

Managing resources and innovation inside the industry (Industrial) 4.0 Revolution: The role of Supply Chain¹

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Abstract

Purpose of the paper: *On the lights of Resource Based View (RBV), this research aims to analyse the impact of resources on Process Innovation (PI) in the context of Industry 4.0 (I4.0), thus proposing stimuli coming from Supply Chain (SC) as moderator of this relationship.*

Methodology: *Our conceptual model was tested on a sample of 115 Italian firms and data were collected through a structured survey submitted to purchasing and buyer agents/managers.*

Results: *The econometric analysis shows a positive impact of resources 4.0 on PI, and horizontal stimuli coming from SC (Competitors, Universities, Consultants, and Technology Transfer Offices) were found to positively moderate this relationship. Moreover, post-hoc analysis shows that firms can obtain higher PI outcomes combining the exploitation of horizontal 4.0 stimuli with changes on BM.*

Research limitations: *This research presents three main limitations: (i) geographic location, all firms are Italian; (ii) timing, it assesses I4.0 in an early stage for the Italian entrepreneurial ecosystem; (iii) moderate sample size.*

Practical implications: *This study contributes to the understanding of both academic and practitioners of the impact of I4.0 on SC, trying to grasp not only the effect of internal resources but also of external stimuli.*

Originality of the paper: *To the best of our knowledge this paper is the first one analysing the impact of I4.0 stimuli on SC. Moreover, the survey involved a relevant number of on-field experts in comparison to similar studies on Supply Chain and I4.0 effects.*

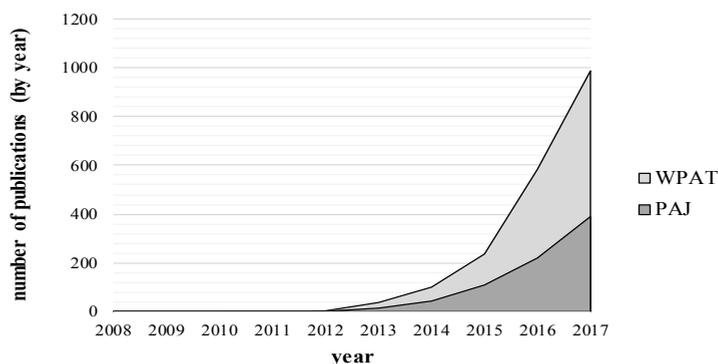
Key words: industry 4.0; supply chain; innovation; technological resources; business model

1. Introduction

I4.0 has been a trend topic over the last few years, reaching almost a thousand works published in 2017 (see Figure 1). Moreover, as Table 1 highlights, this research topic has engaged the academic attention from several disciplines, such as engineering, computer science, business and so forth (see also: Kang *et al.*, 2016; Hermann *et al.*, 2016 and Liao *et al.*, 2017).

¹ The authors would like to thank ADACI and all its members for their fruitful collaboration in conducting this survey.

Fig. 1: Works on Industry 4.0



Source: SCOPUS, January 2008-December 2017

Research strategy: “Industry 4.0” OR “Industrie 4.0” in “Title, Abstract, and Keywords”.

This area graph shows trends in the number of Industry 4.0 articles. WPAT = works published in all document types; PAJ = articles published in academic journals.

Tab. 1: subject areas of works on Industry 4.0

Subject Area	No.	%
Engineering	583	74,84%
Computer Science	224	28,75%
Business, Management and Accounting	179	22,98%
Materials Science	134	17,20%
Decision Sciences	116	14,89%
Chemistry	49	6,29%
Social Sciences	44	5,65%
Physics and Astronomy	40	5,13%
Chemical Engineering	25	3,21%
Energy	23	2,95%
Mathematics	23	2,95%
Economics, Econometrics and Finance	18	2,31%
Environmental Science	12	1,54%
Arts and Humanities	10	1,28%
Biochemistry, Genetics and Molecular Biology	7	0,90%
Earth and Planetary Sciences	6	0,77%
Agricultural and Biological Sciences	5	0,64%
Pharmacology, Toxicology and Pharmaceutics	4	0,51%
Medicine	3	0,39%
Psychology	2	0,26%
Neuroscience	1	0,13%

Note: The sum is not 100% because works overlap different subject areas

Source: Our elaboration

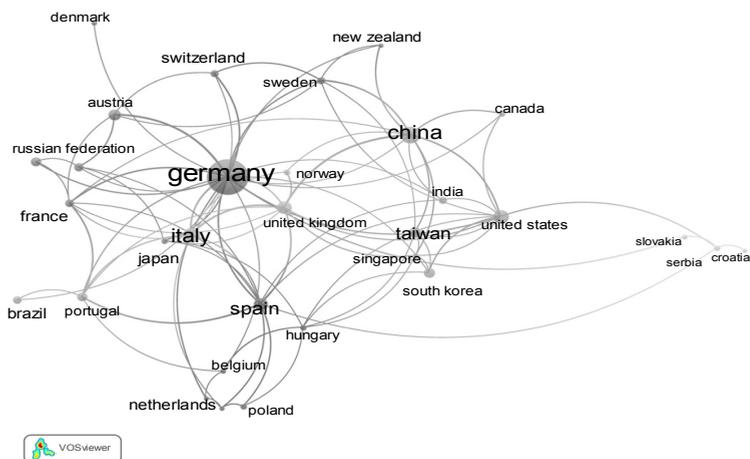
This interest is stimulated by the pervasive ability of I4.0 to integrate and merge the digital and virtual world both vertically and horizontally (Ghobakhloo, 2018). Indeed, we can consider I4.0 as a further step towards the digitalization of the manufacturing sector, driven by the (i) rise of available data, (ii) improvement of analytics and business-intelligence, (iii) enhancement of human-machine interaction, and (iv) progress in transmitting digital instructions to the non-digital reality (Sung, 2018). However, while technical aspects and the impacts of I4.0 technologies have been broadly discussed analytically, there is still need for both theoretical and empirical studies (Ben-Daya *et al.*, 2017; Bienhaus and Haddud, 2018).

The term *Industrie 4.0* (Industry 4.0) and its paradigms were designed in Germany (Kagermann *et al.*, 2013) to secure the future of the national manufacturing industry. The design and implementation processes were linked and supported by the “HightechStrategie” (HTS) plan launched by the German Ministry of Education and Research (Horst and Santiago, 2018). Following the German attempt, other countries introduced their own I4.0 plans: the UK (“UK Catapult - High Value Manufacturing”), USA (“Manufacturing USA”, 2014), France (“Industrie du Futur”, future industry, 2015), The Netherlands (“Smart Industry”, 2014), and Italy² (“Piano Nazionale Industria 4.0”, National Plan on industry 4.0, 2016). Nevertheless, the leading role of Germany on I4.0 emerges also at a research level, where this country authors (i) account for almost the 40% of the total work published and (ii) gain a central position in the international research scene as the most cited (see figure 2). Other countries extensively dealing with I4.0 are China, Italy, Spain, the US and the UK.

While differing *in* introduction and development policies, all the national plans aiming to introduce I4.0 focus on the same technologies and paradigms. However, scholars have not been able to reach a shared definition about I4.0, offering a noticeable variety of them (Bittighofer *et al.*, 2018), which were more than 100 until 2016 (Bidet-Mayer and Ciet, 2016). This is why Pereira and Romero (2017) defined I4.0 as an “umbrella term” for a new paradigm regarding future industrial developments renouncing to identify a sole definition of I4.0.

² The “Piano Nazionale Industria 4.0” (PN4.0), also called “Piano Calenda” from the surname of the Ministry of economic development who promoted it, was presented for the first time in Milan in September 2016. It involved the government, some universities, some nation-wide research centres, some industrial organisations, as well as trade unions and the Italian investment bank CDP Spa. The PN4.0 aims to encourage investments in innovation as well as competencies. It helps companies in acquiring I4.0 technologies via tax breaks, and innovative start-ups to design I4.0 business thanks to venture capital financing. Moreover, there is help also coming from universities and research centres which are requested to perform researches in the I4.0 field. Several “Digital Innovation Hubs” (DIH) play the role of dissemination, technology transfer and help for companies and organisations. Moreover, the “Competence Centres 4.0” (CC4.0) are in charge of I4.0 formation, launch and participation in innovative processes (both at local, national and international level), and field testing. (www.mise.gov.it).

Fig. 2: Countries



Source: SCOPUS, January 2008-December 2017

Research strategy: "Industry 4.0" OR "Industrie 4.0" in "Title, Abstract, and Keywords".

Nevertheless, analysing technical details of the fourth industrial revolution, we understand that I4.0 bases its pillars on existing technologies rather than on new ones: the difference relies on the exploitation of those technologies (Baur and Wee, 2015). For example, according to Schmidt *et al.* (2015) big data and cloud computing are driving forces for I4.0, but those technologies have already been used in several other contexts and for different applications (Drath and Horch 2014). Therefore, superior benefits come from a more integrated connectivity of all the actors and factors involved along the whole chain. Some scholars underline the important trend leading to the integration between physical and virtual spaces (Li Da Xu *et al.*, 2018), especially in manufacturing sectors. Indeed, not only machines, but also products, data, "things" and humans are connected according to the new I4.0 paradigms (see among the others: Kang *et al.*, 2016; Lin *et al.*, 2017; Lu, 2017; Wahl, 2015), thus leading to a necessary rethinking and reorganization of the whole industrial processes (Hermann *et al.* 2016). However, connection affects not only production systems, being the cornerstone for new organizational structures (Fantoni *et al.* 2017b), but also the value chain as a whole, especially in manufacturing industries (Rüßmann *et al.*, 2015). Indeed, according to Schrauf and Bertram (2016), the digital supply chain is the core of all the activities 4.0 implemented in the ecosystem, and in the near future, always more actors will count on digitised horizontal and vertical value-chain processes (Geissbauer *et al.*, 2016). Indeed, this adoption process of technologies and methods 4.0 aiming at both integration and interconnection of the SC, is also visible at regional level (Bertini, 2017). This careful attention paid to integration and interconnection is due to the fact that Integrative Technologies, such as Big Data, Internet of Things, and Additive Manufacturing, are considered core driving forces to increase profitability and competitiveness modifying SC outline through interconnectivity (Bucy *et al.*, 2016; Zhong *et al.*, 2016),

et al., 2017; Ghobakhloo, 2018). Indeed, the innovation of firms' processes is crucial to gain both productivity and efficiency improvements, and an effective competitive advantage (Terjesen and Patel, 2017; Trantopoulos *et al.*, 2017). However, given "the complexity of identifying, developing, and implementing process innovations" (Terjesen and Patel, 2017, p. 1421), firms should rely on external sources such as SC actors (Trantopoulos *et al.*, 2017). This is also due to the fact that I4.0 technologies, by integrating services and guaranteeing access to industrial ecosystem's information, offer a significant contribution to all the partners of the SC (Li Da Xu *et al.*, 2018). Moreover, I4.0 has a positive impact in process optimisation (i.e. in PI) during the engineerization process thanks to virtual simulations (Müller *et al.*, 2018). Furthermore, scholars point out not only the importance of I4.0 for product development, but also indicate the crucial role of I4.0 in increasing, optimising and, more generally, positively affecting processes in the whole SC (see, among others, Pereira and Romero, 2017 and Popkova *et al.*, 2019). Even though I4.0 affects both process and product innovation, focusing on the SC, I4.0 significantly affects mainly the processes (Lin *et al.*, 2017, and Fernández-Miranda *et al.* 2017). Among several positive influences of I4.0 on SC in terms of PI, some authors underline flexibility, greater communication and efficiency (among others, see: Ding, 2018, and Dalenogare *et al.*, 2018), while Kovács and Kot (2016) point out PI effects on logistics as a whole. Hence, when considering SC and I4.0 we believe it is relevant to focus our attention on I4.0 impact on PI.

Unfortunately, not only PI literature lacks quantitative analysis (Trantopoulos *et al.*, 2017) and a conclusive understanding of PI's antecedents (Keupp *et al.*, 2011; Terjesen and Patel, 2017), but also the research on the impact of I4.0 on PI is still scarce and fragmented.

Therefore, to enhance the discussion over these literature gaps, this research relies on the resource-based view (RBV) approach (Barney, 1991; Armstrong and Shimizu, 2007). Indeed, it is widely recognized that both internal resources (and capabilities) and external sources are able to affect firms' innovation, alone or jointly (Arora and Gambardella, 1994; Veugelers and Cassiman, 1999; Caloghirou *et al.*, 2004; Di Stefano *et al.*, 2012). Therefore, understanding (i) how resources are internally exploited according to the new I4.0 paradigm and (ii) what is the impact of external stimuli on PI, will promote a deeper understanding of Supply Chain 4.0 (SC4.0). Hence, from the perspective of internal firm resources, we aim to investigate the following research question: (RQ1) *What is the impact of Resources 4.0 on PI?*

From the perspective of external sources coming from suppliers, partners, and customers (Thomke and Von Hippel, 2002; Von Hippel, 2007) or from the "environment" (e.g. institutions. Lee *et al.*, 2001), we considered the impact of what we defined *Stimuli 4.0 coming from SC*. Based on Trantopoulos *et al.* (2017) we individuated the possible players bringing innovation in the SC (i.e. suppliers of materials, suppliers of machineries, suppliers of software, customers B2B, customers B2C, distributors/trade, competitors, university and public research centres, consultants, and technological transfer offices), whose impact was evaluated by interviews, and that were then divided, through factor analysis, into upstream,

downstream and horizontal sources. Hence, we want to understand: (RQ2) *What is the role of stimuli 4.0 coming from SC on PI?*

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Lastly, a key strength of this research concerns the target respondent of the survey, namely purchasing and buyer agents/managers. Indeed, since this category plays a significant role in the development and procurement of resources, they are expected to have a substantial stake in the acquisition of key 4.0 resources. Therefore, thanks to the valuable collaboration of ADACI³, we were able to gather data from a consistent panel of on-field experts.

The article is organized as follows: Section 2 discusses the theoretical framework, the conceptual model, and the research hypothesis; Section 3 outlines the sample characteristics, variables operationalization, and empirical methodologies; Sections 4 presents and discusses the findings; Section 5 draws some conclusions and discusses possible limitations and further research topics.

2. Theoretical Background and Conceptual Model

Considering the theoretical background exposed in the previous section, and looking at the origin of resources in a deeply interconnected and mutating environment, an internal/external investigation of resources' flows (Kogut and Zander, 1992 and Wahl, 2015) will allow a deeper understanding of the mutual influences exerted by actors involved in the SC4.0.

For what concerns the internal perspective, RBV theory stresses the importance of resources as they grant a competitive advantage to the company owing them thanks to their value, rareness, inimitability, and sustainability (Barney, 1991; Grant, 1991; Barney, 2001). However, firms are borderless in the SC, having both inter-organizational relationships as well as integrated business processes, (Halldórsson *et al.*, 2015; Zanni and Pucci, 2012). Thus, the RBV theory applied to SC4.0 should be analysed under a more flexible lens, admitting (i) the coexistence of different boundaries (Carlile, 2004) and (ii) the twofold impact of resources 4.0 coming both from inside the firm and from other SC actors. However, we should still define what we mean by "I4.0 resources". The current literature has highlighted several technologies enabling I4.0 and deeply influencing the firms' processes and production (Kreipl and Pinedo, 2004; Carbonneau *et al.*, 2008; Sahay and Ranjan, 2008; Visich *et al.*, 2009; Gebbers and Adamchuk, 2010; Lopez *et al.*, 2012; Maslarić *et al.*, 2016; Tian, 2016; Nakasumi, 2017; Wamba *et al.*, 2008; Witkowski, 2017; Majeed and Rupasinghe, 2017; Barreto *et al.*, 2017; Khaqqi *et al.*, 2018), thus bringing disruptive changes to the whole SC (Lu, 2017), and

³ ADACI, Associazione Italiana Acquisti e Supply Management (Italian Association for Purchasing and Supply Chain Management) is the leading Italian association for procurement and supply chain management. Founded in 1968, ADACI is also the founder of the International Federation of Purchasing and Supply Management (IFPSM), the union of 48 National and Regional Purchasing Associations worldwide (sources: <https://www.adaci.it> and <http://www.ifpsm.org/>).

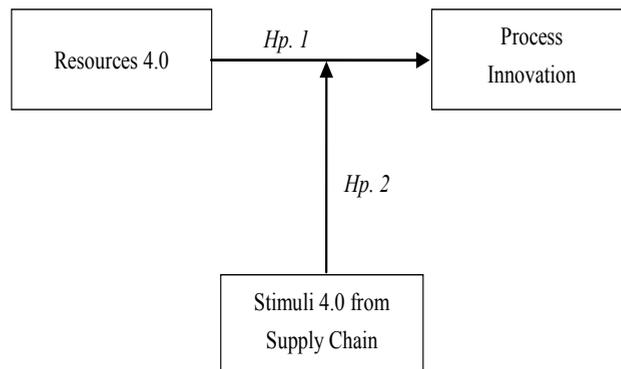
fostering SC progress (Witkowski, 2017). Among the other, they underline: advanced manufacturing solutions, additive manufacturing, augmented reality, simulation, horizontal/vertical integration, industrial internet, cloud, cyber-security, blockchain, big data and analytics. Given these theoretical bases, our first research hypothesis is: (Hp.1) *the procurement and development of resources linked with the I4.0 paradigm has a positive impact on the PI of a firm.*

For what concerns the external perspective, while Trantopoulos *et al.* (2017) focused on firms search for external stimuli, this inquiry aims to reverse the perspective looking for external stimuli influencing firm's process innovation.

The new SC4.0 is completely integrated, coordinated and controlled using an ICT platform (Atti, 2018b), and it has become a crystalline integrated ecosystem (Schrauf and Bertram, 2016). Moreover, Atti (2018b) states that the SC4.0 helps the co-creation and co-innovation thanks to the integration of procurement. The supply network structure of independent but well-connected actors looks after a collaborative advantage for everyone in the chain (Chen and Paulraj, 2004). Indeed, the integration among different firms of the SC is both horizontal (with Universities, Consultants, Technology Transfer Offices etc.), within the value chain, and vertical (with Suppliers, Customers, Distributors etc.), with linkages aiming to increase performances for outward-facing firms (Frohlich and Westbrook, 2001). Moreover, since the literature underlined how external sources, which might be vertically or horizontally linked with the company, are able to influence the adoption of innovations (Terjesen and Patel, 2017; Trantopoulos *et al.*, 2017), a similar result should be expected also in the case of 4.0 resources. Hence, we believe that stimuli coming from other players in the SC are able to moderate the effect of resources 4.0 on PI. Therefore, our second hypothesis is: (Hp.2) *stimuli 4.0 coming from the SC are able to positively moderate the impact of the Resources 4.0 on PI.*

Our research questions and hypothesis are visually summarized in Figure 4, thus showing our conceptual model.

Fig. 4: Conceptual Model



Source: Our elaboration

3. Methodology

3.1 Data Collection

Data were collected through a survey submitted both online and offline from July to October 2018 to Italian firms.

For what concerns the online channel, the e-mail survey was submitted to 467 firms obtaining 31 usable answers (redemption rate of 6, 64%). A presentation letter, outlining both research objectives and privacy information, was attached to each e-mail. For what concerns the offline channel, the research team attended several Conferences and Workshops organized by ADACI (Italian association for purchase and supply management), distributing the questionnaire directly to purchasing and buyer agents/managers, thus collecting 93 answers. Of these responses, 9 did not specify the company name, consequently were excluded. Data concerning the number of employees and years from the constitution were then gathered through secondary sources, namely the Chamber of Commerce. Therefore, we obtained 115 usable answers from: 33 Micro firms (employees < 10), 34 Small (10 ≤ employees < 50), 31 Medium (50 ≤ employees < 250), and 17 Large firms (employees ≥ 250). Respondents are mainly located in the north of Italy (62%).

3.2 Measures

The variables here presented are outlined in table 2, thus showing items description and Cronbach alpha when necessary.

Dependent Variable: Process Innovation is the outcome variable of our analysis and was measured through a multi-item construct developed by the research team, starting from Terjensen and Patel (2017). Firms were asked to state if they had introduced systems improvements concerning (1) supply, (2) storage, (3) production, (4) distribution, or (5) sale and post-sale in the last three years. Each item was operationalized as a dummy *where* 0 stands for not introduced, while 1 for introduced. Consequently, the PI variable was operationalized as the arithmetic mean of the five items.

Independent Variables: *Resources 4.0* was operationalized starting from the *Piano Calenda* (2016). Firms were asked to state if they had introduced one or more of the following resources in the last three years: (a) advanced manufacturing solutions, (b) additive manufacturing, (c) augmented reality, (d) simulation, (e) horizontal/vertical integration, (f) industrial internet, (g) blockchain, (h) cloud, (i) cyber-security, (l) big data and analytics. Each item was operationalized as a dummy *where* 0 stands for not introduced, while 1 for introduced. Consequently, the *Resources 4.0* variable was operationalized as the arithmetic mean of the 10 items. *Stimuli 4.0 from Supply Chain* was adapted from Trantopoulos *et al.* (2017), thus distinguishing among 10 possible players acting as sources of innovation: [1] suppliers of materials, [2] suppliers of machineries, [3] suppliers of software, [4] customers B2B, [5] customers B2C, [6] distributors/trade, [7] competitors, [8] university and public research centres, [9] consultants, and [10] technological transfer offices. Then, firms were asked to evaluate the

impact held by each actor on their learning process regarding Industry 4.0, from 1 “no impact” to 5 “high impact”. Finally, through factor analysis, we obtained three variables merging [1], [2], and [3] in *upstream sources*, [4], [5], and [6] in *downstream sources*, and [7], [8], [9], and [10] in *horizontal sources*. The reliability test over these three constructs provided satisfactory results, showing Cronbach’s alphas greater than 0,7 (Hair *et al.*, 2010).

Tab. 2: Measures description

Variables	Items	Cronbach's α
Process Innovation		-
(dummy, 1 = "selected")	Technological improvements to supply systems	
Source: our processing and adaptation starting from	Technological improvements to storage systems (incoming logistics)	
Terjensen and Patel, 2017	Technological improvements to production systems	
	Technological improvements to distribution systems (outbound logistics)	
	Technological improvements to sales and after-sales processes	
Resources 4.0		-
(dummy, 1 = "selected")	Advanced Manufacturing Solutions	
Source: Piano Calenda, 2015	Additive Manufacturing	
	Augmented Reality	
	Simulation	
	Horizontal/Vertical Integration	
	Industrial Internet	
	Blockchain	
	Cloud	
	Cyber-security	
	Big Data and Analytics	
Stimuli 4.0 from Supply Chain		
(likert scale 1-5)	Upstream	0,727
Source: our processing and adaptation starting from	Suppliers (materials)	
Trantopoulos <i>et al.</i> , 2018	Suppliers (machinery)	
	Suppliers (software)	
	Downstream	0,730
	Customers (B2B)	
	Customers (B2C)	
	Distributors/Trade	
	Horizontal	0,800
	Competitors	
	Universities and Public or Private Research Centres	
	Consultants	
	Technological Transfer Offices	
Control variables		
(Natural logarithm of the number of years since the constitution)	Age (log)	-
(Natural logarithm of the number of employees)	Size (log)	-
(Percentage of foreign sales on total turnover)	Foreign sales	-
(Percentage of R&D expenditure on total turnover)	R&D expenditures	-
(dummy, 1 = "selected")	Busin. Model Innovat.	-

Source: Our elaboration

Control Variables: To reliably test the relationship among dependent and independent variables and to control for endogeneity, we introduced several control variables able to influence PI. We employed the natural logarithm of (i) the number of years since the constitution and (ii) the number of employees, to control respectively the firm's Age and Size, and the percentage of (i) foreign sales on the total turnover and (ii) R&D expenditure on the total turnover, to control *the Foreign Sales and R&D expenditures* (Terjensen and Patel, 2017; Trantopoulos *et al.*, 2017). Moreover, we added *Business Model (BM) Innovation* as a further control variable. This was operationalized asking firms if the innovation brought by Industry 4.0 changed their business model (dummy 0/1), thus the strategic and organizational procedures through which firms generate value (Pucci, 2016).

4. Findings

Table 3 outlines the descriptive statistics and Pearson's correlation among dependent, independent, and control variables. The correlation indicators do not reveal problems in terms of multicollinearity, as confirmed by low VIF scores and high Tolerance for all variables, see Table 4.

Tab. 3: Descriptive statistics and correlations

		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
[1]	Process Innovation	1,000									
[2]	Age (log)	0,117	1,000								
[3]	Size (log)	0,092	0,481	1,000							
[4]	Foreign sales (%)	0,242	0,223	0,405	1,000						
[5]	R&D Expend. (%)	0,122	-0,365	-0,070	0,278	1,000					
[6]	Busin. Model Innovat.	0,333	-0,029	0,171	0,041	0,052	1,000				
[7]	Resources 4.0	0,374	0,165	0,298	0,144	0,110	0,287	1,000			
[8]	Stimuli 4.0 from SC (Upstream)	0,152	0,181	0,307	0,272	0,131	0,204	0,280	1,000		
[9]	Stimuli 4.0 from SC (Downstream)	0,169	0,125	0,128	0,198	0,066	0,367	0,154	0,344	1,000	
[10]	Stimuli 4.0 from SC (Horizontal)	-0,012	0,221	0,331	0,199	0,077	0,157	0,143	0,481	0,457	1,000
	Mean	0,400	2,819	3,475	0,355	0,082	0,426	0,232	3,388	2,597	2,841
	Std. Dev.	0,244	1,021	1,880	0,351	0,106	0,497	0,186	0,948	0,934	0,930
	Min	0,000	0,000	0,000	0,000	0,000	0,000	1,000	1,000	1,000	1,000
	Max	1,000	4,248	8,497	1,000	0,800	1,000	0,700	5,000	5,000	4,500

Note: N = 115; Correlation coefficients greater than 0,198 in absolute value are statistically significant at 95%.

Source: Our elaboration

Tab. 4: VIF scores and tolerance

	VIF scores	Tolerance
Age (log)	1,66	0,60
Size (log)	1,72	0,58
Foreign sales (%)	1,45	0,69
R&D Expend. (%)	1,44	0,70
Busin. Model Innovat.	1,30	0,77
Resources 4.0	1,24	0,81
Stimuli 4.0 from SC (Upstream)	1,47	0,68
Stimuli 4.0 from SC (Downstream)	1,50	0,67
Stimuli 4.0 from SC (Horizontal)	1,60	0,63

Note: Mean VIF 1,49; Condition number: 16,366

Source: Our elaboration

In order to investigate the relationship between Process Innovation and Resources 4.0, as mediated by Stimuli 4.0 from SC, we employed a linear regression analysis. Table 5 shows the results of the hierarchical regression divided in 6 tested models: in Model A, we entered only control variables; in Model B, we introduced the main effect; in Model C, we inserted the moderating variables; from Model D to F, we introduced interaction terms.

Tab 5: Linear Regression Results

	Mod. A	Mod. B	Mod. C	Mod. D	Mod. E	Mod. F
Age (log)	0,043	0,034	0,037	0,038	0,038	0,042
	0,027	0,027	0,028	0,029	0,028	0,028
Size (log)	-0,017	-0,026*	-0,021	-0,021	-0,022	-0,018
	0,013	0,012	0,013	0,013	0,014	0,013
Foreign sales (%)	0,148*	0,155*	0,150*	0,149*	0,152*	0,145*
	0,072	0,069	0,071	0,072	0,071	0,068
R&D Expend. (%)	0,233	0,117	0,154	0,154	0,134	0,261
	0,185	0,172	0,181	0,182	0,191	0,201
Busin. Model Innovat.	0,171***	0,135**	0,135**	0,136**	0,134**	0,141**
	0,045	0,045	0,047	0,047	0,048	0,046
Resources 4.0		0,385***	0,376**	0,109	0,587	-0,737
		0,111	0,119	0,475	0,443	0,475
Stimuli 4.0 from SC (Upstream)			0,008	-0,006	0,006	0,025
			0,026	0,038	0,026	0,028
Stimuli 4.0 from SC (Downstream)			0,010	0,011	0,027	0,016
			0,031	0,030	0,051	0,032
Stimuli 4.0 from SC (Horizontal)			-0,042	-0,039	-0,043	-0,123*
			0,034	0,035	0,034	0,053
Resources 4.0 X Stimuli 4.0 from SC (Upstream)				0,075		
				0,129		
Resources 4.0 X Stimuli 4.0 from SC (Downstream)					-0,077	
					0,150	
Resources 4.0 X Stimuli 4.0 from SC (Horizontal)						0,369*
						0,147
Constant	0,194*	0,183*	0,22*	0,256*	0,190	0,352**
	0,078	0,075	0,098	0,116	0,120	0,110
R2	0,188	0,260	0,276	0,278	0,278	0,314
Adj. R2	0,151	0,218	0,214	0,208	0,208	0,248

Note: N = 115; * p<0.05; ** p<0.01; *** p<0.001

Source: Our elaboration

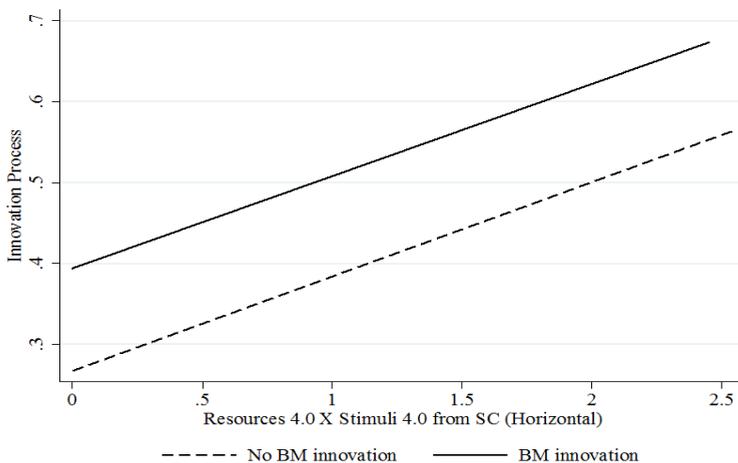
For what concerns control variables, both Age and R&D expenditures are not significant in all models, while Size is significant at 10% only in Model B, but its magnitude is almost negligible. On the other hand, Foreign Sales and BM innovation show a positive and significant impact on PI in all models, respectively at 10% and 5% levels.

For what concerns Hp.1, Model B confirms a positive and significant effect of Resources 4.0 on Process Innovation (at 1% level). This effect is almost the double in magnitude if compared to Foreign Sales and BM Innovation. Additionally, Model C suggests that there is not a direct effect of Stimuli 4.0 from SC on PI, and this is true regardless of the source.

For what concerns Hp. 2, both Model D and E show an insignificant interaction term, thus upstream and downstream sources are not able to moderate the relationship among Resources 4.0 and Process Innovation. On the other hand, Horizontal sources are able to act as moderators, as shown in Model F. Consequently, Competitors, Universities, Consultants, and Technological Transfer Offices can enhance the ability of Resources 4.0 to bring PI in firms. Therefore, we can conclude that Hp. 2 is partially supported.

Given the magnitude and significant levels of both BM innovation and the interaction term Resources 4.0 X Horizontal stimuli we conducted the post-hoc analysis shown in Figure 5. What emerges from the interaction among resources, horizontal stimuli, and business model is that firms, not introducing changes in their business model, are less able to gather advantages from both resources 4.0 held and horizontal stimuli received. Therefore, to adapt and change both organizational and strategic procedures it seems fundamental to obtain higher PI results.

Fig. 5: Three-way interaction among Resources 4.0, Horizontal stimuli, and BM innovation



Source: Our elaboration

5. Discussion and conclusions

This research points out three main results. Firstly, resources 4.0 have a positive impact on firms' PI. Hence, following the RBV perspective, the procurement and development of resources 4.0 enhances the competitive advantage of firms fostering PI. Secondly, our panel of respondent reveals that the positive relationship among resources 4.0 and PI is nurtured by horizontal partners (such as University, Consultant, etc.), rather than from upstream or downstream actors. However, we should highlight how these results may be affected by both sample composition and the timing of data collection. For what concerns the former, our sample is largely composed by medium and large companies (more than 40% of the interviewed). Indeed, their behaviour is different from the micro and small ones, since they have more public sector linkages (Rothwell and Dodgson, 1991) especially for technical inputs. Moreover, the SC sees the involvement of two main actors: the broker, pushing for the I4.0 introduction in SC, and the receiver, adapting to technological changes required from brokers. While the first are usually larger companies, the second are usually smaller subcontractors. For what concerns the timing of data collection, since the sample is mainly composed by Italian manufacturing firms (73%), we should take into account that the Italian 4.0 plan was introduced only in 2016. Therefore, given the initial stage of the Italian I4.0 and the complexity and abstraction level required for the I4.0 implementation, firms may be searching for stimuli from Universities, consultants and horizontal partners in general. Indeed, being at the early stage of I4.0, the competencies linked with resources 4.0 mainly come from Universities, research centres and specialised experts. Therefore, we expect a different relationship among 4.0 stimuli and PI in future I4.0 stages of implementation. Thirdly, from the post-hoc analysis emerges that firms can obtain higher PI results if they combine the exploitation of horizontal 4.0 stimuli with changes on BM. In general, the adoption of new and distinctive resources lays the foundations for the whole business model reconfiguration inside firms (Morris *et al.*, 2005), thus enhancing efficacy and efficiency of value creation, provision, and capture (Amit and Zott, 2001; Venkatraman and Henderson, 1998; Pucci *et al.*, 2013; Pucci *et al.*, 2017). Additionally, the literature underlines how new technologies, or existing technologies applied for other purposes (Casprini *et al.*, 2014), may enable the appearance of new BMs (Baden-Fuller and Haefliger, 2013; Teece, 2010; Zott *et al.*, 2011; Baden-Fuller and Mangematin, 2013; Casprini, 2015; Teece, 2017). Indeed, companies will be asked soon to compete on quickness in delivery, execution of processes and decision making (Atti, 2018a), therefore the exploitation of I4.0 resources will be crucial to develop an adequate and competitive BM. Therefore, our findings confirm resources ability - in this case 4.0 resources - to impact on the BM outline, thus influencing how companies are organised and how they deal with suppliers, partners and competitors (Prause, 2015; Bauer *et al.*, 2014; Russo, 2018).

This paper contributes both to the academic and the non-academic literature thanks to its integration of scholars' knowledge and the expertise of a renewed national association of procurement and supply chain

management (ADACI). Moreover, there are several implications also from a managerial point of view. First, this study shows the importance for companies to be at the forefront of technological adoption, following the I4.0 paradigm, since this will turn in a positive influence for PI. Second, it demonstrates to managers and companies the importance of horizontal chains, as also pointed out in the literature by Lin *et al.* (2017), e.g. the connections with universities and consultants. Hence, when we are at an early stage of technological introduction companies rely more on external providers which already have available these technologies to close the gap as soon as possible. This is definitely true, considering the size of the companies in our sample, for medium and big size companies, which are in turn those usually acting as leaders for the whole chain. Moreover, managers should consider that BM changes allow companies to obtain higher PI results than the ones gained thanks to resources 4.0 and/or external stimuli 4.0 alone. This will allow all the companies to benefit both from (internal) adoption of I4.0 technologies and from external influences of the SC, with a special role played by horizontal partners with whom companies should always collaborate.

Considering the results about the impact of I4.0 on the players of the SC both directly, thanks to the positive impact of I4.0 technologies adoption within the companies, and indirectly, as well as the results about the positive horizontal influence of technologies 4.0, for what concerns the theoretical contribution, we can enlighten the comprehensive impact of I4.0 for the whole chain: the technology linked with the I4.0 paradigm has an effect in the whole chain, both directly and indirectly.

It is interesting to point out that this research signals which actors need to be supervised in further studies, as also pointed out by Lin *et al.* (2017) in their study about China and Taiwan: the horizontal partners.

In conclusion being, to the best of our knowledge, the first one on this topic, this study contributes in developing the current report-based knowledge with an empirical study based on an experts' survey. Moreover, the results showing the impact of resources 4.0 and PI, the drivers of innovation in SC4.0 as well as the effects on BM represent a first impulse to further analysis on these topics.

There are several limitations in this study. First, the sample of this study is limited to Italian companies, thus it would be extremely fruitful to extend the survey to other countries. Indeed, a comparison between the current maturity level of I4.0 and the policies in the Italian context with other countries would be extremely interesting both from a practical and an academic point of view. Second, we analysed the Italian context at an early stage, while a replication of this study later on will allow a comparison of different maturity stages within the same country and additionally a better analysis of the effects of Piano Nazionale 4.0, leading to significant and stimulating discussions both for scholars and practitioners.

Third, due to the small size of our sample, this paper may be threatened by biases regarding sample characteristics. Further studies based upon similar RQs, might offer interesting and stimulating results to the audience.

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