LINKING DIVERSITY IN THE SKILL WORKFORCE STRUCTURE, ORGANIZATIONAL INNOVATION AND TECHNOLOGICAL INNOVATION STRATEGIES.

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Abstract

This paper offers a comprehensive and deep analysis of the relationship between skill diversity in the workforce and the technological innovation activities of industrial firms. We stress the relevance of breaking down the concept of diversity into more accurate dimensions – variety and separation– that have different effects on technological innovation. We distinguish technological innovation –both embodied in artefacts and disembodied– to understand the specific effect of diversity skill workforce dimensions on technological innovation. Finally, we analyse the moderating effect that the adoption of organisational innovations has on the relationship between diversity skill workforce and technological innovations. Results show a positive and significant relationship between skills variety and technological innovation activities, which is highly complementary to organisational innovation external to the firm. Skills separation, in turn, shows a nonlinear relationship with technological innovation. It is affected by organisational innovations showing the relevance of balanced professional staff. The study conducts an eight yearlong longitudinal analysis of the whole manufacturing industry in a developing country. In addition to the theoretical discussion of diversity and innovation, the results offer new evidence about innovation determinants in traditional manufacturing industries.

Key words: skill workforce diversity, firm organization, technological innovation, Latin America

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1.Introduction

Innovation has become a central topic on the economic and management research agenda (Nag et al., 2007; Fagerberg & Verspagen, 2009). Empirical evidence confirms the positive association between the adoption of innovation activities and both innovation and firm performance (Inauen & Schenker-Wicki, 2011). Despite a plethora of papers that have focused on this topic, however, some dimensions of the firm innovation process are still a "black box" (Arrighetti et al., 2014). Aiming at improving understanding of this process, some papers have distinguished between innovation that is externally developed (e.g. embodied in artefacts such as capital goods, software or standardised processes) from that which is internally developed or disembodied (Vivarelli et al., 1996; Cassiman & Veugelers, 2000). This distinction allows the identification of different technological innovation (TI) strategies (Santamaría et al., 2009; Pellegrino et al., 2012), however, evidence of the determinants of TI strategy are far from conclusive, and researchers are reviewing the way that firms innovate, taking into consideration new determinants and moderating factors of the innovation process (Damanpour et al., 2009).

Less attention has been paid to the role of people and the way they are organised in the innovative behaviour of firms (Lund & Gjerding, 1996; Lee & Walsh, 2016). Our paper tries to contribute to this stream of research relating diversity in the skill workforce structure and the adoption of organisational innovations (OI) to explain the ability to conduct both embodied and disembodied TI strategies. In today´s organisation, employees are more likely than ever before to work with other employees of different demographic or functional backgrounds (Toosi, 2009). Diversity in human resource increases the knowledge base, absorbing the different cultural views, educational levels and tenure background of employees (Østergaard et al., 2011; Parrotta et al., 2014), however, diversity might also lead to conflict, distrust and negative effects for out-group members (Shore et al., 2009). Race, gender, age, sexual orientation, national origin, tenure, educational and functional backgrounds have been the diversity dimensions mostly studied (Laursen et al., 2005; Shore et al., 2009; Bell et al., 2011).

Educational level is perhaps the most important source of knowledge and expertise in firms (Dahlin et al., 2005) and a key factor for innovation (Pelled, 1996). Lazear (1999) developed a theoretical model demonstrating that diversity in skill workforce structure is positively associated with both the adoption of innovation activities and firm performance. Formal education is one of the basic tools enabling agents to use knowledge in a transformative way. For instance, complex problem-solving processes require integrative formal knowledge (Lundvall & Johnson, 1994), which in turn facilitates the search for and processing of information, and being creative and innovative (Dahlin et al., 2005). However, we know very little about how diversity in the skill workforce structure derived from the heterogeneity in educational levels, affects adoption innovation activities (Fernández-Cardoso, 2013). Empirical evidence is scarce, and generally cross-sectional, focused on a wide range of outcome measures and potentially based on a variety of contingencies (Yang & Konrad, 2011). Østergaard et al. (2011) called for longitudinal analysis to study the relationship between diversity in education and the innovativeness of firms over time. Camisón and Villar-López (2014) suggested a causal relationship between the adoption of OI in business practices, workplaces and external relationships, and the development of TI capabilities. We thus suggest that the adoption of OI may moderate the relationship between skill workforce diversity and persistence in the adoption of different TI strategies.

We use a unique database of 447 enterprises, with 50 or more employees, for the period 2006 to 2012, including three waves of the Uruguayan Innovation Industrial Survey. In addition to information on both technological and organisational innovation activities, the questionnaire includes information about the workforce structure, distinguishing not only different segments (e.g. professionals, technicians and blue collar workers) but also different professional specialisations. Following Harrison and Klein (2007), we are thus able to introduce some conceptual refinements in measuring educational diversity in terms of variety (heterogeneity in educational specialisation) and separation (differences in the level of education). These dimensions represent a unique pattern of differences among members and therefore, differences on educational levels are conceptualised in different ways. The questionnaire also includes several measures of how firms internally organise their work and adopt OI in business practices.

The contributions of the paper are threefold. First, we incorporate diversity in the skill workforce structure in the debate about the factors behind the adoption of TI strategies and key human resource factor for firm innovation. Secondly, the relationship between the diversity of people and the way they are organised has been only been partially addressed to explain the TI behaviour of firms. This is the first study analysing its complementarities to explain the adoption of embodied and disembodied TI strategies. Using longitudinal data we allow for stronger statements about the persistence of certain practices over years in the process of innovation. Finally, the data comes from a Latin-American context, from Uruguay. Despite the long background to innovation, industry and development in Latin America, this region has received little attention in the academic literature on innovation and human resource management (Bello Pintado et al., 2015). Thus, this paper provides evidence that broadens the debate about the universality of certain practices of innovation and internal organisation.

2. Theoretical Framework

2.1 Diversity in Educational Level: Separation and Variety

According to Harrison and Klein (2007) diversity is the distribution of differences among the members of a unit with respect to a common attribute, in our case, educational level. The pattern of differences must be considered when elaborating an argumentation about how diversity of the variable of interest is related to processes or outcomes in order to differentiate between separation, variety and/or disparity. We consider the diversity of the skill-workforce structure as a unit-level construct for the whole organisation and not as the differences between a focal member and other members, according to the following two dimensions.

Variety is the composition of differences in kind, source, or category of relevant knowledge or experience among unit members (Harrison & Klein, 2007). The number of categories represented contributes to organisation diversity. Diversity in terms of variety in the educational level corresponds to the presence of different educational levels among the firm's members. Variety in educational specialisation involves every member in the unit having different expertise from the others. According to the knowledge-based-view perspective, the information processing theory and the absorptive capacity argument, diversity in the educational specialisation of unit members allows different perspectives and the treatment of information from different sources, which in turn can enhance the performance of different tasks through continuous improvement.

Separation refers to the composition of differences in (horizontal) positions or opinions among unit members, primarily regarding value, belief, or attitude; disagreement or opposition. It represents the dissimilarity about a particular attitude or value (Harrison & Klein, 2007). Its effects are thought to be symmetrical. In the case of educational level diversity, a unit composed of high school graduates would be considered homogeneous in educational level, as would another composed of members with professional degrees, if diversity was conceptualised as separation. An organisation half composed of high school graduates and half composed of members with professional degrees would represent the maximum amount of diversity in terms of separation (Bell et al., 2011).

2.2 Skill-workforce structure diversity and technological innovation.

The focus and scope of the interest researchers have in diversity is both varied and broad. The evolutionary economics of innovation sees diversity as one of the pillars of its approach (Nelson & Winter, 1982; Silverberg et al., 1988). Within the evolutionary framework, diversity boosts development processes (Dosi et al., 1994) and similarly it appears as one of the main factors in the evolutionary path of a firm (Malerba & Orsenigo, 2000). The management literature focuses mainly on the multi-dimensional nature of diversity, analysing its impact on firm performance. Although it has been also addressed from a technological perspective (Breschi et al., 2003), attention has mainly been from a human resource perspective. Most papers considered the individual characteristics of top management teams (Harrison & Klein, 2007; Pitcher & Smith, 2001) but a limited number of empirical papers have been developed at the firm level, using linked employer-employee data (Østergaard et al., 2011).

In the resource based view perspective, internal firm resources are seen as drivers for competitive advantage (Wernerfelt, 1984). Barney (1991) stated that resources with the potential to provide a firm´s success are rare, valuable, inimitable, and non-substitutable. Wright & McMahan (1992) put “people” on the radar as strategic resources, and from there, concepts such as dynamic capabilities (Teece et al., 1997) or absorptive capacity (Cohen & Levinthal, 1990) have been at the intersection of strategy with other fields, such as human resources or innovation.

The diversity structuring the educational level and professional profiles increases the knowledge base, which in turn might contribute to developing distinctive capabilities through routines in different activities related to innovation (Nelson & Winter, 1982), such as identifying and exploiting new and different sources of information (Zahra & George, 2002) or broadening points of view (Lundvall & Johnson, 1994). Heterogeneity in the educational level of workers is a source of creativity and the generation of new ideas fostering a firm´s innovation activity (Berliant & Fujita, 2011). Relatedly, Sutz (2012) stressed that diversity, as an indicator of learning capability, can be approximated through the variety of professional backgrounds. This author noted that the specialisation of professionals and technicians indicates the potential ability of a firm to follow knowledge-intensive and interactive processes, particularly in developing countries.

According to these views, variance in group composition around skills, abilities, information use and knowledge promotes innovation activities, however, from a cost perspective, diversity also leads to an increase in transaction costs related to communication, coordination and the motivation of a heterogeneous workforce.

From another perspective, the social organisation view turns the similarity attraction paradigm around (Horwitz, 2005). In this view, diversity is contrary to the effectiveness of the group since more similar individuals are supposed to be more effective when working together. As a result, workers are aligned along social identity in a way that might cause conflict (Schneider & Northcraft, 1999). This situation often results in competitive behaviour, and less cooperation and communication than in homogeneous groups.

Empirically, evidence connecting diversity in the skill workforce structure and TI strategies is scarce, and also has opposing sides. First of all, it is important to note that evidence usually comes from business case studies that often look at work-team compositions, mostly focused on diversity in top management teams (Bantel & Jackson, 1989; Pitcher & Smith, 2001). Less attention has been paid to the composition of the whole workforce within the firm in order to understand the development of TI. A firm level analysis may contribute to more comprehensive information with which to understand the relationship between labour diversity and innovation. The composition of a firm's workforce contributes to diversity in the knowledge base of the firm, and so analysing diversity in the skill work force structure should include the composition of the entire firm and not only that of the top management team (Østergaard et al., 2011).

Williams and O´Reilly (1998), in their review of diversity in organisations over the last 40 years, point out that empirical evidence shows that diversity by itself is more likely to have negative than positive effects on group process and performance. In general, impediments to group functioning associated with conflict, social categorisation and attraction are common, however, they claim that diversity in the skill workforce structure associated with educational level is an exception in these results, mainly due to the innovation process. Bentel and Jackson (1989) and Kimberly and Evanisko (1981), found a positive association between diversity in educational level and technical innovation, due to team abilities to generate creative solutions to complex problems.

From another perspective, Dahlin et al. (2005) showed that team diversity in educational level provided information-processing benefits that outweighed the limitations associated with social categorisation processes. Interestingly, they found an inverted U-shaped curvilinear effect, indicating that teams with greater diversity in educational levels used broader ranges of information and used them more deeply, but only up to a point. Cohen and Levinthal (1990) also pointed out that there was a saturation point above which there are no further benefits from diversity.

Empirical studies have confirmed a positive relationship between diversity in the skill workforce structure (at team or firm level) and innovation performance (Söllner, 2010; Østergaard et al., 2011; Parrotta et al., 2014), however, in our view the understanding of how the diversity of the skill workforce structure affects the adoption of TI is a necessary step for assessing its effect on the performance of innovation.

Analysis should also distinguish between different types of TI strategies (embodied and disembodied).

Outsourcing knowledge and innovation activities could offer cost savings and superior performance, but can also put a firm's unique resources and capabilities at risk (Mudambi & Tallman, 2010). Grimpe and Kaiser (2010) argued that 'gains' from R&D outsourcing need to be balanced against the 'pains' that stem from a dilution of firm-specific resources and the deterioration of integrative capabilities. With the extent to which firms engage in internal R&D activities and the breadth of formal R&D collaborations, the effectiveness of R&D outsourcing increases (Cassiman & Veugelers, 2006). Both external and internal TI demand knowledge capabilities in a firm's workforce, however, although the real knowledge requirements of TI through artefact acquisition has always been under suspicion (Pellegrino et al., 2012; Santamaría et al., 2009) it is a basic resource in the innovation strategies of firms. It has been said for developing countries that the most frequent TI is the acquisition of knowledge embodied in artefacts (Katz, 1984; Goedhuys & Veugelers, 2012).

Organisations with different skills profiles have broad and varied knowledge bases, which provide different views of the innovation process. *A priori*, the presence of different professional profiles at the level of skilled workers should also contribute to the development of TI activities, mainly those that are internally developed. In this sense, variety in the skill workforce structure, capturing the breadth and balance of the knowledge base of the firm, is expected to be a TI enabler, however, other issues associated with the organisation of heterogeneous and highly skilled workers may lead to diseconomies of specialisation and higher transaction costs. Asymmetries of information and potential social conflicts are higher, and organising people to collaborate and coordinate their work is more difficult, when their profiles are highly separated. A curvilinear (inverted U-shape) relationship between separation in the segment of skilled workers and TI adoption is thus expected, since a great horizontal distance between the skilled groups can negatively affect the adoption of TI. In sum, a moderate degree of separation can enhance TI activities, but too much separation may block such activities.

H1a. Variety in the skill workforce structure is positively associated with the likelihood of adopting TI.

H1b. Variety in the skill workforce structure is more positively associated with the likelihood of adopting disembodied TI than embodied TI.

H1c. Separation in the skill workforce structure within an organisation is positively associated with the likelihood of adopting TI.

H1d. There is an inverted U-shaped relationship between separation in the skill workforce structure and the likelihood of adopting disembodied TI in the segment of high skilled workers (professional categories).

2.2 The moderating role of organisational innovation.

Diversity and innovation have a complex and controversial relationship, potentially moderated by contingent factors. In this sense, skill-workforce diversity and TI might be conditioned by the organisational context and the adoption of OI (Yang & Konrad, 2011).

OI comprise changes in the structure and processes of an organisation, as a result of implementing new managerial and working concepts and practices, such as the implementation of teamwork in production, supply chain management or quality-management systems (OECD, 2005; Armbruster et al., 2008). As noted, the positive or negative effects of diversity in the skill workforce structure on TI may be associated with new combinations of internal and external knowledge, different points of view, or with higher absorptive capacity. Heterogeneous capacities influence TI strategy depending on the organisational practices implemented (e.g. the use of inter-functional groups, the implementation of bottom-up information flow practices or the relationships with external stakeholders).

Sapprasert and Høyvarde (2012) show that the persistence of OI, and its mutual combination with TI activities, has positive effects on a firm's performance. Camisón and Villar-López (2014) demonstrated that organisational innovation favours the development of TI capabilities. Harrison and Klein (2007) suggest that favourable outcomes of diversity are conditioned for the effective participation of employees in the decision making process. These studies suggest that the role that diversity plays in the adoption of TI demands consideration of the presence of OI.

On the other hand, Williams and O´Reilly (1998) note that the positive effects of employee diversity on the innovation process are associated with the initial steps (creative, searching, etc.), but with potential negative effects during the implementation phase. This evidence reinforces the view that it would be easier to develop effective working relationships in homogeneous workplaces than in diverse workplaces (Van Knippenberg et al., 2004).

In the presence of a wide variety of professional profiles, the adoption of OI to facilitate the meetings and complementarities between different profiles, reducing vertical differentiation or promoting work in inter-functional groups, may reinforce the development of new ideas or complex problem-solving associated with the internal development of TI (Kimberly & Evanisto, 1981). The presence of heterogeneous profiles may favour sustaining close relationships with customers and suppliers. Communications, demands, and new developments can be better understood through a varied skill workforce structure (Kochan et al., 2003). These OI also facilitate the exploitation of group capacities associated with members' educational backgrounds, facilitating the application of routines which in turn contributes to building TI capabilities (Camisón et al., 2010). Routines in the initial face of TI enhanced by OI can overcome potential difficulties to manage a diverse skill workforce during the implementation phase (Østergaard et al., 2011). In sum, it is expected that variety complements the skill workforce structure, explaining TI.

Potential complementarities (or substitutive) effects from OI, with regard to separation are not clear. According to theories of similarity attraction and social categorisation (Byrne et al., 1971) a moderated separation could be associated with cooperation, trust and social integration (Harrison & Klein, 2007). Conversely, extensive separation promotes conflict, low cohesion, and withdrawal (Tsui et al., 1995). Within this framework, OI are especially important in separated organisations (e.g. two extreme categories, very low and very high skilled workers) so as to overcome the potential negative effects in adopting TI. For instance, the effective participation of workers in the improvement process, effective communication between managers and employees for acquisitions, or close relationships with suppliers and customers co-working at the plant level, are particularly important to improve effectiveness in the decision-making process related to innovation. In sum, OI practices promote involvement and trust, which in turn facilitate routines and the development of competencies, related to the innovation process (Teece et al., 1997).

Among high skilled workers, however, the interaction between separation and OI can have different effects on TI. On the one hand, it could be expected for moderate levels of separation in the skill workforce structure that OI will increase the positive impact on the adoption of TI. For high levels of separation a softening in the problems of separation is expected and therefore, complementarities with OI will reduce the fall in the inverted-U shaped relationship. In sum, OI reduces the negative effects of potential conflict not in terms of social categorisation but in terms of differences in thinking and knowledge.

H2a. There is a complementary relationship between variety in the skill workforce structure and OI that explains the likelihood of adopting both embodied and disembodied TI.

H2b. There is a complementary relationship between separation in the skill workforce structure of the organisation and the adoption of OI in explaining the adoption of both embodied and disembodied TI.

H2c. The adoption of OI slow the inverted U-shaped relationship between separation in the skill workforce structure in the segment of highly skilled workers and the likelihood of adopting disembodied TI.

3. Methods

Over the last 30 years, the Uruguayan innovation system has experienced several changes. The most relevant are the rebuilding process of the research basis, initiated in 1985, after the dictatorship intervention, and the more recent public policies that, since 2005 have changed the Uruguayan NSI's governance and have increased the public budget for research and innovation (Bianchi et al., 2014), but the innovative activity rate in industrial firms has not grown since 1985. Around 30% of firms are considering both technological and organisational innovation activities (ANII, 2014. Bianchi, 2007). The Uruguayan NSI shows chronic weakness (Arocena & Sutz, 2010). It is the cycles of the national economy, rather than the innovative strategies of the firms, that explain the industrial dynamics throughout this period (Bittencourt, 2012).

This does not mean that innovation does not exist in Uruguayan industry. Recent studies show that innovation activities have had a positive impact on labour productivity (Crespi & Zuniga, 2012) and product innovation has influenced the creation of skill jobs (Aboal et al., 2011). These recent empirical works used data from different waves of the Uruguayan Innovation Industrial Survey (UIIS), but none analysed either workforce diversity or organisational innovation.

3.1 Data and process

The unit of analysis is the industrial firm. The dataset resulted from merging three waves of the UIIS. The survey was carried out by the National Institute of Statistics and the National Innovation and Research Agency.

The sample is representative of the whole Uruguayan manufacturing industry, according to activity sector (ANII, 2014). Information is collected through personal interviews and, since it is an official survey, answers are compulsory for all the sampled firms. This procedure guarantees highly reliable data.

In this research we worked with the last three waves of the UISS, which cover the period 2004-2012. Since analysing skill workforce diversity requires a minimum firm size, we selected a subsample that included firms with 50 or more employees. Our final database is comprised of 1,077 observations, from 447 firms. More than 61% (276) of these firms were surveyed in the three waves, 18% twice and 20% only once. The final database allows a longitudinal analysis.

The UIIS questionnaire is based on the Bogota Manual (Jaramillo et al., 2001), which is the Latin-American adaptation of the Oslo Manual (OECD, 2005). One of the most important guidelines in the Bogota Manual is to collect information about the broad set of activities that companies carry out to innovate, before asking whether achieved innovative results. The concern about innovation activities is based on a long term accumulation of industrial studies that show how the technological behaviour of the Latin American industry was only partially based on R&D. The surveys should be able to measure other activities as well as R&D. This allows us to distinguish between disembodied TI (internal and external R&D and reception of technology transfer) and the acquisition of embodied TI (capital goods and information technology).

Embodied innovation activities are more common in the Uruguayan industry, as a result of innovative capital goods acquisitions. It is worth mentioning that, even though we used weight sampling criteria for all the calculus, the final subsample is representative of the bigger firms, which show much higher innovation rates than the whole sample (Table 1).

Table 1 Firms that conducted technological innovation activities (%) according to type of TI and year

Type of innovation activities	Sample	2006	2009	2012	Total
Disembodied TI	Whole sample	8.13	14.38	10.50	11.20
	Final Sample (>50 employees)	29.90	30.10	27.20	29.10
Embodied TI	Whole sample	14.88	24.91	21.68	20.84
	Final Sample (>50 employees)	38.98	45.37	48.16	44.38
TI (embodied or/and disembodied)	Whole sample	17.99	29.45	24.50	24.37
	Final Sample (>50 employees)	48.45	50.75	53.66	51.05

Source: Author elaborations based on UIIS database
All the results were weighted by sample criteria

3.1.1 Dependent variable: technological innovation activities

We distinguished between two types of technological innovation activities and tested different models with three dependent variables: i) disembodied technological innovation, includes firms that carried out R&D activities, both internal or external, or that received technological transfer; ii) embodied technological innovation, includes firms which acquired artefacts, such as capital goods or information and communication technologies, with the aim of make innovations; iii) technological innovation as a whole, includes the two previous conditions.

It is worth considering that 72% of the firms that conducted disembodied TI had also carried out TI activities embodied in artefacts. In turn, only 47% of the firms that conducted TI activities based on the incorporation of artefacts had also conducted disembodied innovation activities.

3.1.2 Independent variables: diversity of the skill workforce structure

Following Harrison and Klein (2007), we break the concept of diversity into two dimensions: variety and separation. We approximate a measure of skill variety considering the specialisation of the firm's professionals. This is a suitable proxy for the knowledge variety of the firm. This variable counts the presence of at least one of the ten professions registered by the survey. Following the criteria used by Parrotta et al. (2014), we aggregated professional specialisations into five categories: engineering, exact sciences; life sciences; architects; and social sciences, humanities, lawyers and accountants. The maximum possible mark for variety is 5. Finally, we controlled professional variety according to the firm's size. Our final variable is calculated as the ratio between variety and the number of employees in the firm.

We measured diversity as separation, calculating two indicators. First, we considered the entire workforce of the firm by measuring the distance between the highly qualified and less qualified workforce. We took into account the ratio between professional and technical employees, and white and blue-collar workers. The second indicator of separation is related only to the professional employees of the firms. We measured separation taking into account the horizontal distance between social science professionals (*literati)* and scientific-technological professionals (*numerati).* The variable *literati* includes professionals from social science and the humanities and the most traditional professions, such as accountants and lawyers. Professionals from the field of chemistry and physics, mathematics and statistics, biological sciences, human and animal health sciences, engineering fields (civil, electric, mechanic, and chemical); architects; computation engineers and; agronomic engineers comprise the *numerati*. Both, *literati* and *numerati* are crucial for the strategic development of a firm (Teece, 2010) but a high horizontal separation can negatively affect the firm's innovation performance. This indicator thus measures the balance within the workforce (Ostegaard et al., 2011), defined as the ratio between *numerati* and *literati*.

According to the way these indicators were built -a ratio between two class- greater separation is found in the tail of variable distribution. Less separation and more balance will be found when the variable - measured as a ratio and before being centred by the mean - reaches 1.

3.1.3 Moderating variables

To analyse the moderating effects of the OI on the relationship between a workforce's diversity and TI activities, we adapt the classification elaborated by Camisón and Villar-Lopez (2014), measuring internal and external OI activities.

We measure internal OI activities through an unweighted index variable which counts whether the firm introduced some of the following OIs during the time covered by each survey wave: continuous improvement groups; inter-functional working groups; permanent internal communications practices; economic incentive systems; broad position description; vertical differentiation (reduction in hierarchical levels); or process certification.

External OI activities are also measured through an unweighted index variable that counts whether the customers, suppliers, universities or technological centres, have become one of the three most important of partners of the firm in conducting innovation activities; and, whether the firm participates in networks.

3.1.4 Control variables

Our analytical model is completed with five control variables that are commonly analysed as potential determinants of TI activities (Cohen, 2010). We tested the following indicators: i) the size of the firm, both measured as the log of the number of employees and as the log of the firm annual turnover; ii) the foreign direct investment (FDI) into the firm, measured as a dummy variable which takes positive values if the foreign capital is equal or more than 10% of the whole capital of the firm; iii) export, measured as the percentage of export over the total turnover of the firm and as a dummy that indicates whether the firm's exports are equal or more than 10%; iv) the sector of activity. We used seven groups of the International Industry Sector Classification (IISC) (third revision) : food, beverages and tobacco; textiles, clothing, leather and shoes; wood and paper; chemical, rubber and minerals; metallurgy and transport vehicles; machinery and equipment (industrial, office, electrical, communication and medical); and others (print and furniture); v) the age of the firm, measured as the difference between the year of the survey wave and the year when the firm began business.

Table 2 Name and type of variables included in the final models

Variable	Name	Type	Variable	Name	Type
1. Technological Innovation	*Ytech*	Dichotomist	6. Separation Professional	*Sprof*	Continuous (standardised)
2. Embodied Innovation	*Yembodied*	Dichotomist	7. Internal OI	*OIint*	Continuous (standardised)
3. Disembodied Innovation	*Ydisembodied*	Dichotomist	8. External OI	*OIext*	Continuous (standardised)
4. Professional Variety	*Variety*	Continuous (standardised)	9. Size firm (log)	*logSize*	Continuous
5. Separation Skill Workforce	*SSW*	Continuous (standardised)	10. Age	*Age*	Continuous

Table 3 Descriptive statistics and correlation (variables included in the final models)

Variable	s.d.	Min.	N	1	2	3	4	5	6	7	8	9
1. Technological Innovation	0.500	0	1077									
2. Embodied Innovation	0.497	0	1077	0.8748*								
3. Disembodied Innovation	0.454	0	1077	0.6275*	0.4219*							
4. Variety	1.016	-1.200	1077	0.1508*	0.1183*	0.1876*						
5. SSSW	0.940	-0.193	1076	0.0487	0.0485	0.0602*	0.0918*					
6. Sprof	0.996	-0.664	1024	0.1822*	0.1797*	0.1896*	0.1665*	0.2922*				
7. Internal OI	1.016	-1.353	1077	0.3046*	0.2384*	0.3489*	0.1436*	0.0635*	0.2040*			
8. External OI	0.984	-0.953	1077	0.4571*	0.4103*	0.3600*	0.0733*	0.1018*	0.1233*	0.3003*		
9. Size firm (log)	0.752	3.912	1077	0.1921*	0.1954*	0.1465*	-0.3707*	-0.0080	0.1867*	0.2601*	0.1660*	
10. Age	22.40	0	1067	0.2043*	0.1717*	0.1675*	0.0684*	-0.0116	-0.1182*	0.1353*	0.1007*	0.1656*

* P < 0.05

3.3 Models and estimations

Logit regression models for pooled data were used to test the hypotheses outlined in this paper. Models are estimated using robust standard errors for correlations within the observation of the same unit (firm) through several waves (*clusters*).

The first model, used to test *H1a* and *H1b*, is specified as:

+ (1)

Where: *y* is a dichotomist independent variable: to conduct or not conduct TI activities, and *i* the type of TI activity; *v* is the independent variable: *Variety*; and (*z*) is a vector of control variables.

Testing H1c and H1d was conducted through the following specification:

(2)

Where: *y, i* and *z,* are identical as described in (1); *s* is the independent variable: *Separation* and *j* the different separation measures (skill of the whole workforce and professionals).

We ran models with three different dependent variables to test the relationship between diversity and different types of innovation activities. There are no significant differences between the total number of firms that conducted any TI activity and those that conducted embodied TI activities. Only 13% of the firms that conducted TI activities did not conducted at least one TI activity embodied in artefacts. Meanwhile more than 40% of the firms that conducted TI activities did not conduct disembodied TI. Thus we only present the results for two types of innovation: the general measure of TI activities and the disembodied activities. For the latter, models were estimated only for a subsample of the firms which conducted TI activities.

All the control variables were tested in the econometric models but only the size of the firm, measured as the log of the number of employees, and the age of the firm show significant relationships with the dependent variables.

Finally, we tested OI moderating effects on the relationship between diversity and TI activities.

To test H2a we used the model:

(3)

Where: *y, i, v* and *z,* are identical as described in (1); *OI* is the moderating variable: Organisational Innovation and *g* are the different OI dimensions: internal and external.

To test H2b and H2c we ran a model specified as:

(4)

Where: *y, i, s, j* and *z,* are identical as described in (2); and *OI* and *g* are identical as is described in (3).

All the models were estimated in successive steps incorporating each variable in each new estimation (Tables 4-6)

Table 4. Results of logit regressions Models 1 and 2

	Dependent variable: Technological innovation					Dependent variable: Disembodied innovation				
	(1)	(2)	(2)	(2)	(2)	(1)	(2)	(2)	(2)	(2)
Models		Step 1	Step2	Step 1	Step 2		Step1	Step2	Step 1	Step 2
Variables										
Variety	0.526***					0.708***				
	(0.0904)					(0.119)				
SSW		0.276	0.853				0.289	0.429		
		(0.476)	(0.977)				(0.418)	(0.530)		
SSW squared			-0.0301					-0.0123		
			(0.0350)					(0.0193)		
Sprof				0.489***	0.633***				0.318**	0.398**
				(0.154)	(0.127)				(0.149)	(0.167)
Sprof Squared					-0.0423***					-0.0213*
					(0.0117)					(0.0115)
logSize	0.715***	0.393***	0.403***	0.291***	0.272***	0.540***	0.0502	0.0541	-0.0184	-0.0248
	(0.114)	(0.0958)	(0.0967)	(0.101)	(0.0998)	(0.135)	(0.110)	(0.110)	(0.112)	(0.112)
Age	0.0103***	0.0127***	0.0121***	0.0118***	0.0117***	0.00287	0.00541	0.00527	0.00541	0.00539
	(0.00333)	(0.00333)	(0.00341)	(0.00340)	(0.00342)	(0.00421)	(0.00425)	(0.00426)	(0.00433)	(0.00434)
Constant	-3.596***	-2.111***	-2.103***	-1.528***	-1.394***	-2.494***	-0.104	-0.115	0.238	0.282
	(0.554)	(0.470)	(0.468)	(0.499)	(0.492)	(0.670)	(0.546)	(0.545)	(0.566)	(0.568)
Observations	1,067	1,066	1,066	1,014	1,014	590	590	590	572	572

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 Results of logit regressions Model 3

	Dependent variable: Technological innovation				Dependent variable: Disembodied innovation			
Models	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2
Variables								
Variety		0.408***		0.454***		0.603***		0.660***
		(0.0934)		(0.109)		(0.118)		(0.117)
Internal OI	0.552***	0.465***			0.630***	0.552***		
	(0.0766)	(0.0757)			(0.0987)	(0.101)		
*Variety * OIint*		0.00377				0.0609		
		(0.0834)				(0.107)		
External OI			1.123***	1.085***			0.315***	0.311***
			(0.107)	(0.106)			(0.0988)	(0.106)
*Variety * OIext*				0.0865				0.261*
				(0.130)				(0.139)
logSize	0.258***	0.528***	0.277***	0.553***	-0.102	0.359***	0.0112	0.542***
	(0.0985)	(0.116)	(0.104)	(0.121)	(0.110)	(0.135)	(0.108)	(0.137)
Age	0.0122***	0.0103***	0.0133***	0.0112***	0.00646	0.00420	0.00538	0.00318
	(0.00332)	(0.00336)	(0.00356)	(0.00355)	(0.00426)	(0.00424)	(0.00427)	(0.00428)
Constant	-1.423***	-2.677***	-1.468***	-2.739***	0.488	-1.752***	-0.0254	-2.624***
	(0.480)	(0.566)	(0.519)	(0.600)	(0.547)	(0.674)	(0.543)	(0.681)
	1,067	1,067	1,067	1,067	590	590	590	590

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6 Results of logit regressions Model 4

	Dependent variable: Technological innovation	Dependent variable: Disembodied innovation										
Models	(4) Step 1	(4) Step 2	(4) Step 3	(4) Step 1	(4) Step 2	(4) Step3	(4) Step 1	(4) Step 2	(4) Step3	(4) Step 1	(4) Step 2	(4) Step3
Variables												
Sprof	0.371**	0.482***	0.521***	0.437***	0.626***	0.611***	0.264*	0.311*	0.552***	0.299**	0.403**	0.300***
	(0.151)	(0.121)	(0.142)	(0.144)	(0.148)	(0.186)	(0.155)	(0.168)	(0.182)	(0.145)	(0.167)	(0.112)
Sprof squared		-0.0305**	-0.0433		-0.0581***	-0.0547		-0.0131	-0.163***		-0.0435*	-0.0189
		(0.0137)	(0.0423)		(0.0176)	(0.0598)		(0.0123)	(0.0599)		(0.0248)	(0.0116)
Internal OI	0.518***	0.513***	0.387***				0.604***	0.600***	0.505***			
	(0.0813)	(0.0804)	(0.0931)				(0.102)	(0.102)	(0.105)			
*Sprof * OIint*	-0.100	-0.0444	-0.428***				-0.0790	-0.0550	-0.364*			
	(0.109)	(0.126)	(0.160)				(0.146)	(0.154)	(0.199)			
*Sprof squared * OIint*			0.220**						0.177**			
			(0.0985)						(0.0689)			
External OI				1.061***	1.051***	1.010***				0.323***	0.323***	0.290***
				(0.115)	(0.107)	(0.131)				(0.102)	(0.102)	(0.105)
*Sprof * OIext*				0.125	0.0836	-0.0679				0.0396	0.121	-0.0550
				(0.205)	(0.0787)	(0.257)				(0.137)	(0.123)	(0.160)
*Sprof squared **						0.0378						0.0482

OIext												
						(0.0725)						(0.0361)
logSize	0.192*	0.179*	0.157	0.215**	0.182*	0.178*	-0.139	-0.142	-0.165	-0.0455	-0.0579	-0.0781
	(0.103)	(0.103)	(0.102)	(0.107)	(0.106)	(0.107)	(0.113)	(0.113)	(0.113)	(0.111)	(0.111)	(0.111)
Age	0.0120***	0.0119***	0.0120***	0.0127***	0.0124***	0.0124***	0.00701	0.00697	0.00689	0.00555	0.00551	0.00541
	(0.00345)	(0.00346)	(0.00348)	(0.00361)	(0.00362)	(0.00362)	(0.00440)	(0.00440)	(0.00442)	(0.00441)	(0.00442)	(0.00441)
Constant	-1.043**	-0.959*	-0.800	-1.113**	-0.897*	-0.880*	0.653	0.676	0.895	0.246	0.334	0.503
	(0.509)	(0.503)	(0.501)	(0.534)	(0.530)	(0.533)	(0.567)	(0.568)	(0.573)	(0.561)	(0.560)	(0.568)
Observations	1,014	1,014	1,014	1,014	1,014	1,014	572	572	572	572	572	572

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4. Findings and final remarks

Empirical evidence supports the theoretical discussion presented in this paper. The econometric exercises reveal that variety and separation have different relationships with the probability that a firm conducts TI activities. The relevance of analysing several dimensions within the concept of diversity has therefore been corroborated.

The results confirmed a significant and positive relationship between *variety* in the specialisation of professionals and the implementation of TI activities. We confirmed *H1a* both for embodied and disembodied TI activities. It is worth noting that the relationship between variety of professional specialisations, *"what is the knowledge of those that have knowledge in a firm*" (Sutz, 2012: 51), is more intensive in those activities that involve the development of a firm's endogenous knowledge, disembodied TI. Therefore, we can also confirm *H1b* (Table 4).

The measures used to analyse the effect of separation on innovation behaviour demonstrated different results. Skill separation within the whole workforce of the firm (*SSW*) did not show a significant relationship with TI activities (Table 4), however separation measured through the specialisation of professionals (*numerati* and *literati*) showed a significant inverted U-shaped relationship with the probability of conducting both embodied and disembodied TI activities (Figure 3). *H1c* is thus partially confirmed, and *H1d* is confirmed.

We propose an interpretation in line with the original concept of separation (Harrison & Klein, 2007) and specifically with the relationship between *numerati* and *literati* proposed by Teece (2010). Innovations based on scientific and technological knowledge require articulation with management practices and business strategy in order to be successful. Since the capabilities of these firms are embedded in people, a balance between the professional specialisations should contribute to conducting TI activities. The result can then be interpreted as a positive effect up to a threshold where a higher separation – less balance between professional specialisations – has a negative effect. Low or high values of the threshold – less balance – therefore imply a lower effect on the propensity to conduct TI. In the specific context of Uruguayan industry, a more balanced professional staff appears to be an innovation requirement. Earlier studies show that Uruguayan industry has traditionally employed lawyers, and mostly accountants, and engineers and scientists have been scarcer (Berazategui et al., 2013).

With regard to the role of OI in the diversity-TI relationship, estimations suggest interesting results (Table 5 and 6). A positive and significant relationship between the probability of simultaneously conducting TI and OI – internal and external – has been confirmed through all the models tested (Table 5). This result is consistent with the theory and it was expected according to both international literature (Camisón & Villar-López, 2014; Battisti & Stoneman, 2010) and previous local studies (ANII, 2014), however, a complete interpretation of findings in the presence of moderating variables should take into consideration both individual and interaction effects (Aiken et al., 1991). Findings indicate that OI positively interacts with variety to explain the implementation of TI, but only for the adoption of external OI. This complementarity effect between external OI and variety is noticeable for disembodied TI (Figure 1).

Figure 1: Two-way interaction effect between Variety and External OI. Dependent Variable Disembodied TI activities.

There is no significant relationship between variety and internal OI. The complementary relationship between OI and skill workforce variety as stated in *H2a* is only partially confirmed.

Earlier studies of Uruguayan and Latin American innovative behaviour showed that the presence of professionals explains the collaborative innovation efforts of firms (ECLAC-IDRC, 2011). Our findings regarding the complementary effect of variety and external OI on TI offer more accurate knowledge about the determinants of collaborative innovation, showing that the presence of professionals and a minimal degree of variety within those professionals, is compatible with new collaborative innovation (external OI) in order to conduct disembodied TI.

The potential moderating effects were tested only for separation between highly skilled (professionals) employees. Separation in the skill workforce at an organisation level (*SSW*) does not have a statistical significant effect on TI adoption (Table 4). Estimation results allow us to partially confirm *H2b* and *H2c*. We found significant evidence of a U-shaped relationship between separation among professionals and the adoption of both embodied and disembodied TI activities (Figure 2). Moderate levels of separation between professionals promote higher levels of TI adoption, indicating that the more the “balance” between professionals categories, the more TI adoption.

Figure 2. Relationship between *separation* among professionals and the adoption of TI activities

The relationship between the probability of conducting TI activities and separation among professionals moderated by the adoption of internal OI is interesting and deserves cautious consideration. When a moderating OI effect is not considered, separation among professionals and TI shows a significant inverted U-shaped relationship. This result is in agreement with the theoretical and empirical literature (Lin, 2014) and corroborates our hypothesis, however, the estimation shows that internal OI adoption strongly moderates the effect of separation on TI activities. Estimation indicates that a balanced separation among professionals has a positive impact on TI when the firm has conducted internal OI (e.g. reducing hierarchical levels, information sharing, participatory decision-making initiatives). Conversely, firms which have a high separation among professionals and low internal OI activities – low participation channels and more hierarchical organisation – show a positive impact on the probability of conducting TI activities (Figure 3). This result opens a new research question rather than offering a conclusion. It suggests the effect of horizontal and participatory organisation design in highly diverse – measured as separation – firms. A first hypothesis could be that these firms required more and better central articulation than “balanced” firms.

Figure 3. Moderating internal OI effects on relationship between *separation* in skilled workers and TI activities

4.1 Final remarks

The research findings contribute to a comprehensive and in-depth study of the relationship between skill diversity and innovation in a low innovative context. Most of our hypotheses were confirmed, which corroborates the relevance of diversity as a determinant of the probability that a firm will conduct technological innovation activities. This paper also sheds light on the dimensions of these variables. Both TI and diversity require accurate measurement through dimension/indicators that allow the specific effects of some types of diversity on some types of TI to be distinguished.

Our research confirmed that when working with a representative longitudinal database for the entire manufacturing industry in a developing country, older and bigger firms will present a high propensity to conduct TI. The results also show that the high heterogeneity within sectors affects the significance of the activity sector as a TI predictor. Beyond these basic results that were previously known, this paper highlighted the relevance of a knowledge diversity embedded in professional trained people as a critical factor for conducting TI activities. Our result show a complementary effect between specific types of diversity and specific types of OI on the probability of conducting TI activities.

New research directions arise following these different results. Firstly, the necessity of a better understanding of the internal OI process, which allow analysis of the extent to which it is related to knowledge management. Arguably, future qualitative research is required to complement the survey analysis. Secondly, evidence of the relevance of professionals and external OI to conducting embodied TI stresses the need to improve our understanding of the sources of knowledge in a weak system of innovation and the specific role of skills diversity in recognising external sources of knowledge.

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