MANAGEMENT AND TECHNOLOGICAL INNOVATIONS: IS THERE A VIRTUOUS CIRCLE?

Meriam Attia, Ouidad Yousfi

Organizational and technological innovations: Is there a virtuous circle?

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Abstract

Purpose: The main aim of the current paper is to determine whether organizational innovations influence technological ones or vice versa.

Design /approach: This study is drawn a sample of listed firms on the SBF120[3] index and French Community Innovation Surveys (CIS)s carried out between 2004 and 2016.

Findings: Our study provides the following: First, we show that the introduction of new technological innovations could stimulate organizational changes in a firm's structure. Second, the adoption of new management practices is likely to increase the introduction of new processes, however, it is not sufficient to favor the development of new or significantly improved products.

Research limitations/implications: We studied different types of innovations, but we have ignored other forms of non-technological innovation, such as marketing innovations. It would be interesting to analyse the interaction between marketing and technological innovations.

Practical implications: From a business perspective, we emphasize that firms should introduce new organizational methods in the firm's business practices, workplace organization, or external relations, and adopt managerial transformations to boost their innovation potential.

Originality/value: To the best of our knowledge, this is the first paper that looks at the dynamic character between organizational and technological innovations, especially through a longitudinal study.

Keywords: Product innovation, process innovation outcomes, technological innovations, organizational innovations.

JEL Classification Codes: G30, O30, O31, M21

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[3] The SBF120 index consists of the largest 120 capitalizations listed on the French stock Exchange market (SBF: Société des Bourses Françaises).

1. Introduction

Innovation activities are traditionally perceived to comprise product and process innovation. Both types of innovation are often associated with the development or application of new technologies. Technological view on innovation has been well criticized: indeed, technological innovation deals with the introduction of new products and processes directly for customers (OCDE, 2005; Mairesse and Mohnen, 2005), while, organizational innovation describes the application of new and/or improved ideas and processes within the firm's workplace such as employee management, marketing, database management, distribution of responsibilities, and managing external relationships to help reduce costs and create value for the firm and other external stakeholders (Weerawardena, 2003; OECD, 2005; Chetty and Stangl, 2010; Damanpour and Aravind, 2012). Thus, innovation strategy cannot be focusing only on technological innovation (Cozzarin and Perzival, 2006). In France, for instance, 30% of firms have developed non-technological innovations and introduced new organizational methods between 2012 and 2014 (CIS 2014, Community Innovation Survey[4]).

Organizational innovation is a critical output for firms (Liao and Wu, 2010; Camisón and Villar-López, 2014; and Karlsson and Tavassoli, 2015), a source of value creation (Hwang et *al.*, 2008; Hamel, 2009), and an indicator for the intra-firm diffusion of different organizational practices (Armbruster et *al.*, 2008). Furthermore, organizational innovations could be a precondition for the development of new products, driven by the necessity of introducing changes in job positions and organizational processes to favor the introduction of new processes and new products (Damanpour and Gopalakrishnan, 2001; Arranz et *al.*, 2019; and Donbesuur et *al.*, 2020). Actually, organizational innovations such as improved communication channels, new relationships with external networks, and new and improved information sharing in international markets could improve firms' efficacy in new product introductions in the international markets, which in turn could improve the sales and profitability of these introductions. Thus, organizational innovations such as new or improved systems and structures are necessary conditions for a firm's overall innovativeness (Gunday et *al.*, 2011; and Donbesuur et *al.*, 2020).

[4] Insee (Institut national de la statistique et des études économiques)

Moreover, according to socio-technical system theory, any change in an organization's technological system requires changes in the administrative system to adjust to the demands created by the technological system. In other words, when a company introduces new products to the market, it could generate changes in the organizational infrastructure to design the production process and to effectively support the design and marketing of new products (Sapprasert and Clausen, 2012; Camisón and Villar López, 2014; Karlsson and Tavassoli, 2015). Therefore, a causality perspective should be adopted to achieve a better understanding of the interaction between organizational and technological innovations.

Despite the significance of organizational innovation, the number of studies on organizational innovation has only increased in recent years (Damanpour and Aravind, 2012; Doran, 2012; Camisón and Villar-López, 2014; Ballot et *al.*, 2015; Favoreu et *al.,* 2018; and Arranz et *al.*, 2019). Unlike technological innovation, the literature on organizational innovation is still scattered (Armbruster et *al.,* 2008; and Mol and Birkinshaw, 2009): The first studies have focused primarily on the determinants of organizational innovation (Hamel, 2006; Armbruster et *al.,* 2008; Birkinshaw et *al.,* 2008; Mol and Birkinshaw, 2009; and Battisti and Stoneman, 2010). They conclude that organizational innovation depends on several environmental or organizational factors, such as managerial knowledge, technological skills, and market (Schmidt and Rammer, 2007; and Damanpour et *al.,* 2018).

Another brand of the literature argues that there is a synergistic interaction between organizational and technological innovations (Piva et *al.,* 2005; Damanpour et *al.*, 2009; Battisti and Stoneman, 2010; Ballot et *al.,* 2015; and Arranz et *al.*, 2019). In fact, each innovation is specific, however, it is their combination that contributes to the firm's performance (Schmidt and Rammer 2007; Ballot et *al.* 2015; Arranz et *al.*, 2019; and Donbesuur et *al.*, 2020) conclude that firms need to combine organizational innovation with product and process innovation to achieve higher profit margins.

Then, several authors have extensively explored the complementarity link between organizational and technological innovations. (Piva and *al.,* 2005; Damanpour et *al.,* 2009; Battisti and Stoneman, 2010; Ballot et *al.,* 2015; Anzola-Román et *al.,* 2018; Azar and Ciabuschi, 2017; and Arranz et *al.,* 2019). Drawing upon two large samples of French and UK manufacturing firms using CIS4, Ballot et *al.* (2015) show how firms could take advantage of the interplay between different forms of innovation. They find conditional complementarities between product and process innovations in French and UK firms and between organizational and product innovations in French firms. They show that the presence of complementarities depends on the national context as well as on firm size and firm capabilities, this is consistent with the contingency perspective. In the same line, Doran (2012) analyses whether different forms of innovation act as complements or substitutes in Irish firms' production functions. He suggests that there is a substantial degree of complementarity among different forms of innovation. Out of six possible innovation combinations, three are complementary, and none exhibits signs of substitutability.

In the light of the previous discussion and to the best of our knowledge, there are no studies on the dynamic character between organizational and technological innovations. In other words, the existing literature has ignored the perspective of how increasing organizational innovations could influence technological ones and vice versa.

Furthermore, the existing evidence is based on cross-sectional method to assess the links between organizational and technological innovations (Doran, 2012; Camisón and Villar-López, 2014; and Azar and Ciabuschi, 2017). However, the cross-sectional nature of the data cannot capture the dynamic character in these associations. The use of longitudinal data, such as CIS data, over a long period can overcome such limitations and help to shed the light on how different innovation types could influence each other.

In the light of the previous discussion, we aim to contribute to the literature on how innovations could interact. To the best of our knowledge, there are no studies on the dynamic interaction between organizational and technological innovations. This study is conducted on longitudinal data from the Community Innovation Surveys (CIS)s carried out between 2004 and 2016 in firms listed on SBF120 index[5]. It determines how increasing organizational innovations could influence technological ones and vice versa.

[5] The SBF120 index consists of the 120 largest capitalizations listed on the French Stock Exchange market (SBF: Société des Bourses Françaises).

The choice to focus on the French market is timely because of the huge number of initiatives and programs introduced to foster innovation in the last years (EUROPE 2020, Horizon 2020, Innovate Europe[6], Entrepreneurship and Innovation Program[7], the European Innovation Council EIC, and the EU Agency on disruptive innovation and Bpifrance). In 2020, France has the 12th position in the Global Innovation Index GII (16th position in 2019). [8]

This paper provides the following results:

First, our findings highlight that introducing successful technological innovations would be constrained to reorganize their production, workforce, sale, and distribution systems (Mohnen and Röller, 2005; Polder et *al.,* 2010; Gunday et *al.,* 2011; and Donbesuur et *al.,* 2020). This result is in line with Camisón et *al.* (2010) who show that innovation process could generate organizational innovation through the adaptation of job positions to the new process.

Second, our study puts forward that organizational changes, help firms to easily introduce a successful process innovation (Damanpour and Gopalakrishnan, 2001). They are a necessary precondition for process innovation to be fully implemented and exploited (Lam, 2005, and Donbesuur et *al.,* 2020). Also, they could enhance coordination and cooperation mechanisms inside organizations, which, in turn, create an appropriate environment for the adoption of process innovation (Gunday et *al.,* 2011).

However, our study provides evidence that implementing new advanced management practices is not sufficient to favor the development of new products. One explanation is that product innovation is multidimensional. It depends on appropriate organizational infrastructure, engineering, and technology skills to design the process production, layout, and logistics to effectively support the new product design and its commercialization (Camisón and Villar López, 2014). Our result is not consistent with previous findings (Arranz et *al.,* 2019) arguing that innovation capabilities operate through reciprocity and complementary relation, where technological product and organizational innovation are all determining factors of one another.

[6] https://www.eppgroup.eu/newsroom/publications/innovate-europe-we-put-people-at-the-heart-of-innovation
[7] http://ec.europa.eu/cip/eip/index_en.htm
[8] https://www.capital.fr/entreprises-marches/la-france-bondit-au-classement-mondial-de-linnovation-1379354

This paper is structured in the following. The literature review and hypotheses are presented in section (1). The data and methodology are detailed in the "Sample and Research Design" section. Section (3) discusses the models and the results. The last section concludes the study and presents future research perspectives.

2. Literature review and hypotheses

According to resource-based perspectives, firm's superior performance depends on its capacity to deploy these resources using organisational processes (Barney et *al.*, 2001). In fact, organizational innovation in business practices, innovations in workplace organization, or new organizational methods in external relations could favor a more efficient organization, innovative manufacturing, and technological processes (Lam, 2005; Camisón and Villar-López, 2014).

Moreover, the dynamic capabilities perspective describes how managers acquire resources, alter the resource base, integrate, and recombine these resources to create firm value. Thus, these capabilities are made up of both organizational and managerial routines that help in coordinating, learning, and resource reconfiguration (Easterby-Smith et *al.,* 2009; Prange and Verdier, 2011; Michailova and Zhan, 2015; and Lewandowska et *al.*, 2016). Indeed, introducing a new organizational structure to facilitate teamwork and project type organization, or introducing a new human resources management system leads to enhanced intra-organizational coordination and cooperation mechanisms, which, in turn, create an appropriate environment for the adoption of product and process (Gunday et *al.*, 2011).

In the same vein, Prajogo and Sohal (2006) observe that quality control in a company improves technological innovation when developing a product. They underline that adequate organizational innovation, for example, job task design, affects the efficiency of the new product development process. Moreover, Teece (2010) shows that in order to profit from process innovations, firms must adopt new organizational methods. For example, business practices such as quality control can promote an increase in efficiency, and therefore, could improve the capability to develop process innovation (Damanpour and Gopalakrishnan, 2001; and Shoenmakers and Duysters, 2006).

In addition, using a set of innovative work practices such as teams, flexible job assignments, or training leads to higher output levels and product quality (Mol and Birkinshaw, 2009). Hence, organizational innovation could be a precondition for the development of new products, meeting the necessity of introducing changes in job positions and in organizational processes to facilitate the new product development.

Regarding the reciprocal interactions between technological innovation and organizational innovation, it has been argued that, according to socio-technical system theory (Emery and Trist, 1965; Damanpour and Gopalakrishnan, 2001), any change in an organization’s technological system requires changes in the administrative system to adjust to the demands created by the technological system (Arranz et *al.*, 2019). In the other world, the introduction of a flexible production system leads to changes in the way tasks and job shifts are assigned. Hence, the development of a new production process could generate organizational innovation through the adaptation of job positions to the new process (Camisón et *al.*, 2010).

To fully understand the drivers of organizational innovation, it is necessary to analyze the history of the firm's innovations. Organizational changes have been shown to be arising from the development of the latest innovations in firms (Sapprasert and Clausen, 2012; Karlsson and Tavassoli, 2015). Indeed, when a company introduces new products to the market, it could generate changes in the organizational infrastructure to design the production process and effectively support the design and marketing of new products (Sapprasert and Clausen, 2012; Camisón and Villar López, 2014; and Karlsson and Tavassoli, 2015). In the same vein, Danneels (2002) focuses on the impact of product innovation on organizational innovation and concludes that technological innovation is likely to induce organizational changes in the firm.

Therefore, firms embracing organizational changes as an ongoing effort and part of their organizational routines are prone to foster continuous improvements in the technological sphere. Adopting organizational innovation could enhance a firm’s overall innovativeness (Gunday et *al.*, 2011). Similarly, to introduce successful technological innovations, firms would be constrained to reorganize their production, workforce, sale, and distribution systems (Mohnen and Röller, 2005; and Polder et *al.*, 2010). The extant literature is silent and provides limited insights on the extent to which organizational innovations could generate technological ones or vice versa. In light of the previous discussion, this study supposes that there could be a dynamic interaction between organizational and technological innovations. It assumes that there could be a virtuous circle between these types of innovation.

H1a: The introduction of new organizational practices is likely to favor the development of new processes and vice versa.

H1b: The introduction of new organizational practices is likely to drive the development of new products and vice versa.

3. Sample and Research Design

3.1. Sample and data collection process

The study is conducted on firms[9] listed on the SBF120 index between 2004 and 2016. Governance and ownership structure datasets are hand-collected from annual reports available on the firms' websites. Based on Factset-IODS and Bloomberg databases, we have collected the financial dataset. Finally, innovation datasets are provided by the Community Innovation Surveys (CIS) and the R&D surveys of the INSEE[10].

3.2. Variables and measures

Table (1) lists the definition of all the variables used in this analysis.

Innovation variables are taken from a question on CIS survey. The question defined product innovation as the market introduction of a new good or service or significantly improved good or service respective to functionalities. In line with Galia and Zenou (2013) and Attia et *al.*, (2020), we defined product innovation **(PROD)** as a dummy variable equal to 1, if the firm has introduced at least a new good/service or significantly improved existing good/service, and 0 otherwise. Similarly, we defined process innovation **(PROC)** as a dummy variable equal to 1, if

[9] This study does not exclude firms belonging to the banking and finance sector (Financial services firms) from the final sample. In our sample, we have 12% of firms belonging to the financial sector have introduced organizational innovations.

[10] https://www.insee.fr/en/statistiques/4631323?sommaire=4631329

the firm has introduced at least a new or a significantly improved process in the production/supply procedures, and 0 otherwise. Finally, organizational innovation **(OI)** is defined as a dummy variable equal to 1, if the company has been successfully engaged in any type of organisational innovation, and 0 otherwise.

Moreover, directors board could provide large and diverse resources to the firms, such as strategic advice, knowledge, and networking which could be value-enhancing for innovation (Talke et *al.*, 2010; Torchia et *al.*, 2011; Pathan and Faff, 2013; Galia and Zenou, 2013; Galia et *al.*, 2015, Attia et *al.*, 2020). In fact, directors could have a positive impact on innovation (Torchia et *al.*, 2011; Pathan and Faff, 2013). Thus, we introduce in our analysis board variables that could affect the relationship between organizational and technological innovations.

- **IND** is the percentage of independent directors on board. The board independence has been one of the indicators that reflect corporate transparency. Board independence could be an innovation catalyst based on the previous literature (Attia et *al.*, 2020; Lu and Wang, 2018).
- **GEN** is the percentage of female directors on boards. After the introduction of the gender quota law of Copé-Zimmermann in 2011, French companies have to appoint at least 40% of female directors. Attia et *al.* (2020) and Diaz-Garcia et *al.* (2013) argued that gender diversity could increase innovation. Female directors generate a certain dynamism and creativity that promote radical innovation.
- **FOR** is the percentage of foreign directors on board. Directors of different ethnic backgrounds may stimulate a firm to improve or develop new products sold abroad as they also possess knowledge about global markets and customers' tastes (Kerr and Lincoln, 2010), this could stimulate innovation.
- **SIZE** is the total number of directors on board. A larger board size can grant resourceful coalition (Xie et a*l.*, 2009). In line with the dependence resource theory, more directors provide more resources and ideas.
- **CEO-TEN** is the CEO tenure and it is given by the number of years since the executive has been appointed to the CEO position.

- **DUL** is a dummy variable that takes 1 if the company has CEO-Chair dual structure. The CEO duality establishes strong leadership. Indeed, the separation between the management function of the CEO and the control function of the chairman reduces the disciplinary power which harms innovation. Yet, Blibech and Berraies (2018) found a negative effect of the CEO duality on innovation since it might stimulate the CEO opportunistic behavior.

In addition, ownership structure is a critical determinant when it comes to innovation strategy (Chang et *al.*, 2006; Belloc, 2011; Choi et *al.*, 2012; Lodh et *al.*, 2014; Diéguez-Soto et *al.*, 2016). In line with Singh and Vinnicombe (2003), Terjesen et *al.* (2009), and Nekhili and Gatfaoui (2013), we add ownership structure in our models:

- **IN-O** is the share of capital held by institutions. Indeed, institutional investors foster innovation by reducing career risks (Aghion et *al.*, 2013; Schain and Stiebale, 2020).
- **ST-O** is the state ownership measured by the share of capital held by the State. Wang et *al.* (2019) claimed that governmental ownership provides support that enhances innovation.
- **FO-O** is the share of capital held by foreign investors. Guadalupe et *al.* (2012) concluded that foreign owners drive product and process innovation and foster foreign technology adoption.
- **FA-O** is the share of capital owned by family members. Indeed, 2/3 of firms listed on the French Stock Exchange are family firms (Nekhili et *al.*, 2019).

Furthermore, we introduce some financial characteristics of the firm such as firm's size **(TA)** is the total assets. Subrahmanya (2015) shows that smaller companies have greater better flexibility. They can develop and implement easier new innovative ideas. Yet, size might indicate better solvency and higher financial capacities due to the economy of scale, which supports innovation. Turning to the financial structure we use:

- **LEV** is the debt book to total asset ratio. It measures corporate leverage. Indeed, increasing the corporate debt affects corporate innovation negatively. It increases the risk level, which in return limits the innovation investment (Attia et *al.*, 2020).

- **ROA** (Return on assets) is an indicator of financial performance. It reflects the ability of the company to honor its engagements (Lee et *al.*, 2016; Lin et *al.*, 2011)
- **R&D** is the expenses to total assets ratio R&D (see among others Lin et *al.*, 2011; Attia et *al.*, 2020, Loukil et *al.*, 2020).

Finally, we consider industry dummy variables to control for industry effects.

Table 1: Variable definition

Variable	Definition
Innovation variables	
PROD	Is a dummy variable equal to 1, if the firm has introduced at least a new good/service or significantly improved existing good/service, and 0 otherwise.
PROC	Is a dummy variable equal to 1, if the firm has introduced at least a new or a significantly improved process in the production/supply procedures, and 0 otherwise.
OI	is a dummy variable equal to 1, if the company has been successfully engaged in any type of organisational innovation, and 0 otherwise.
Board variables	
FOR	Is the percentage of foreign directors on board.
IND	Is the percentage of independent directors on board.
GEN	Is the percentage of female directors on board.
CEO-TEN	Is the number of years since the executive has been appointed to the CEO position.
DUL	Is a dummy variable equal to 1, if the CEO is also the chairman of the board, and 0 otherwise.
SIZE	Is the total number of directors on board.
Control variables	
IN-O	Is the institutional investors' share of capital.
ST-O	Is the state's share of capital
FO-O	Is the foreign investors' share of capital.
FA-O	Is the family's share of capital.
TA	Is the total asset
ROA	Is the return on asset ratio.
LEV	Is the ratio of debt book value to total assets.
Industry	Are dummy sectors
R&D	Is the R&D expenses to total assets ratio.

3.3. Descriptive statistics

The sample consists of 120 listed companies on the SBF120 index between 2004 and 2016**:** 20% of the firms belong to the consumer goods, and services, 24% of the firms belong to the technology and communication sector. Almost 21% are in the machinery and industrial sector, and 15% are in the banking and finance sector (Table 2).

Table 2: Sample composition

Industry	Percentage (%)
Technology and Communication	24
Consumer goods and services	20
Industrials	20.70
Financial	15
Utilities	4.15
Drugs and Healthcare	7
Oil and Gas	4.15
Basic Materials	5

Statistics on innovation measures (Table.3, Panel A) show that only 19.09% of firms have introduced a new or a significantly improved product or service, 18.38% have implemented a new or a significantly improved process, and 26.32% have been successfully introduced management innovations. Innovation proxies seem lower in our sample than in some other studies. For instance, Galia and Zenou (2013) found that 65% of firms have implemented product innovation, thus introduced at least a new or significantly improved good or service, 63% of firms have implemented process innovation from 2006 to 2008. With only one type of innovation studied, Østergaard et *al*. (2011) found that 55% of firms of their sample implemented product innovation from 2003 to 2005. In fact, their studies have been conducted on larger samples of listed and non-listed firms.

Furthermore, in line with Godard and Schatt (2005), descriptive statistics on board directors (Table 3, Panel B) show that the average board consists of 12 members, half of them (50%) are independent and 20% have a foreign nationality. We underline that the percentages of independent and foreign directors significantly vary among firms, particularly in multinational companies. Regarding gender diversity, the percentage of female directors on boards is almost 18% despite the introduction of gender legislation on board composition.

Finally, the average CEO tenure is almost 7.5 years. Furthermore, despite the New Economic Regulation (NRE)[11] act passed in 2001 on the separation between control and management functions, 55.56% of boards display dual structure (Table.3, Panel A).

Table 3: Descriptive statistics of variables

Panel (A). Descriptive statistics of qualitative variables: Table of frequencies

Variables		N	Percentage (%)
PROD	0	568	80,91
	1	134	19,09
PROC	0	573	81.62
	1	129	18.38
OI	0	518	73.68
	1	185	26.32
DUL	0	312	44.44
	1	390	55.56

Panel (B). Descriptive statistics of quantitative variables

Variable	Obs	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
FOR	702	20.19281	20.01874	0	95.45454	1.269866	4.563018
IND	702	49.79591	21.60189	0	100	-.0098385	2.759103
GEN	702	17.6465	13.79327	0	57.27273	.3991883	2.127211
CEO-TEN	703	7.517781	8.162045	0	46.5	1.349185	7.119305
SIZE	702	12.40741	3.475609	0	23	.0837806	2.990964
ROA	701	3.788092	5.878992	-38.73175	53.32191	-.5975894	20.35753
LEV	695	24.9085	15.04501	.1467355	74.50291	.3609613	1.935184
IN-O	702	32.06893	24.78117	0	89.3595	.3609613	1.935184
ST-O	702	4.427831	14.92768	0	94.25	4.145128	20.67524
FA-O	702	8.773573	17.61349	0	80.45	2.06652	6.23012
FO-O	702	11.12875	16.93292	0	90.725	2.070482	7.227676
TA	701	76705.66	260758	26.3283	2035576	5.259083	32.34139
R&D	702	.0007183	.0046295	0	.073609	10.23015	128.2471

[11]https://www.diplomatie.gouv.fr/IMG/pdf/Mandatory_reporting_built_on_consensus_in_France.pdf

Notes: PROD is a dummy variable equal to 1, if the firm has introduced at least a new good/service or significantly improved existing good/service, and 0 otherwise. PROC is a dummy variable equal to 1, if the firm has introduced at least a new process in the production/supply procedures, and 0 otherwise. OI is a dummy variable equal to 1, if the company has successfully engaged in any type of organizational innovation, and 0 otherwise. FOR is the percentage of foreign directors on board. IND is the percentage of independent directors on the board. GEN is the percentage of female directors on the board. CEO-TEN is given by the number of years since the executive has been appointed to the CEO position. DUL is a dummy variable equal to 1, if the CEO is also the chairman of the board, and 0 otherwise. SIZE is the total number of directors on board. IN-O is the institutional investors' share of capital. ST-O is the state's share of capital. FO-O is the foreign investors' share of capital. FA-O is the family's share of capital. TA is the total asset. ROA is the return on asset ratio. LEV is the debt book value to total assets. R&D is the R&D expenses to total assets ratio.

Table 4: Industry distribution of firms with organizational innovation

Industry	Percentage (%)
Technology and Communication	10.34
Consumer goods and services	41.37
Industrials	15.51
Financial	12.06
Utilities	6.89
Drugs and Healthcare	5.17
Oil and Gas	0.04
Basic Materials	8.62

Table (4) shows that 58 firms operating in varied industries, have introduced organizational innovations between 2004 and 2016: 41.37% of firms are in consumer goods and services sector while 15.51% of firms belong to the industrial sector, and 12% are financial institutions.

The correlation matrix in table (5) shows some significant coefficients that exceed 0.5. However, the variance inflation factor values range from 1.08 to 1.34: They are below the accepted threshold of 2. Accordingly, we conclude that there is no multicollinearity problem.

Table (6) presents the mean difference tests between firms with at least one innovation and firms without innovation. In line with Attia et *al.* (2020), it shows that, on average, innovative firms have large boards and spend more money in R&D activities. However, non-innovative firms display a significantly high percentage of foreign directors on board. Finally, the table reports that firms with family ownership are more prone to introduce innovation.

Table 5: Pearson Correlation Matrix

	PROD	PROC	OI	R&D	CEO-TEN	DUL	IND	FOR	GEN	SIZE	ROA	LEV	INT-O	ST-O	FA-O	FOR-O	TA
PROD	1																
PROC	0.8833*	1															
	(0.0000)																
OI	0.2443*	0.2171*	1														
	(0.0000)	(0.0000)															
R&D	0.1205*	0.0979*	0.0932*	1													
	(0.0014)	(0.0094)	(0.0135)														
CEO-TEN	0.0122	0.0129	-0.0233	0.1318*	1												
	(0.7463)	(0.7327)	(0.5377)	(0.0005)													
DUL	0.0916*	0.1061*	0.0470	-0.0113	0.1450*	1											
	(0.0152)	(0.0049)	(0.2136)	(0.7653)	(0.0001)												
IND	-0.0292	-0.0070	0.1044*	-0.0135	-0.122*	-0.083*	1										
	(0.4400)	(0.8540)	(0.0056)	(0.7207)	(0.0012)	(0.0273)											
FOR	-0.154*	-0.145*	-0.0184	-0.074*	-0.0210	-0.0394	0.2630*	1									
	(0.0000)	(0.0001)	(0.6267)	(0.0486)	(0.5791)	(0.2969)	(0.0000)										
GEN	-0.0191	-0.0398	0.0528	-0.155*	0.0665	0.0921*	0.0654	0.1264*	1								
	(0.6136)	(0.2923)	(0.1622)	(0.0000)	(0.0782)	(0.0146)	(0.0835)	(0.0008)									
SIZE	0.1251*	0.1344*	0.1132*	-0.110*	-0.124*	0.0723	-0.0448	-0.0157	0.0294	1							
	(0.0009)	(0.0004)	(0.0027)	(0.0033)	(0.0009)	(0.0555)	(0.2356)	(0.6778)	(0.4363)								
ROA	0.0494	0.0569	0.0419	0.0847*	0.0792*	0.0086	-0.082*	-0.0218	-0.0721	-0.0724	1						
	(0.1910)	(0.1326)	(0.2685)	(0.0249)	(0.0361)	(0.8196)	(0.0298)	(0.5648)	(0.0562)	(0.0555)							
LEV	-0.0204	-0.0430	-0.077*	-0.085*	-0.098*	0.0056	-0.0189	-0.0167	0.0168	0.1578*	-0.183*	1					
	(0.5911)	(0.2571)	(0.0414)	(0.0246)	(0.0096)	(0.8824)	(0.6189)	(0.6599)	(0.6575)	(0.0000)	(0.0000)						
INT-O	-0.0252	-0.0683	0.0156	-0.0544	-0.0651	0.0175	0.0417	0.0575	0.4020*	0.1631*	-0.0631	0.1050*	1				
	(0.5052)	(0.0707)	(0.6804)	(0.1500)	(0.0849)	(0.6427)	(0.2694)	(0.1280)	(0.0000)	(0.0000)	(0.0951)	(0.0056)					
ST-O	0.0416	0.0477	0.0244	-0.0405	-0.110*	0.0921*	-0.206*	-0.078*	0.0640	0.363*	-0.096*	0.0147	0.1777*	1			
	(0.2711)	(0.2072)	(0.5186)	(0.2835)	(0.0034)	(0.0146)	(0.0000)	(0.0387)	(0.0902)	(0.0000)	(0.0106)	(0.6983)	(0.0000)				
FA-O	0.1268*	0.0979*	0.1060*	0.0239	0.1618*	-0.0482	-0.148*	-0.0377	0.0026	-0.134*	0.1150*	-0.154*	-0.127*	-0.13*	1		
	(0.0008)	(0.0095)	(0.0049)	(0.5277)	(0.0000)	(0.2026)	(0.0001)	(0.3189)	(0.9460)	(0.0003)	(0.0023)	(0.0000)	(0.0007)	(0.0005)			
FOR-O	-0.120*	-0.121*	-0.0316	-0.0147	-0.098*	0.0074	0.1152*	0.1913*	0.0556	-0.0311	0.0466	0.0490	0.2235*	-0.09*	-0.17*	1	
	(0.0014)	(0.0013)	(0.4026)	(0.6974)	(0.0090)	(0.8441)	(0.0022)	(0.0000)	(0.1411)	(0.4101)	(0.2183)	(0.1973)	(0.0000)	(0.0095)	(0.0000)		
TA	0.0194	-0.0146	0.1232*	-0.0391	-0.096*	-0.103*	-0.0112	-0.0256	0.1091*	0.3212*	-0.134*	0.1643*	0.1076*	0.0366	-0.11*	-0.08*	
	(0.6089)	(0.6998)	(0.0011)	(0.3015)	(0.0108)	(0.0061)	(0.7671)	(0.4983)	(0.0038)	(0.0000)	(0.0004)	(0.0000)	(0.0044)	(0.3331)	(0.0018)	(0.0306)	1

Notes: PROD is a dummy variable equal to 1, if the firm has introduced at least a new good/service or significantly improved existing good/service, and 0 otherwise. PROC is a dummy variable equal to 1, if the firm has introduced at least a new process in the production/supply procedures, and 0 otherwise. OI is a dummy variable equal to 1, if the company has successfully engaged in any type of organizational innovation, and 0 otherwise. FOR is the percentage of foreign directors on the board. IND is the percentage of independent directors on the board. GEN is the percentage of female directors on the board. CEO-TEN is given by the number of years since the executive has been appointed to the CEO position. DUL is a dummy variable equal to 1, if the CEO is also the chairman of the board, and 0 otherwise. SIZE is the total number of directors on board. IN-O is institutional investors' share of capital. ST-O is the state's share of capital. FO-O is the foreign investors' share of capital. FA-O is the family's share of capital. TA is the total asset. ROA is the return on asset ratio. LEV is the debt book value to total assets. R&D is the R&D expenses to total assets ratio. * significant at the 5% levels.

Table 6: Mean difference tests between firms with at least one innovation and firms without any innovation

Variables	OI			PROC			PROD		
	0	1	MDT	0	1	MDT	0	1	MDT
FOR	20.41	19.58	0.84	21.58	14.04	7.53***	21.69	13.83	7.87***
GEN	17.21	18.86	-1.65	17.91	16.49	1.42	17.77	17.10	0.67
IND	48.58	53.56	-4.98**	49.99	49.48	0.51	50.22	48.50	1.72
CEO-TEN	7.63	7.20	0.43	7.47	7.72	-0.25	7.47	7.73	-0.26
SIZE	12.17	13.06	-0.89**	12.19	13.39	-1.21***	12.20	13.30	-1.11***
ROA	3.64	4.20	-0.56	3.63	4.49	-0.86	3.65	4.39	-0.74
LEV	25.55	22.96	2.59**	25.17	23.55	1.63	25.01	24.28	0.74
IN-O	31.84	32.71	-0.88	32.87	28.51	4.36*	32.07	30.78	1.28
ST-O	4.21	5.04	-0.83	4.09	5.93	-1.84	4.13	5.71	-1.58
FA-O	7.66	11.89	-4.24**	7.96	12.40	-4.45**	7.69	13.37	-5.68***
FO-O	11.45	10.23	1.22	12.10	6.81	5.29***	12.12	6.92	5.20***
LnTA	10.96	11.78	-0.82***	11.27	11.14	0.13	11.22	11.37	-0.16
LnR&D	0.001	0.002	-.001**	0. 0005033	0.00	-.0011698**	0.002	0.003	-.001***

Notes: FOR is the percentage of foreign directors on board. IND is the percentage of independent directors on board. GEN is the percentage of female directors on board. CEO-TEN is given by the number of years since the executive has been appointed to the CEO position. SIZE is the total number of directors on board. IN-O is the institutional investors' share of capital. ST-O is the state's share of capital. FO-O is the foreign investors' share of capital. FA-O is the family's share of capital. TA is the total asset. ROA is the return on asset ratio. LEV is the debt book value to total assets. R&D is the R&D expenses to total assets ratio. *, **, *** indicate statistical significance at 10%, 5%, and 1% levels

4. Empirical model

To assess the association between organizational innovation and technological innovations. In the first time, we consider a bivariate logit regression:

$$INNOV_{i,t}=\beta_0+\beta 1*OI_{i,t}+\sum\beta 2*X_{i,t}+\varepsilon_{i,t} \quad \textbf{(1)}$$

$$OI_{i,t}=\beta_0+\beta 1*INNOV_{i,t}+\sum\beta 2*X_{i,t}+\varepsilon_{i,t} \quad \textbf{(2)}$$

Where $\boldsymbol{INNOV_{i,t}}$ is the measure of product and process innovations of the firm i, at the year t. It could be $\boldsymbol{PROD_{i,t}}$, $\boldsymbol{PROC_{i,t}}$. $\boldsymbol{OI_{i,t}}$ is a dummy variable equal 1 is the firm i has introduced an organizational innovation at the year t. $\mathbf{X_{i,t}}$ is the independent variables that could affect the relationship between *OI* et *INNOV*. $\mathbf{X_{i,t}}$ consists of board characteristics (the percentage of independent directors **IND**, foreign directors **FOR**, women directors **GEN**, size of board **SIZE**, duality **DUL**, and CEO tenure **CEO-TEN**), ownership structure (**FAM-O**, **FOR-O, ST-O,** and **IN-O**), some financial characteristics of the firm (Firm's size **LnTA**, industrial affiliation), and financial structure (Return on asset **ROA**, debt ratios **LEV,** and the ratio of R&D expense **LnR&D**).

Then, to provide a better understanding of causality between technological and organizational innovations, we perform the Granger causality test (Granger, 1969): the most common methodology for evaluating the nature of the causal relationship between two variables. Specifically, we test whether technological innovations are Granger-caused by organizational innovation or the reverse.

Table 7: Results of logit regressions and Granger causality test

Logit regressions				
Variables	PROC	PROD	OI	OI
OI	1.27** (-2.82)	1.71*** (-3.43)		
PROD			1.70*** (-3.85)	
PROC				1.27** (-3.07)
DUL	0.97*	0.99*	-0.11	-0.13
	(-1.77)	(-1.80)	(-0.29)	(-0.33)
CEO-TEN	-0.03	-0.03	0.01	0.01
	(-0.85)	(-0.68)	-0.41	-0.46
FOR	-.05**	-.07**,	0.01	0.01
	(-2.74)	(-3.15)	-0.70	-0.56
IND	0.01	0.01	0.01	0.01
	-0.94	-0.78	-1.38	-1.42
GEN	-0.01	0.02	0.01	0.01
	(-0.38)	-0.86	-1.07	-1.18
SIZE	0.15	0.12	0.05	0.06
	-1.52	-1.09	-0.65	-0.75
INT-O	0.00	0.00	0.00	0.00
	(-0.02)	(-0.32)	(-0.05)	-0.01
LN-ST-O	-0.40	-0.39	0.07	0.06
	(-1.18)	(-1.04)	-0.32	-0.28
LN-FA-O	0.15	0.19	0.18	0.18
	-0.64	-0.78	-1.16	-1.17
LN-FOR-O	-.36*	-0.16	0.01	0.01
	(-1.73)	(-0.78)	-0.08	-0.11
ROA	0.06	0.06	-0.01	-0.01
	-1.11	-1.03	(-0.29)	(-0.30)
LEV	-.04*	-0.03	-0.03	-0.03
	(-1.66)	(-1.24)	(-1.62)	(-1.59)
LnR&D	0.00	0.00	.002*	.002*
	-1.11	-0.97	-1.65	-1.71
LnTA	0.68	1.06	0.41	0.44
	-1.01	-1.47	-0.97	-1.03
Industry-effect	YES	YES	YES	YES
Const	-6.34**	-8.46**	-5.11**	-5.23***
	(-2.50)	(-3.00)	(-3.16)	(-3.20)
N	664	696	689	689
N of firms	111.00	117.00	116.00	116.00
Wald chi2	33.78	33.47	36.84	32.60
P> chi2	0.04	0.06	0.02	0.05
Causality Wald Test				
OI	5.833** (0.045)	0.366 (0.545)		
PROC			5.498** (0.019)	
PROD				5.037** (0.025)

Notes: PROD is a dummy variable equal to 1, if the firm has introduced at least a new good/service or significantly improved an existing good/service, and 0 otherwise. PROC is a dummy variable equal to 1, if the firm has introduced at least a new process in the production/supply procedures, and 0 otherwise. OI is a dummy variable equal to 1, if the company has successfully engaged in any type of management innovation, and 0 otherwise. FOR is the percentage of foreign directors on the board. IND is the percentage of independent directors on the board. GEN is the percentage of female directors on the board. CEO-TEN is given by the number of years since the executive has been appointed to the CEO position. DUL is a dummy variable equal to 1, if the CEO is also the chairman of the board, and 0 otherwise. SIZE is the total number of directors on the board. IN-O is the institutional investors' share of capital. ST-O is the state's share of capital. FO-O is the foreign investors' share of capital. FA-O is the family's share of capital. TA is the total asset. ROA is the return on asset ratio. LEV is the debt book value to total assets. R&D is the R&D expenses to total assets ratio.
*, **, *** indicate statistical significance at 10%, 5%, and 1% level of significance, respectively.

Bivariate logit regressions in the table (7) confirm that technological and organizational innovations are interconnected. Our findings provide evidence that there is a close relationship between organizational and technological innovations (Damanpour and Gopalakrishnan, 2001; Camisón et *al.,* 2012; and Hervas-Oliver et *al.,* 2012). Our results are consistent with previous findings (Damanpour and Gopalakrishnan, 2001; and Hervas-Oliver et *al.,* 2012) arguing that organizational innovations are beneficial for other types of innovation, especially process innovation (Hollen et *al.*, 2013), and for product innovation (Doran, 2012).

Moreover, the Granger causality test (Table 7) confirms the existence of a reciprocity relation between organizational and process innovation: OIs drive, in the Granger sense, more PROC innovations and vice versa. It seems, therefore, there is a virtuous circle between these types of innovation. We can accept ***H1a.***

Our findings conclude that the development of innovation process could generate organizational innovation through the adaptation of job positions to the new process. Indeed, the introduction of a flexible production system could lead to changes in the way tasks and job shifts are assigned (Camisón et *al.,* 2010). For instance, when a firm adopts a quality system in the control of production, it drives many changes in processes (Damanpour, 2010).

Similarly, organizational changes, such as improving job task design, inter-organizational collaboration, or developing business practices, could easily introduce a successful process innovation (Damanpour and Gopalakrishnan, 2001). In other words, organizational innovation seems to be a necessary precondition for process innovation to be fully implemented and exploited (Damanpour et *al.*, 1989; Lam, 2005). This result is in line with Gunday et *al.* (2011), based on an empirical study of manufacturing firms in Turkey, they find that structural improvements stimulated by organizational innovations (for example, introducing a new organizational structure to facilitate teamwork and project type organization, introducing a new human resource management system) enhances intra-organizational coordination and cooperation mechanisms. They, in turn, could create an appropriate environment for the adoption of process innovation.

Surprisingly, when we focus on product innovation, Granger causality test shows that causality runs in one direction from innovation product to organizational innovation. Hence, we reject ***H1b***. Our finding underlines that the development of new products is likely to increase organizational changes in firm's structure (Mohnen and Röller 2005; Polder et *al.*, 2010). According to socio-technical system theory, when a company introduces new products to the market, it generates changes in the organizational infrastructure in order to design the production process and effectively support the design and marketing of new products (Camisón and Villar López, 2014). However, the introduction of new organizational practices does not necessarily lead to the development of product innovation. Our results provide evidence that implementing new advanced management practices is not sufficient to favor product innovation. One explanation is that product innovation is multidimensional. It depends on appropriate organizational infrastructure, engineering, and technology skills to design the process production, layout, and logistics to effectively support the new product design and its commercialization (Camisón and Villar López, 2014). This is in line with Prajogo and Sohal (2006), who demonstrate that only simply implementing new advanced management practices (OI) is not sufficient to favor product innovation. For instance, the use of total quality management does not directly favor product innovation if that relationship is mediated by technology and R&D management. Another explanation is that in the current study we have analyzed only direct association between technological and organizational innovations without exploring the moderating channels through which they could interact.

In addition, table (7) provides some interesting results about the influence of board attributes on innovation. Unlike Yuan and Wen (2018) who provide evidence that managerial foreign experience is positively associated with corporate innovation, our findings show that the presence of foreign directors on board is negatively and significantly associated with both proxies PROC and PROD. FOR coefficients are significant at the 5% level. One explanation could be the low percentage of foreign members in French boardrooms: 20 % on average (panel B, table 3). Also, directors who have different cultural backgrounds could provide diverse perspectives that are not automatically supported by the other board members. Also, they could be non-valuable for innovation and solving problems because of their lack of connection with everyday operations and the local business culture (Berliant and Fujita, 2011). Even though ethnic diverse directors have better knowledge of global markets and customers' tastes, they may not be powerful enough to influence the business strategy. Consequently, they could be less influential on the firm's ability to develop new products (Kerr and Lincoln, 2010). Also, we found that CEO-duality is positively associated to PROD and PROC regressions. This result is not consistent with Blibech and Berraies (2018) who found that CEO duality is negatively associated to innovation as the duality of functions diminishes the disciplinary power of the board and affects the strategies. In fact, Goel and Jong (2017) find positive moderating effects of CEO duality on the associations between corporate risk-taking and innovation and between prior innovations and performance in IT companies. This moderated effect is due to effective and strong CEO incentives. In fact, some recent studies highlight the benefits of the CEO-chair structure (Dalton et *al.,* 2007), such as the unity of command in complex environments (Boyd, 1995) and in turnaround situations (Mueller and Barker, 1997). In fact, the duality structure strengthens the CEO power (Brockmann et *al.,* 2004; Bach and Smith 2007) and increases the CEO influence over the decision-making process (Sheikh, 2018).

5. Conclusion

The present study contributes to the emerging literature on how innovations may interact, specifically organizational and technological innovations (Damanpour and Schneider, 2006; Damanpour and Wischnevsky, 2006). The aim of our contribution is to show whether the existence of a reciprocity relation between organizational and technological innovations.

Our study provides evidence that the introduction of new technological innovations could stimulate organizational changes in a firm's structure. We may conclude that process innovations may shape the business management in several ways such as driving more partnerships, designing differently existing jobs, and creating new tasks. The development of innovation process could generate organizational innovation through the adaptation of job positions to the new process. Moreover, when a company introduces new products to the market, it could generate changes in the organizational infrastructure in order to design the production process and to effectively support the design and marketing of new products (Camisón and Villar López, 2014).

Second, our study highlights that the adoption of new organizational practices is likely to increase the introduction of new processes: The successful introduction of new organizational methods of business management in the workplace seems to boost creativity and to stimulate firms to improve or develop new processes. While product innovation is multidimensional, it depends on appropriate organizational infrastructure, engineering, and technology skills to design the process production, layout, and logistics to effectively support the new product design and its commercialization (Camisón and Villar López, 2014). The implementation of new advanced organizational practices is not sufficient to promote the development of new or significantly improved products.

Finally, this study provides evidence of the influence of boards on innovations: it shows that directors who have different cultural backgrounds could provide diverse perspectives but are not automatically valuable for innovation and solving problems. Although ethnic diverse directors know global markets and customers' tastes, they may not lead the firm to develop new products sold abroad as they.

From a business perspective, we emphasize that firms should introduce new organizational methods in the firm's business practices, workplace organization, and develop new management practices to easily introduce successful technological innovations which, in turn could challenge the business management and lead to new management changes. Moreover, firms should well choose and select their technological innovations because the introduction of these innovations could impact the organizational infrastructure.

To the best of our knowledge, this is the first paper to analyze the dynamic interaction between organizational and technological innovations through a longitudinal study. However, this research has several limitations. First, we have not explored non-technological innovation, such as marketing innovation and its influence on organizational and technological innovations. Moreover, we have neglected the lag structure between the introduction of innovation and its impact on the other ones. In fact, innovation strategies are long-term projects and need some time to be implemented and produce outcomes. Finally, our data analysis is exclusively drawn on French firms; empirical evidence conducted on many countries would be valuable to test the robustness of these findings. All these issues are left for future papers.

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