The role of technology in supporting supply chain collaboration: what's next for purchasing and Industry 4.0?

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Abstract

Industry 4.0 (I4.0) technologies have a profound impact on supply chain management, as they change supply chains structure, improve its digitization, and foster introduction of new business models. This paper aims to analyse the role played by I4.0 technologies in driving buyer - supplier supply chain collaborations, and the impact on supply chain performances. To do that, we design a model to explore the relationships between supply chain technology, collaboration and performances, tested through data collected on 141 Italian manufacturing companies. Results confirm that traditional supply chain technologies play a crucial role in fostering buyer-supplier collaboration (and improve performances), while same conclusions cannot be drawn for I4.0 technologies, mostly due to still the limited diffusion of I4.0 in the Italian scenario.

Keywords: eProcurement, industry 4.0, supplier collaboration

Theoretical background

Significant investments by industrial firms in Industry 4.0 (I4.0) technologies, at present and planned for the coming years, highlight the expectations of managers about the benefits achievable by their adoption. The term I4.0describes "*the fourth industrial revolution, a new step of organization and management of whole supply chains over the life cycle of products*." (Drath and Horch, 2015). The term became a striking brand and an often-cited buzzword in many practitioners´ publications, as a marketing slogan of companies or industry associations to describe a bundle of innovative technologies (Adolph, 2014). I4.0 has been able to bring to industries new economic and technological paradigm characterized by the increase of connectivity, virtualization, spread of simulation models, decentralization of decision making, capability to collect data in real-time, (Van Thienen *et al.,* 2016).

The attention around "I4.0" has grown as well in the academic world, even though the analysis of its features as well as the analysis of its medium and long-term impacts is still at an early stage (e.g. Lee et al., 2014). In particular, an open point of discussion is how much these new technologies can contribute to enhance supply chain collaboration, especially within the supply network (Glas and Kleeman, 2016).

This makes relevant to analyze not just the role of I4.0 technologies per se, but also clarify the link between purchasing and I4.0, as this fourth industrial revolution enables several new possibilities for purchasing. The complexity in this link lies in the fact that new technologies work alongside traditional purchasing technologies (such as eProcurement tools; Ronchi et al., 2010). Moreover, these new technologies can have profound changes in the buyer-supplier relationship, such as contract analysis software or digital negotiations, which could revitalize eMarketplaces.

Information sharing, in fact, is one of the most important asset to be managed as far as collaboration are concerned (e.g. Hsu et al., 2008). In particular, in a co-design partnership, this involves information related to the new product development process, and the product know-how (e.g. Petersen *et al.,* 2005); for operational collaboration, the availability of real-time inventory data, production planning, and sales/demand forecasts are crucial to achieve successful collaborative relationship (e.g. Revilla and Knoppen, 2015). In this sense, potentialities and advantages generated by the use of technologies are expected to influence buyer – supplier supply chain collaboration, making it more agile, efficient and effective (Adams et al., 2014). Traditional technologies – like eProcurement supporting the purchasing process – as well as I4.0 technologies (e.g. cloud computing and smart factory) could foster the adoption of collaborative approaches with suppliers, as they ease the information sharing process.

Besides this, also relevant tools used to support collaborative relations shouldn't be neglected (e.g. inter-functional teams, co-location of workers, more traditional communication tools), as they are expected to increase the knowledge sharing, the information exchange and the early identification of problems (Soosay and Hyland, 2015).

Given the above, the aim of the paper is to better explore how supply network collaborations are affected when introducing I4.0 technologies. We assume the perspective of Simatupang and Sridharan. (2005) on supply chain collaboration, formulating the following research questions:

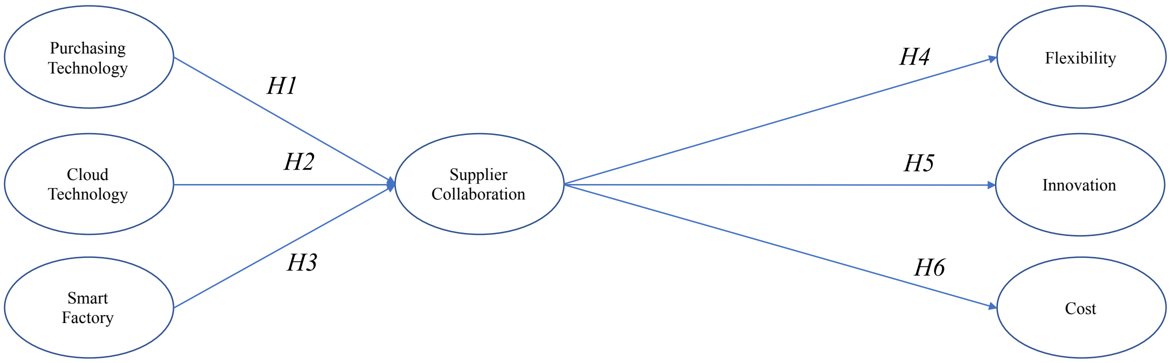
- RQ 1: Which is the role played by traditional purchasing technologies and I4.0 in driving supplier collaborations?
- RQ 2: How I4.0 supplier collaborations impact supply chain performance?

Research model and methodology

Following the previous discussion, the research has been developed in order to explore the research framework in *Figure 1.*

Our first research question is broken down into three hypotheses regarding the impact of traditional purchasing (H1), cloud (H2) and smart factory (H3) technologies on supplier collaboration. The second set of hypotheses is related to the impact of collaboration on SC performance: flexibility (H4), innovation (H5) and cost (H6).

Figure 1 – Research framework



In particular, the model hypothesis are the following:

- *H1: Use of traditional technologies to support the purchasing process influence the adoption of collaborative relationships with suppliers (Puschman et al., 2005);*
- *H2: Use of cloud computing technologies influence the adoption of collaborative relationships with suppliers (Kasensap, 2015);*
- *H3: Use of smart factory technology influences the adoption of collaborative relationships with suppliers (Ben Daya et al., 2017);*
- *H4: The implementation of collaborative partnerships with supplier has positive relations on the flexibility performance (Yu et al. 2001);*
- *H5: The implementation of collaborative partnerships with supplier has positive relations on the cost performance (Corsten and Felde, 2005);*
- *H6: The implementation of collaborative partnerships with supplier has positive relations on the innovation performance (Luzzini et al., 2015)*

Methodology

In order to test the hypotheses, we designed and delivered a survey to Italian companies, focused on supplier collaboration practices and I4.0 technology usage.

The questionnaire is composed of five sections. Section one aims to collect general information about the respondent company. Section two aims to evaluate the organization of the purchasing department and its maturity (i.e. status and level of visibility) within the company. Section three evaluates supply chain collaboration practices, in terms of: typology of collaboration, supply chain visibility and information sharing, and collaboration tools. Section four aims to assess the use of technology to support business processes (including I4.0 and traditional eProcurement ones). Finally, section five aims to collect information about supply chain performances - time, cost, innovation, quality, sustainability, and flexibility.

Every question has been designed as multiple-choice using a 1-5 Likert scale (Groves et al., 2011).

The target sample included 854 organizations (all with revenues higher than 50.000.000 € and number of employees higher than 50); from this, we obtained 141 responses. From Table 1, it can be noticed that the majority of respondent companies have revenues included between 51 and 500 million euro, with 15% having revenues higher than 500 million euro. About 70% of the answers come from respondents operating in the purchasing department, of which 27% are supply chain or purchasing directors.

Table 1 – Sample descriptives

Descriptive	*%*	***Descriptive***	*%*
Industry affiliation		**Respondent position**	
Clothing and leather trade	7.1%	Purchasing director	34.3%
Agricultural products, food and related	3.8%	Supply Chain Responsible	16.9%
Production and trade of beverages	2.2%	Category Manager	9.6%
Manufacturing and trade of chemical products, rubber, cables and related	7.1%	Buyer	6.2%
Large-scale retail trade	7.1%	Other job titles	33.1%
Manufacturing and sale of pharmaceutical products, para-pharmaceutical, dietetic, cosmetic and related	7.7%		
Manufacturing and sale of electronic products, household appliances, radio and TV equipment, computer and related	7.7%		
Restaurant activities and related activities	1.1%		
Production, distribution and sale of electricity and gas	1.6%	**Revenues (million €)**	
Jewellery, gold working and related activities	0.5%	1 - 50	4.0%
Manufacturing and trade of wood furniture	4.9%	51 - 500	57.2%
Automotive	5.5%	501 - 3000	26.6%
Manufacturing and trade of eyewear, frames and optical lenses	2.2%	> 3000	12.1%
Other manufacturing and service business	41,2%		

Data analysis

To test the model, Exploratory Factor Analysis and Structural Equation modeling have been used.

In order to operationalize the constructs included in the model, we selected specific items in line with the existing literature, according to which the questionnaire was designed. To confirm this construct design, we run a Exploratory Factor Analysis; *Table 2* summarizes the main items used to measure the constructs in the survey and the main references used for their operationalization, as well as the indicators of loading and Cronbach Alpha (all the items were measured on a 1–5 Likert scale). These results show consistency with our assumptions and the constructs included in the model.

Table 2 – Results of the exploratory factor analsysis (λ: factor loading, CA: Cronbach's alpha)

Constructs	**Indicators**	**λ**	**CA**
Supplier Collaboration	*Early Supplier Involvement*	.720	.709
	Collaboration in processes improvement	.687	
	Collaboration to reduce innovation time to market	.638	
	Operative processess collaboration (JIT, VMI, CPFR, CR)	.502	
	Information sharing with suppliers on inventories and sale forecasts	.663	
	Supply chain transparency and information sharing	.515	
Purchasing technologies	*Use of technologies to manage strategic purchasing activities*	.853	.763
	Use of technologies to manage tactic purchasing activities	.859	
	Use of technologies to manage operational purchasing activities	.704	
Smart factory	*Use of embedded sensors in the product for real-time monitoring*	.821	.754
	Use of RFID technology to track the products in real-time along the supply chain	.718	
	Use of connected products (Smart Products) to improve processes	.716	
	Use of QR codes to track products in real-time along the supply chain	.718	
Cloud Computing Technologies	*Use of cloud computing technologies to collect data*	.934	.917
	Use of cloud computing technologies to analyse data	.898	
	Use of cloud computing technologies to share data and information among supply chain actors	.870	
Collaboration tools	*Use of computer tools enabling co-design activity*	.834	.752
	Use of remote communication tools such as videoconferencing, teleconferencing and web-meetings	.789	
	Use of EDI technology for asynchronous data exchange	.671	
	Creation of inter-company teams	676	
Innovation performance	*Introduction rate of new product/service to the market*	.892	.713
	Success rate of new products/services brought to the market	.858	
Flexibility performance	*Ability to minimize the impact of supplier volume variations*	.935	.815
	Ability to minimize the impact of supplier delivery time variations	.876	
Cost performance	*Distribution Cost*	.909	.794
	Purchasing Cost	.882	

The presented hypotheses were tested using covariance-based structural equation modelling (CB-SEM), which is a common method employed for this type of research in combination with partial least square structural equation modelling (PLS-SEM) (Perols et al., 2013). Since the objective of our research is theory testing and confirmation, we decided to adopt both CB-SEM and PLS-SEM as they are more suitable when the research objective is prediction and theory development (Hair et al., 2011).

The model was tested using the maximum likelihood (ML) estimation method (White, 1982), as ML is able to provide more realistic indexes of overall fit and less biased parameter values for paths that overlap with the true model as compared to other methods such as generalized least squares and weighted least squares (Olsson et al., 1999). The ML estimation assumes that the variables in the model are (conditionally) multivariate normal, which is true for our dataset according to the Doornik-Hansen test (χ^2 = 316,531; p > χ^2 = 0.000).

The Confirmatory Factor Analysis indexes reveal a good model fit (i.e. χ^2/Df = 1.253; RMSEA = .042; CFI = .959; TLI = .949). Considering the indexes on constructs reliability, the results highlights the good reliability of every construct (AVE > 50%).

The postulated path model produced a sufficient fit to the data (χ^2/Df = 1.618; RMSEA = .066; CFI = .892; TLI = .876) (Hooper et al., 2008). *Table 2 and Figure 3* depict the results of the hypotheses testing. The structural model shows a highly positive and significant relationship between use of traditional purchasing technologies and supplier collaboration, thus failing to reject H1; no statistical significance, instead, is found on the relationship between I4.0 technology and supplier collaboration, thus rejecting H2 and H3. In turn, supplier collaboration reveals having an impact on supply chain flexibility, innovation and cost performance (thus failing to reject H4, H5 and H6).

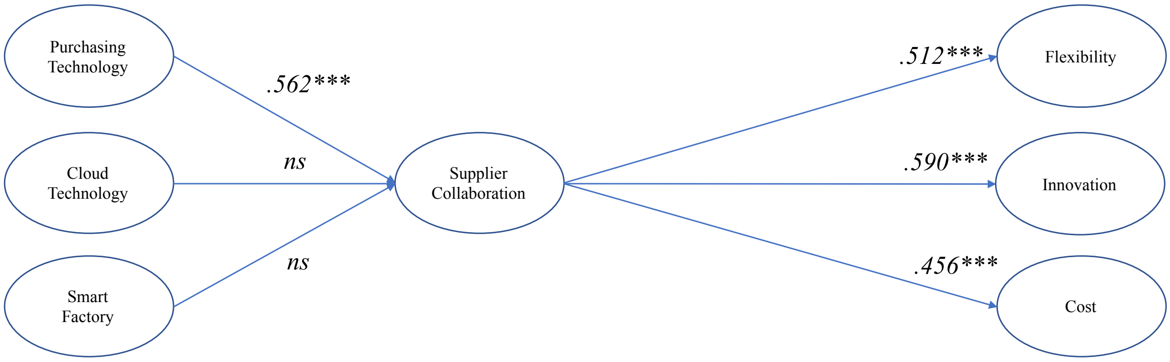
Table 2 – Results of the Structural Equation Model

Model Fit: $\boldsymbol{X^2}$ = 296.109; Df = 183; $\boldsymbol{X^2}/\boldsymbol{Df}$ = 1.618; RMSEA = .066; PCLOSE= 0.031; CFI = .892; TLI = .876

Parameters estimates		Std. error	z	95% Confidence Interval		Conclusion
Purchasing Technology → Supplier Collaboration	.562***	.101	5.55	.364	.761	***Accept H1.1***
Cloud Technology → Supplier Collaboration	.048	.099	.49	-.147	.243	***Reject H1.2***
Smart Factory → Supplier Collaboration	.050	.105	.48	-.116	.257	***Reject H1.3***
Supplier Collaboration → Flexibility Performance	.512***	.106	4.83	.305	.720	***Accept H1.4***
Supplier Collaboration → Cost Performance	.590***	.150	3.93	.296	.884	***Accept H1.5***
Supplier Collaboration → Innovation Performance	.456***	.124	.3.69	.215	.701	***Accept H1.6***

*Notes: *p<0.5; **p<0.01; ***p<0.001 (two tailed test)*

Figure 2 – Measurement model



Findings and discussion

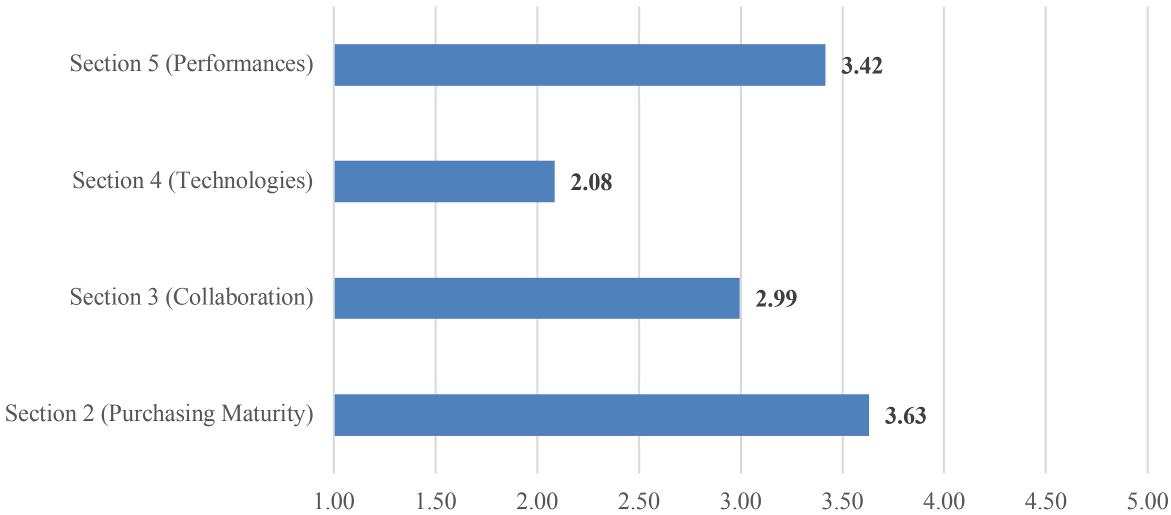
The present paper aims to shed light on the role that technology (traditional and I4.0) can play in supporting buyer – supplier supply chain collaboration, and the benefits obtained from these initiatives.

As evident from the model testing, mixed evidence is found relating to the role of technologies. The results of the hypothesized model support the (diffused) idea that the adoption of traditional technologies in the purchasing process has a positive influence on the collaboration with suppliers, while this is not verified if we refer to I4.0 technologies.

On one side, results support the theoretical statement that the adoption of traditional technologies to support the purchasing process has a positive influence on the collaboration initiatives with suppliers. The role of traditional technologies supporting collaboration is not new, and well-grounded in the literature (e.g. Hsin et al., 2013).

On the contrary, no significant relationship is found between use of I4.0 technologies and buyer – supplier collaboration. This result can mainly be related to a simple reason, as it's evident how there is a very limited diffusion of those technologies among the Italian companies, as reported by the following Figure 3 showing the average value obtained for each section of the survey (from which it can be noticed that general adoption of technologies is quite low for our sample).

Figure 3 - Mean values for each questionnaire section



If we analyse the average answers provided in the "technology" section of the survey, we can note that this type of technologies is still poorly diffused in Italy, as for both the use of tracking technologies, and the use of smart products, the distribution of responses is strongly polarized towards very low usage values. Even in case of cloud computing technologies, distribution of responses is strongly polarized towards low values.

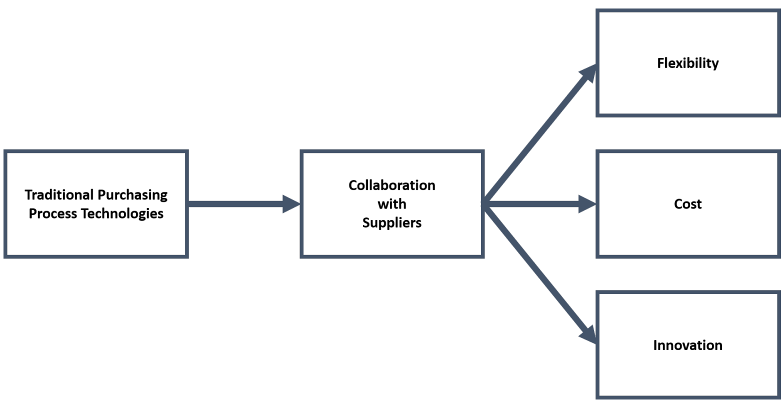
Model testing supports instead H5, H6 and H7, meaning that buyer – supplier collaborative relationships (at operational, codesign or development level) are positively related to an improvement of supply chain performances, in terms of cost, flexibility and innovation.

Figure 5 sums up the main findings of the research. The actual managerial implications are that nowadays the main driver facilitating and leading the collaboration with suppliers are still the traditional technologies adopted in the purchasing process. It emerged that technologies characterizing the Industry 4.0 are still not enough diffused to be statistically tested, however considering the positive relation between traditional technologies and collaboration, it cannot be excluded that a similar relation involving industry 4.0 technologies exists as well.

Finally, the conclusion of the analysis is that the use of technology is positively related to collaborative relations with suppliers, which is in turn positively related with the supply chain performances of flexibility, cost and innovation. The positive relation between supplier collaboration and cost, flexibility and innovation performances are consistent with literature, as the discussion about the potential benefits given by intense collaboration programs is grounded in the supply chain literature since long (e.g. Jap, 1999; Narayanan et al., 2015).

So, we can finally represent in *Figure 4* the main results of the research:

Figure 4 – Representation of results



To conclude, we can also highlight some research constraints and to set the basis for further investigations. Main limitations refer to the sample characteristics and the methodology used. On one side, we have already discussed that the 141 companies are all Italian, which has been revealed a country where I4.0 technologies are not so diffused, and a structured industrial plan focused on the I4.0 revolution is missing. So, a first improvement could be to enlarge the perspective by trying to explore the same model using a multi – country sample.

Second, the research uses a survey approach to investigate the topic; a survey allows generalizability and deductibility of results but makes slightly possible to explore conclusions from different perspective, approximate reality through the survey questions, need to stick to hypotheses that drove the questionnaires design (making difficult discovering something new). So, a further development could be to try to analyse the topic with multiple case studies.

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