination of innovation types used for the majority of years are those that combine commercial innovation with both product and process.

Table 2: Frequencies of combination of different innovation types (2008-2014) (%)

	Product and process	Product and organizational	Product and commercial	Process and organizational	Process and commercial	Organizational and commercial
2008	35.71	29.41	20.42	32.78	20.43	20.91
2009	38.35	29.11	20.60	32.11	20.79	20.43
2010	39.53	28.23	20.48	30.97	20.48	20.03
2011	26.91	23.56	18.48	27.15	17.77	19.89
2012	22.59	20.94	17.01	23.62	16.65	19.98
2013	21.18	18.70	16.74	20.80	16.13	18.38
2014	26.12	23.69	20.77	25.23	19.35	22.32

Following with the analysis of relatedness in the adoption of innovation types, we first regress each innovation type (product, process, organizational and commercial) on selected determining factors based upon a random effects probit estimation. The results of these analyses are reported on table 3. Although this is not the objective of the paper, we briefly summarize the main results of these estimations, which allow us to identify the factors that affect the different innovation types. First, a group of factors -cooperation with clients (both public and private), cooperation with consultants, and external knowledge acquisition expenditures and cooperation with universities- are determining factors only for the case of product, process and commercial innovation, respectively. Second, cooperation with suppliers and with competitors are determining factors for both process and organizational innovations. In third place, machinery acquisition expenditures is a determining factor for process, organizational and commercial innovations. And, finally, a group of determining factors for all the innovations types (internal R&D expenditures, external R&D expenditures, training expenditures, market introduction expenditures, government funding and cooperation with firms).

Table 3: Random effects probit estimations results (marginal effects)

	$Product_{it}$	$Process_{it}$	$Organizational_{it}$	$Commercial_{it}$
$Irdex_{it}$	0.752 (0.049)***	0.416 (0.050)***	0.551 (0.046)***	0.649 (0.051)***
$Erdex_{it}$	0.173 (0.039)***	0.159 (0.038)***	0.233 (0.034)***	0.162 (0.035)***
$Machex_{it}$	-0.059 (0.044)	1.590 (0.053)***	0.317 (0.036)***	0.175 (0.037)***
$Trainex_{it}$	0.2062 (0.053)***	0.664 (0.053)***	0.510 (0.042)***	0.395 (0.042)***
$Eknowex_{it}$	0.0659 (0.111)	0.066 (0.113)	-0.018 (0.089)	0.210 (0.088)**
$Markiex_{it}$	2.151 (0.062)****	0.078 (0.038)**	0.261 (0.032)***	0.403 (0.032)**
$Goverfun_{it}$	0.656 (0.065)***	0.630 (0.066)***	0.444 (0.060)***	0.332 (0.066)****
$Coopfirm_{it}$	0.365 (0.080)***	0.327 (0.078)***	0.136 (0.069)***	0.175 (0.069)**
$Coopsu_{t,}$	0.095 (0.073)	0.341 (0.071)***	0.186 (0.064)***	0.068 (0.064)
$Coopucli_{it,}$	0.238 (0.076)***	0.111 (0.0736)	-0.002 (0.066)	0.101 (0.07)
$Cooprcli_{it,}$	0.307 (0.110)***	0.038 (0.105)	-0.002 (0.095)	0.063 (0.093)
$Coopcom_{it,}$	-0.021 (0.079)	0.227 (0.077)***	0.178 (0.070)**	0.023 (0.070)
$Coopcon_{it}$	-0.014 (0.083)	0.154 (0.080)**	0.071 (0.072)	0.099 (0.072)
$Coopuni_{it,}$	0.094 (0.073)	-0.027 (0.072)	0.057 (0.064)	0.195 (0.066)***
$Coopins_{it}$	0.062 (0.068)	-0.088 (0.067)	0.11 (0.061)	0.007 (0.062)
$Size_{it}$	0.077 (0.016)***	0.217 (0.0180)***	0.257 (0.016)	0.045 (0.009)***
$Export_{it}$	0.002 (0.001)**	0.001 (0.001)	0.0006 (0.001)	0.002 (0.001)**
$Group_{it}$	0.104 (0.049) **	-0.009 (0.050)	-0.041 (0.045)	-0.084 (0.048)*
Industry dummies	Included	Included	Included	Included
Time dummies	Included	Included	Included	Included
σ	1.386 (0.036)	1.526 (0.039)	1.419 (0.034)	1.520 (0.036)
ρ	0.657 (0.120)	0.699 (0.010)	0.668 (0.010)	0.698 (0.010)
Wald Chi2	2339.26 (0.000)	2252.0.3 (0.000)	1511.24 (0.000)	1162.20 (0.000)
Log Likelihood	-8566.3943	-9396.8906	-10897.744	-10266.171

Regarding to control variables, firm size exerts a positive and significant effect for all innovation types with the exception of organizational innovations, whereas the exportations and group are only significant for the adoption of product and commercial innovations.

These results allow us to conclude that it seems to exist a group of common determining factors for all the innovation types, together with other group of specific factors for only one of few innovation types. This result would suggest that there exists special characteristics for any innovation type that make their determinants to be also different. A result that should be considered by firms when designing their innovation strategies.

Table 4: Unconditional relatedness between innovation types: correlations between residuals

	ReProduct	ReProcess	ReOrganizational
ReProcess	0.5147		
ReOrganizational	0.6501	0.7744	
ReCommercial	0.7349	0.5417	0.6922

Significant correlations at 1%

We turn now into the results presented in table 4 for conditional relatedness analyses. Table 4 reports that the adoption of all innovation types analyzed is related since all correlation between errors are positive and significant (1% level). Our results suggest a more intense relatedness in the case of organizational and process, and product and commercial innovations. Furthermore, the less intense correlations are between product and process innovations. If we put these results in relation to the frequencies, although the more frequent combinations in the sample are product with process and process with organizational innovations, the more intense relatedness is found for the second one. This confirms the relatedness in the adoption of the four innovation types considered, including market and organizational innovation, and not only the well-studied product and process innovation. These empirical findings are supported by the arguments suggested by several theoretical approaches, including TCE, RBV, KBV and SA, in favour of the relatedness in the adoption of different innovation types.

Table 5: Conditional relatedness between innovation types: pair-wise correlations between residuals

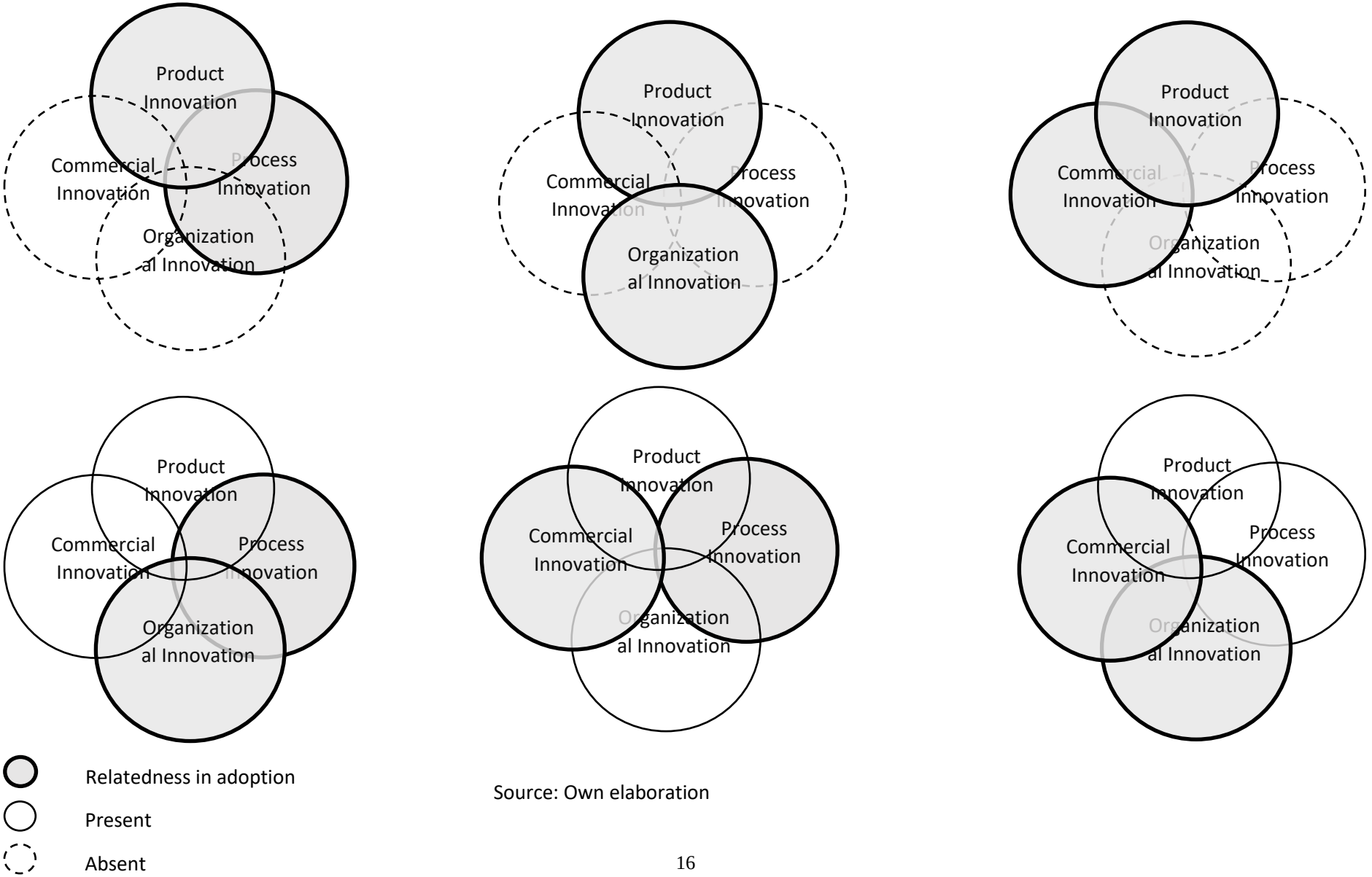
	Organizational=0 Commercial=0	Organizational=1 Commercial=0	Organizational=0 Commercial=1	Organizational=1 Commercial=1
ReProduct-ReProcess	***0.5154***	0.4495	0.4006	0.4482
	Process=0 Commercial=0	Process=1 Commercial=0	Process=0 Commercial=1	Process=1 Commercial=1
ReProduct-ReOrganizational	***0.6441***	0.6038	0.6201	0.5837
	Process=0 Organizational=0	Process=1 Organizational=0	Process=0 Organizational=1	Process=1 Organizational=1
ReProduct-ReCommercial	***0.7493***	0.6777	0.7181	0.6910
	Product=0 Commercial=0	Product=1 Commercial=0	Product=0 Commercial=1	Product=1 Commercial=1
ReProcess-ReOrganizational	0.7358	0.7483	0.6967	***0.7748***
	Product=0 Organizational=0	Product=1 Organizational=0	Product=0 Organizational=1	Product=1 Organizational=1
ReProcess-ReCommercial	0.4758	0.4396	0.4051	***0.4942***
	Product=0 Process=0	Product=1 Process=0	Product=0 Process=1	Product=1 Process=1
ReOrganizational-ReCommercial	0.6068	0.6308	0.5813	***0.6544***

All correlations are significant at a 1% level

Now, we turn to the analysis of conditional correlations (table 5 and figure 1). Thus, we analyze pairwise correlations conditioned to the absence/presence of the third and four types of innovation. As table 6 reports, errors are still positively correlated (1% level). Those adoptions that are strongly related are process and organizational innovations in presence of product and commercial, while the weakliest related are product and process innovation in presence of commercial and in absence of organizational innovation.

As can be seen in Table 5, product innovation appears as a common element of the six most intensely related two by two combinations. First, when we analyze the relatedness between product innovation with the other three innovation types it does not seem to be necessary to adopt a third and/or a fourth innovation type to observe the highest correlation. Second, if we look at the combination of any of the other three alternatives in pairs, the strongest relatedness occurs always in presence of product innovation. In summary, although the existence of relatedness in the two by two adoption of all innovation types is confirmed empirically, the analysis carried out allow us to observe that the intensity of this relatedness is dependent on the adoption of the rest of innovation types. With regards to the extension of the analysis to the relatedness conditioned to the presence/absence of the third and four types of innovation, the results confirm the pertinence of the new method applied in this paper. Aditionally, our findings reveal that the absence, or presence, of some innovation types seems to foster the relatedness between other innovation types (e.g. relatedness in the adoption of product innovation and any of the other three innovation types when the other innovation types are not adopted, or relatedness in the adoption of process and organizational, process and commercial and organizational and commercial innovation when the other innovation types are adopted). Finally, the empirical evidence has allowed us to identify the most intensely related innovation types: process and organizational and product and commercial. This relatedness could be on the basis of the implementation of two different strategic options more oriented to internal efficiency and external efficacy, respectively. These results suggest the more intense relatedness is between those innovation types with similar aims, while the relatedness is less intense when the innovation strategy combines efficacy with efficiency. Furthermore, the less intense correlations are between product and process innovations, in contrast to previous research that suggests the existence of a strong relatedness between both types of innovation, which has also made it the most widely studied relationship in the previous literature. This finding highlights the need to extend the research about the relatedness in the adoption of innovation types to other pairs different than the product-process.

Figure 1: Stronger relatedness between innovation types for each pair-wair correlations



Source: Own elaboration

6. Conclusion

This paper aims to study the existence of relatedness and its degree of intensity in the adoption of different innovation types in a sample of both manufacturing and service Spanish companies. In doing so, this work extends previous literature along three main directions: the inclusion on the analysis of the four innovation types identified in the Oslo Manual, the analysis of how the relatedness in the adoption of two innovation types could be influenced by the presence/absence of the remaining innovation types, and the analysis of the degree of intensity in relatedness in the adoption of different innovation types. Using a sample of 68,190 Spanish companies during the period 2008-2014 and based upon longitudinal methods' analyses the paper confirms the existence of relatedness in the two by two adoption of all innovation types. However, contrary to the traditional approach that suggests a strong relatedness between product and process innovations, this is the less intense link found, on the one hand. On the other hand, the empirical approach suggests that product innovation emerges as a fundamental axis in the innovation strategy because the more intensively used innovation strategies are those combining product innovation with any other innovation type in absence of the rest and those combining any of the other three innovation types in presence of product innovation. Thus the analysis carried out allow us to observe that the intensity of this relatedness is dependent on the adoption of the rest of innovation types.

Implications to the practice of management

The main practical implication for managers is that it provides an interesting picture about the patterns of innovation adoption in firms, as well as a more fine grained analysis about the role of product innovation within their innovation strategy. Thus, although companies consider product innovation as 'necessary' independently of all the other types of innovation they combine it with, our findings show that this is not exactly the case. In particular, the intensity of the interdependencies in the two by two adoption between product innovation and the other innovation types is not dependent on the adoption of the remaining innovation types. Moreover, unlike to the traditional approach that establishes a strong relatedness between product and process innovations, our results show that one of the most intense relatedness between innovation types found -that is, between product and commercial innovation- is not dependent on the adoption of process innovation. This result suggests that product and process innovation happening together not always foster the relatedness between other innovation types and consequently this combination is not in all cases a necessary prerequisite for achieving competitive advantage.

Our results also confirm that internal R&D expenditures, external R&D expenditures, training expenditures, market introduction expenditures, government funding and cooperation with firms are important factors in fostering the adoption of all innovation types. However, cooperation with clients (both public and private), cooperation with consultants, cooperation with universities, external knowledge acquisition and machinery acquisition, only foster the adoption of few innovation types. This knowledge may serve as an important guide for firms when deciding their innovation strategy, in particular the type or types of innovation adopted.

Limitations and future research

Although the paper enriches the knowledge about of the complex task of designing a company´s innovation adoption, it doesn't present evidence about the reasons behind these patterns. Thus, the question remains whether the relatedness between innovation types is due to arguments presented in the literature review. Therefore, we propose as a future research line to develop further research on the reasons explaining them. In doing so the synthesis of the theoretical frameworks presented here would serve as an important and valuable start point.

The findings of this paper, although useful for managers when designing their firm's innovation strategy, do not resolve the question about what to do to increase their chance of success in introducing innovation. Consequently, it would be also interesting to analyse in further research the effects of the most intensely related innovation types on performance. This would allow us to know to which extent these patterns of innovation adoption are being successful for achieving competitive advantages.

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