Environmental Factors Influencing the Adoption of Digitalization Technologies in Automotive Supply Chains

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***Abstract* —** Previous literature shows that there are different environmental factors with different impacts on the adoption of technologies in a supply chain context. Thus, the adoption of technologies in supply chains may vary according to different environmental factors. Despite the existence of several studies about adoption of technologies in supply chain contexts that include environmental factors, there is a gap in identifying which environmental factors influence the adoption of digitalization technologies in supply chains. The purpose of this study is therefore to identify and analyze the environmental factors that influence the adoption of digitalization technologies in the supply chain. An exploratory qualitative research was conducted using semi-structured interviews with Portuguese managers of companies at several tiers of the automotive supply chain. Environmental factors were pointed as particularly critical drivers to promote the adoption of digitalization technologies in the automotive supply chain. Such adoption is mainly driven by the Original Equipment Manufacturer (OEM), through coercive and normative pressures over the other tiers of the supply chain. Relevant factors identified are: compliance with standards and legislation, market and industry pressures, and benchmark the evolution of supply chain partners. This study contributes to the literature with new knowledge concerning new specificities of the environmental factors that showed an important influence on the adoption decision**.**

***Keywords*—** *Digitalization technologies, Supply chain, Technology adoption factors, qualitative study, Industry 4.0*

I. INTRODUCTION

Digitalization technologies for supply chains aim to create an intelligent technological system of digital hardware, software and networks, with capabilities of managing massive amounts of data and cooperation between partners of the supply chain. Such system is conceived to support the interactions between supply chain partners "by making services more valuable, accessible and affordable with consistent, agile and effective outcomes" (1). Digitalization technologies, therefore, support supply chain processes management, using a variety of innovative technologies, such as big data & analytics, cloud computing, cybersecurity, Internet of Things (IoT), Robots, AGVs (Automated Guided Vehicle), ERP (Enterprise Resource Planning) system, and visual computing (1,2).

The full realization of the potential of such technologies requires a good understanding of how they diffuse and are adopted. The decision to adopt is the first step to integrate a new technology in the ongoing work of an organization and be able to benefit from its routine use (3). Therefore, understanding how adoption decisions occur is very important for organizations to improve the outcome of their investments and for innovators to adequately diffuse their innovations. Moreover, it has also proven to be one of the most challenging issues in research, for a long time (4).

The factors influencing technology adoption decision might be divided in technological, organizational and environmental (5). Much of the current literature assumes that technology adoption is driven primarily by the characteristics of a technology, of the adopters, or by perceptions of users about a certain technology. These studies presume that the decision to adopt is guided by rational goals of efficiency. However, the decision to adopt may have more to do with the external environment (cultures, structures, and routines) in which an organization is located, than rational intra-organizational and technological criteria (6). In fact, when environmental conditions change, organizations consider adopting new technologies to stand out from competitors (7).

The environmental context has been pointed by several authors as the strongest influence on the adoption decision (8–10). The higher relevance of those factors might be associated to the fact that it also influences the technological

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and the organizational contexts of adoption (8), being a broader context than the latter two.

It was found in the literature that there are different environmental factors with different impacts on the adoption of technologies in a supply chain context. However, it was also found that, despite the existence of several studies about adoption of technologies in supply chain contexts that include environmental factors, there is a gap in identifying which environmental factors influence the adoption of digitalization technologies in supply chains. In order to fill this gap, we propose to identify and analyze the environmental factors that influence the adoption of digitalization technologies of the supply chain. We conducted an exploratory qualitative research, based on semi-structured interviews to managers of several Portuguese manufacturing companies belonging to the automotive supply chain (including companies at different tiers of the supply chain). The findings from this study allow identifying the most relevant factors that influence the adoption of digitalization technologies in automotive supply chains, and contribute to the literature with a description of how such influence occurs and with new knowledge concerning some of those factors, namely new specificities of some factors that were, to the best of our knowledge, not identified in the literature so far, with important influence on the adoption decision.

The paper starts with this overall introduction and motivation to the focus of our research. Afterwards, a framing within the relevant literature for the topic under study is presented, followed by a thorough description of the research method used. Then the findings are presented and briefly discussed. Finally, the paper ends with a set of conclusions focused on the contributions of the study to the literature, and a set of managerial and policy recommendations, oriented to supply chain managers and policy makers.

II. LITERATURE REVIEW

A. Adoption theories

The adoption of new technologies to respond to market demands is influenced by several factors (11–13). This study uses an integrated approach, described in a conceptual framework (14), to identify the environmental factors that influence the adoption of digital technologies on the supply chain. This conceptual framework combines three important and well-known theories:

a) Diffusion of Innovations theory (DOI) developed by Rogers (3), widely used to describe the organizational and individual innovation adoption process. This theory is predominantly based on the characteristics of the technology and the users' perception of the innovation. The innovation-decision process proposed by this author is composed by 5 stages: knowledge, persuasion, decision, implementation and confirmation. According to this author, five factors influence the decision to adopt an innovation: Relative advantage: is usually measured in terms of costs savings of increased efficiency. Compatibility: degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters; Complexity: degree to which an innovation is perceived as difficult to understand and use; Trialability: degree to which an innovation may be experimented with on a limited basis; and Observability: degree to which the results of an innovation are visible to others.

b) Technology–organization–environment (TOE) framework proposed by Tornatzky and Fleischer (5), argues that the decision to adopt a technological innovation is based on factors related to the organizational and environmental contexts, as well as characteristics of the technology itself. According to this theory the technology context refers to technologies relevant to the organization. It includes all technologies available in the marketplace, those in use by the organization and those that are not currently in use. The organizational context refers to internal characteristics and resources of the organization. And, the environmental context refers to the sector in which the organization conducts its business and its relationships.

c) Institutional theory (INT) argue that organizational decisions are not driven purely by rational goals of efficiency, but also by social and cultural factors, and concerns for legitimacy (15). The institutional environment where the organization is integrated (the rules, norms, routines and rituals of organisational life) influences technology adoption process.

Although the conceptual framework proposed (Fig. 1) identifies three contextual environments/ Technology/Innovation, internal/organizational and environmental/external (14), in this study we focused mainly on the environmental context, and in its relations with the internal context.

B. Environmental factors influencing the adoption of technologies in supply chains

Competitive pressure's influence on technologies adoption in a supply chain context has been recently studied for different technologies such as information technologies (IT) in general (16), electronic supply chain management systems (e-SCM) (10), mobile SCM systems (m-SCM) (17), cloud computing (18,19), radio frequency identifier (RFID) (20,21), green supply chain (Green SC) (8), Internet of Things (IoT) (9), and e-business (22). Generally, it has been found to be a key determinant for the adoption of such technologies, with the exception of m-SCM, where it had no significant influence (17). Competitive pressure was also found to influence the extent of adoption of e-SCM (10), and it was pointed by Hsu and Yeh (9) as the most important influence on the adoption of IoT.

Compliance with standards and legislation has been far less explored in recent literature, and the results are spread and do not lead to a clear conclusion. On the one side, the adherence to standards seem to influence the decision to adopt RFID systems (23). On the other, regulatory environment seem to have no significant influence on the decision to adopt cloud-based services (19). For RFID systems, standards have been defined for a long time, while for cloud-based services legislation is not yet clear (19), which might contribute for the different conclusions reached. It is important to notice that both compliance with standards and compliance with legislation need further investigation in what concerns their influence on the adoption of technologies by supply chains.

Generally, external pressure has been found to significantly and positively influence RFID (24), IoT (25), Green SC (8), social customer relationship management (SCRM) (26), and overall industry 4.0 technologies adoption (12). Specifically, market pressures in the form of customers readiness were found to have positive influence on Green SC (8) and on e-business adoption (22). Moreover, external

pressures from the industry sector in the form of trading partner influence have significant influence in cloud computing adoption in high-tech industry (18), trust and institutional pressures (coercive and normative) has a positive impact on e-SCM adoption (27) and a significant positive influence on RFID adoption (20), and peer pressure is critically important for the adoption of e-SCM (28). However, in some cases external pressure is also found to negatively influence Enterprise Resource Planning (ERP) adoption (29). Still, Awa, Uko and Ukoha (29) suggest that when external pressures are high they have negative impact on the adoption of ERP, but when they are low they have a positive effect on the adoption. Hsu and Yeh (9) found that support from the industry has no significant influence on the adoption of IoT. Similarly, but going slightly forward, other authors suggest that external pressures, in the form of expectations of the market, transaction climate, trading partner influence or supplier interdependence, influence the later stages of the implementation, the stage of assimilation of the technology in the operational routines of the adopter (assimilation stage) of e-SCM or m-SCM, but not the adoption decision (17,28). Likewise, Lin (10) suggested that although trading partners have no influence on the decision to adopt e-SCM, they significantly influence the extent of its use. However, Low, Chen and Wu (18) found that trading partners have significant influence on cloud computing adoption in high-tech industries. Therefore, in what concerns the influence of external pressures in the adoption of technologies in a supply chain, the literature is not completely unanimous. Consequently, it is necessary to further explore the influence of the different types of external pressures in different technologies to come up with a more precise characterization of its influence on the adoption and implementation.

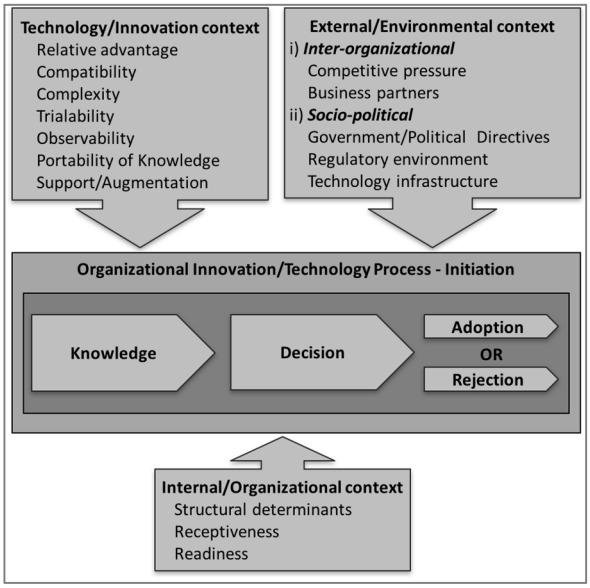

Figure 1: Conceptual Framework (Source: Adapted from (14))

Generally, external pressure has been found to significantly and positively influence RFID (24), IoT (25), Green SC (8), social customer relationship management (SCRM) (26), and overall industry 4.0 technologies adoption (12). Specifically, market pressures in the form of customers readiness were found to have positive influence on Green SC (8) and on e-business adoption (22). Moreover, external pressures from the industry sector in the form of trading partner influence have significant influence in cloud computing adoption in high-tech industry (18), trust and institutional pressures (coercive and normative) has a positive impact on e-SCM adoption (27) and a significant positive influence on RFID adoption (20), and peer pressure is critically important for the adoption of e-SCM (28). However, in some cases external pressure is also found to negatively influence Enterprise Resource Planning (ERP) adoption (29). Still, Awa, Uko and Ukoha (29) suggest that when external pressures are high they have negative impact on the adoption of ERP, but when they are low they have a positive effect on the adoption. Hsu and Yeh (9) found that support from the industry has no significant influence on the adoption of IoT. Similarly, but going slightly forward, other authors suggest that external pressures, in the form of expectations of the market, transaction climate, trading partner influence or supplier interdependence, influence the later stages of the implementation, the stage of assimilation of the technology in the operational routines of the adopter (assimilation stage) of e-SCM or m-SCM, but not the adoption decision (17,28). Likewise, Lin (10) suggested that although trading partners have no influence on the decision to adopt e-SCM, they significantly influence the extent of its use. However, Low, Chen and Wu (18) found that trading partners have significant influence on cloud computing adoption in high-tech industries. Therefore, in what concerns the influence of external pressures in the adoption of technologies in a supply chain, the literature is not completely unanimous. Consequently, it is necessary to further explore the influence of the different types of external pressures in different technologies to come up with a more precise characterization of its influence on the adoption and implementation.

Concerning external support, namely financial support for the investment in the technology being adopted, although Hossain, Quaddus and Islam (24) found that it was not positively related with RFID adoption, the availability of investment (such as business angels, venture capitals or crowd funding) was found to be positively related to the adoption of SCRM by start-ups (26). Moreover, government support was also found to have significant positive influence on, and even to be one of the most important factors influencing the adoption of RFID (20), IoT (9,25), Green SC (8), and SCRM (26).

Most of the recent literature that assesses the influence of environmental uncertainty on the adoption of new technologies in a supply chain context, seem to agree that environmental uncertainty is not a major concern for the adoption of e-SCM (28), nor for the adoption of IoT (25). However, its influence on the adoption of RFID systems has been more deeply studied, and, although it might seem that it has no significant influence on the adoption decision (20), it actually seems to not have particular influence on the initiation of such decision process but have a significant positive effect on the decision itself and a negative effect on the extent to which it is adopted (24). Therefore, it might be interesting to explore the influence of environmental uncertainty on the different stages of the adoption decision to other technologies in the supply chain as well.

In conclusion, competitive pressures are found to have significant positive influence on the adoption of technologies in a supply chain context. Compliance with standards and legislation might have a positive or an insignificant impact on the adoption decision according to the stage of

standardization of the technology and to whether there is legislation in place, as well as on whether such legislation is already mature or not. The influence of external pressures is not clear, although it has been generally found to be positively related to the adoption. However, it is not yet clear if that influence is verified to every technology, or whether such influence depends on the stage of diffusion of the technology, nor is it clear whether external pressures influence the adoption decision or later stages of the implementation process, nor whether that influence might differ according to the intensity of the pressure. External support, namely government support, has been generally found to have positive influence on the decision to adopt technologies in a supply chain context. And, environmental uncertainty although not being a trigger for the adoption process, seems to have the potential to significantly influence positively the decision to adopt and a influence negatively the extent of such adoption.

III. RESEARCH METHOD

The purpose of this study is to identify and describe the environmental factors that influence the adoption of digitalization technologies in supply chains. Portuguese factories of multinational companies in the automotive sector were used to achieve such purpose. The decision process to adopt digital technologies in a supply chain is complex and therefore the factors that influence this decision can be better explored by conducting exploratory research using qualitative evidence. In order to obtain rich and valuable insights about the topic of interest we collected qualitative data using semi-structured interviews. Qualitative data offer the opportunity to understand deeply the topic as well as to clarify misunderstanding aspects (30,31).

Criterion-based convenience sampling (32) was used to identify companies and participants. Companies were selected based on the previous experience and knowledge of the research team. These companies had previously collaborated with some members of the research team and their managers have large experience in the topic of interest (30). The interviewees were selected based on their experience and knowledge about the topic; their ability to speak about the adoption of digital technologies in a supply chain; and their decision-making capability in technological strategy definition and implementation in the organization.

Six managers in four automotive multinational companies were approached and agreed to participate in the study. Consequently, a total of six interviews were conducted between February and May 2018, with the duration between 30 and 70 minutes. Each interview was conducted in Portuguese. The open-ended style of the interviews allowed the respondents to describe their experiences, perspectives and ideas freely, without being limited to predefined concepts or models. Interviewees and companies' characterization is presented in Table 1.

The interviews were recorded and transcribed, and MAXQDA (version 11.0) qualitative analysis software was used to analyze the interviews. A thematic and theory-driven analysis was adopted (33). First, a subset of interview transcripts were analyzed (a) to develop an initial coding scheme for the pre-defined interview topics and (b) to identify topics in the transcripts that were not specifically queried by the interview guide (34). Afterwards, a structural coding was used to identify unanticipated topics in the interview (33,34).

Shenton (35) provided an overview of how to ensure quality in qualitative research, in terms of credibility, transferability, dependability, and confirmability. *Credibility* explores the congruence of the findings with reality (36). Several strategies suggested by Shenton (35) were incorporated to promote credibility. Our interview method has been established in previous research (31,32). Since the research team previously had contact with the interviewees' organizations by field visits and information collected in previous consultancy and research projects, they developed an early familiarity with the culture of participant organization. Triangulation of data sources was used, involving multiple sources of information and individual interviews with a wide range of informants, where individual perspectives and experiences were verified against others.

TABLE I. INTERVIEWEES AND COMPANIES' CHARACTERIZATION

ID	Function	Years in company	Position in SC	SC Technologies	Turnover 2017 (M€)/ # employees
C1I1	Logistic Director	25	Tier 1	ERP, WMS, bar codes, robots, EDI, cloud-based technologies, cyber security technologies	56 / 358
C2I1	Logistic Director	15	Tier 2	AGVs, robots, e-SCM, EDI, RFID, ERP	1300 / 3700
C3I1	Senior Operations Manager	4	Tier 1	Robots, ERP, EDI, e-SCM, Machine Learning, cloud-based technologies (to access information in real time)	133 / 800
C4I1	Logistic and Continuous Improvement Director	23	OEM	EDI, ERP, MRP, RFID, MIR, AGV, cloud-based technologies (to access information in real time)	230 / 450
C4I2	IT Process Management Director	23			
C4I3	Warehouse and internal logistic Director	N/D			

Additionally, in this study, we have examined previous research results that supports our findings. We also carefully explained to the participants that their identities would not be revealed in our work and their participation was voluntary. All these components added credibility to our work. *Transferability concerns to the extent to which the findings of the study can be applied to other situations* (32)**.** To ensure the transferability in this study we provide background data that enable the context description (companies and interviewees) and a detailed description of phenomenon under study was made. As with most qualitative research, the transferability of these results must be understood within the

particular characteristics of organizations and the geographical area of the organizations.

In addition to credibility and transferability, we also considered the *dependability* of the research results, which is the likelihood that others would uncover similar findings if the research was repeated. In order to address dependability, we conducted a transparent coding process, a rigorous interview protocol and a process of rechecking the transcripts. Finally, to achieve confirmability researchers must take steps to demonstrate that findings emerge from the data and are not dependent on human skill and perception (35). Detailed documentation of data handling and analysis provided means for confirmability checking (35).

IV. FINDINGS

For adequately interpreting the findings, it is important to notice that the members of the supply chain manage their activities centered on their client (according to C1I1), namely to achieve the service level required and to reduce uncertainty related to production and logistics activities. With that focus, as all interviewees stressed, members of the supply chain adopt digitalization technologies to improve their reliability and visibility across the supply chain (allow traceability required by OEM's, EDI). They look to access and provide access to information in real time, and reduce errors and costs. According to interviewees, these technologies allow to improve stocks management (reduce levels and errors), supply chain agility and reliability.

"*These tools have made the supply chain more agile and reliable. It reduces errors, costs and we have information in real time.*" (C1I1)

According to some of the interviewees, all members of the supply chain adopt digitalization technologies in production and internal logistics in order to reduce costs and errors (C1I1, C2I1, C4I3). Automation of processes, Robots, AGVs (Automated Guided Vehicle), e-SCM, WMS (Warehouse Management System), MIR (Mobile Industrial Robots) and MRP (Manufacturing Resource Planning) are some examples. The adoption decision was mentioned by every interviewees to be based on the requirements set mainly by the OEM and on the estimation of the return on investment.

Concerning the factors that influence the adoption of digitalization technology in automotive supply chains, environmental factors were recognized by the interviewees as the main drivers for that adoption. Although not every of the factors identified in the literature were referred in the interviews, a few new specific factors emerged.

Competitive pressures did not emerge as a relevant factor for the adoption of digitalization technologies in the automotive supply chain, as it was not referred by any of the interviewees. This might not mean that competition is not important throughout the automotive supply chains, but it seems that it is not an important driver for the adoption of new technologies for digitalization. However, competition emerged implicitly related to other factors, as will be explained in a later paragraph.

Compliance with standards and legislation was referred by some of the interviewees as having influence in the adoption of digitalization technologies. Legislation and public policies were recognized to have influence on the adoption decision (C3I1). Some uncertainty or instability of legislation might create concerns among managers of the supply chain and block some technology adoptions. For example, for a company that produces equipment to control CO_2 emissions from vehicles is very prone to uncertainties of legislation regarding such emissions, and, therefore, its decisions to adopt new technologies are highly influenced by such legislation uncertainties. In such cases, managers value particularly adopting technologies that are flexible to face the several possible legislation scenarios and that have the lower risk of becoming obsolete in any of those scenarios. However, guidelines from the governmental entities, such as the "Recommendations for implementing the strategic initiative INDUSTRIE 4.0" sponsored by the German Federal Ministry of Education and Research (37), might also trigger readjustments in strategies and investment plans, with impact on the technologies adopted in the supply chain.

"It is obvious that the development of i4.0 had a considerable impact on the company targets. We readjusted the investment and the development plans to follow the government guidelines." (C2I1)

Related with standards, although with a different relation from those suggested in the literature, it also emerged that the adoption of technologies might create the need for the adoption of standards that benefit the supply chain. It was widely recognized (by C1I1, C2I1, C3I1 and C4I1) that the will to implement IoT, a digitalization technology that has the potential to increase reliability in the communication between members of the supply chain, led to standardize procedures and data structures within industrial groups and supply chain members, reducing operational problems within those networks.

Concerning external pressures, market and industry tendencies were mentioned by all interviewees as having strong influence on the decision to adopt new technologies in their organizations. They recognized a need to follow technology evolution of the supply chain partners, and mentioned that they benchmark customers, competitors and supply chain partners frequently to learn about technology tendencies and, eventually, decide to adopt. Another source of external pressure is the OEM, which is pointed to use coercive and normative pressures over the other members of the supply chain, through recommendations or requirements to adopt specific technologies (to ensure supply chain traceability, real time information and production visibility), respectively.

"OEM's send a report after each audit with recommendations of improvement or correction. In a first report it is only an alert, with respective time to react. Afterwards, if the same is referred in a second report, it will be a requirement." (C3I1)

"OEM's set the pace, and we do what we can to follow. After all, OEM's are our client." (C1I1)

Other members of the supply chain also put pressure on their own suppliers, in particular to adopt digital technologies to improve communication and prevent errors from inaccurate manual data entry, such as EDI (Electronic Data Interchange). Sometimes, such pressure leads to partnerships with suppliers in order to develop them (C2I1). Moreover, whenever a supplier is not able to adopt a technology (for instance, because they cannot afford the investment), interviewees mentioned that they can provide an IT online

platform to overcome such impediment, to be used at low cost for the suppliers, that enable them to share data conveniently (C3I1).

External support was also mentioned by all interviewees. Interestingly, there was no mention to non-governmental financial support (from business angels, venture capitals, and other sources of funding), which makes sense since they belong to a mature industry, where companies are long established. However, governmental funding (such as the operational program Portugal 2020) was recognized as an important source of support to projects, namely to develop capabilities of human resources and to improve processes and facilities (including the adoption of digitalization technologies).

Associated with this factor other sources of external support also emerged, which were not found in the literature. One important problem faced by the organizations of automotive supply chains is that their workers are not sufficiently skilled to use digitalization technologies (C3I1, C4I1, C4I2, C4I3). Therefore, partnerships with higher education institutions are being used and are relevant to develop internships or small projects that bring the capabilities needed to use new digitalization technologies (C2I1, C3I1 and C4I1).

Finally, concerning environmental uncertainty, market uncertainty was not mentioned by the interviewees. However, all of them mentioned the relation between some uncertainty created by geographic dispersion (a consequence of supply chain globalization) and the implementation of digitalization technologies (namely, ERP, EDI, Cloud GPS, and RFID). The digitalization is improving communication among supply chain members, allowing to work in just-in-time, with lower lead times, and, thus reducing uncertainty.

Furthermore, also concerning environmental uncertainty, every interviewee identified technology evolution as a nuclear concern. To keep up to date, they establish partnerships with technology suppliers, which are also recognized to contribute for adoption success (including improving customization and service level).

In addition, every interviewee highlighted the importance of top management involvement in the adoption decision and in the implementation processes, and their important role as champions for the technology being adopted. That was the only internal factor highlighted by the interviewees. Considering that most of the environmental factors mentioned concern activities (partnerships, applications to funding, monitoring/benchmarking, compliance with standards and legislation) that may require or, at least, significantly benefit from the involvement of top management, this importance of their involvement and championing does not surprise.

V. CONCLUSIONS

In this study, an exploratory qualitative research was conducted in Portuguese manufacturing companies belonging to the automotive supply chain as Tier 1 or 2 suppliers, to identify and analyze the environmental factors that influence the adoption of digital technologies in supply chains. We conclude that digitalization technologies, such us big data & analytics, cloud computing, cybersecurity, Internet of Things (IoT), Robots, AGVs (Automated Guided Vehicle), ERP (Enterprise Resource Planning) system, and visual computing (1,2), are being used to improve supply chain performance as a whole, allowing to work in just in time and with lower lead times. Although this research did not provide the ability to identify the type of influence (positive or negative) of each factor in the adoption decision, we were able to identify the most relevant factors that influence the adoption of digitalization technologies in automotive supply chains, and contribute to the literature with a description of how such influence occurs.

Environmental factors were pointed as the most important drivers to promote the adoption of technology digitalization in the automotive supply chain. Such adoption is mainly driven by the OEM, by using coercive and normative pressures over the other tiers of the supply chain. Among the other tiers of the supply chain there is also evidence of coercive pressures being used, namely from organizations to their suppliers (i.e., towards upstream of the supply chain).

Other important drivers of digitalization technologies adoption are benchmark and to follow the evolution of supply chain partners in what concerns technology adoption. Moreover, very important in this adoption process are partnerships with technology providers to keep updated with technology evolution, and also with higher education institutions to develop de adequate capabilities to take full advantage of the technology potential. These partnerships emerged as a new mechanism of external support, which, to the best of our knowledge, has not been identified in the literature so far. Finally, top management support and championing is also extremely important to be able to adequately respond to the environmental factors' influence.

Besides factors that influence the decision of adoption, it also emerged from our findings that the decision to adopt some technologies might also trigger other actions in the supply chain that may benefit it. In this case, the adoption of IoT triggered the need for standardizing procedures and data structures, leading to a better operational performance of the supply chain

From this research it is possible to draw a few recommendations concerning management practices and public policies related with the adoption of digitalization technologies in automotive supply chains. It became very clear the need to invest in new human resources capabilities that will enable companies to take full potential of the technologies. Such investment requires whiling from managers, namely to establish partnerships with higher education institutions that can help develop human resources, and support from regional and national public authorities, namely to promote such collaborations or partnerships.

Moreover, collaboration with technology providers is essential to achieve adequate technologies for the reality of the supply chains, and adequate levels of service. Such collaboration can also be triggered and/or supported by regional and national authorities.

Finally, it is important to be conscious that policy guidelines have important impacts on organizations' strategies (affecting technology adoption). Therefore, policy makers should listen carefully to the stakeholders of such supply chains and adjust policies to promote their evolution. Moreover, policy makers should avoid legislation uncertainty or instability, by communicating more clearly with the

stakeholders to keep them informed about policy evolution. All these interactions with the stakeholders should, naturally, be careful to avoid favoring some of them and distort competition.

This is an exploratory research; therefore, the conclusions and findings must be confirmed with other stakeholders from other companies and from other supply chains. Nevertheless, this research already provides interesting contributions to systematize knowledge about the environmental factors that influence the adoption of digitalization technologies in supply chains, and how such influence occurs.

REFERENCES

[1] Büyüközkan G, Göçer F. Digital Supply Chain: Literature review and a proposed framework for future research. Comput Ind. 2018;97:157–77.

[2] Dalmarco G, Barros AC. Adoption of Industry 4.0 Technologies in Supply Chains. In: Moreira AC, Ferreira LMDF, Zimmermann RA, editors. Innovation and Supply Chain Management: relationship, collaboration and strategies. Springer; 2018.

[3] Rogers EM. Diffusion of Innovations. 5th edition. New York: Free Press; 2003.

[4] Swanson EB. Information system implementation: Bridging the gap between design and utilization. Homewood, IL: McGraw-Hill, Irwin,; 1988.

[5] Tornatzky L, Fleischer M. The Process of Technology Innovation. Lexington, M.A: Lexington Books; 1990.

[6] Teo HH, Wei KK, Benbasat I. Predicting intention to adopt interorganizational linkages: An institutional perspective. MIS Q. 2003;27(1):19–49.

[7] Damanpour F, Gopalakrishnan S. The dynamics of the adoption of product and process innovations in organizations. J Manag Stud. 2001;38:45–61.

[8] Hwang BN, Huang CY, Wu CH. A TOE approach to establish a green supply chain adoption decision model in the semiconductor industry. Sustainability. 2016;8(2):168.

[9] Hsu CW, Yeh CC. Understanding the factors affecting the adoption of the Internet of Things. Technol Anal Strateg Manag. 2017;29(9):1089–102.

[10] Lin H-F. Understanding the determinants of electronic supply chain management system adoption: Using the technology–organization–environment framework. Technol Forecast Soc Change. 2014;86:80–92.

[11] Gibbs JL, Kraemer KL. A cross-country investigation of the determinants of scope of e-commerce use: an institutional approach. Electron Mark. 2004;14(2):1019–6781.

[12] Nilsen S, Nyberg E. The adoption of Industry 4.0-technologies in manufacturing: a multiple case study. KTH Industrial Engineering and Management; 2016.

[13] Rajan CA, Baral R. Adoption of ERP system: An empirical study of factors influencing the usage of ERP and its impact on end user. IIMB Manag Rev. 2015;27(2):105–17.

[14] Simões AC, Barros AC, Soares AL. Conceptual framework for the identification of influential contexts of the adoption decision. IEEE 16th International Conference on Industrial Informatics (INDIN). Porto, Portugal: IEEE; 2018. p. 1059–64.

[15] DiMaggio P, Powell W. The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields. Am Socioiogicai Rev. 1983;48(2):147–60.

[16] Wu IL, Chen JL. A stage-based diffusion of IT innovation and the BSC performance impact: A moderator of technology-organization-environment. Technol Forecast Soc Change. 2014;88:76–90.

[17] Chan FTS, Chong AY-L. Determinants of mobile supply chain management system diffusion: a structural equation analysis of manufacturing firms. Int J Prod Res. 2013;51(4):1196–213.

[18] Low C, Chen Y, Wu M. Understanding the determinants of cloud computing adoption. Ind Manag Data Syst. 2011;111(7):1006–23.

[19] Hsu CL, Lin JCC. Factors affecting the adoption of cloud services in enterprises. Inf Syst E-bus Manag. 2016;14(4):791–822.

[20] Shi P, Yan B. Factors affecting RFID adoption in the agricultural product distribution industry: empirical evidence from China. Springerplus. 2016;5(1):2029.

[21] Paydar S, Endut IR. Key drivers of RFID adoption in Malaysian retail industry, a theoretical model. In: IEEE International Conference on RFID-Technologies and Applications (RFID-TA). Malaysia; 2013.

[22] Zhu K, Kraemer K, Xu S. Electronic business adoption by european firms: A crosscountry assessment of the facilitators and inhibitors. Eur J Inf Syst. 2003;12(4):251–68.

[23] Cao Q, Jones DR, Sheng H. Contained nomadic information environments: Technology, organization, and environment influences on adoption of hospital RFID patient tracking. Inf Manag. 2014;51(2):225–39.

[24] Hossain MA, Quaddus M, Islam N. Developing and validating a model explaining the assimilation process of RFID: An empirical study. Inf Syst Front. 2016;18(4):645–63.

[25] Lin D, Lee CKM, Lin K. Research on effect factors evaluation of internet of things (IoT) adoption in Chinese agricultural supply chain. In: IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). Bali, Indonesia: IEEE; 2016.

[26] Hasani T, Bojei J, Dehghantanha A. Investigating the antecedents to the adoption of SCRM technologies by start-up companies. Telemat Informatics. 2017;34(5):655–75.

[27] Ke W, Liu H, Wei KK, Gu J, Chen H. How do mediated and non-mediated power affect electronic supply chain management system adoption? The mediating effects of trust and institutional pressures. Decis Support Syst. 2009;46(4):839–51.

[28] Wu IL, Chuang CH. Analyzing contextual antecedents for the stage-based diffusion of electronic supply chain management. Electron Commer Res Appl. 2009;8(6):302–14.

[29] Awa HO, Uko JP, Ukoha O. An Empirical Study of Some Critical Adoption Factors of ERP Software. Int J Human–Computer Interact. 2017;33(8):609–22.

[30] Creswell JW. Research design: Qualitative, quantitative, and mixed methods approaches. 4th editio. Sage publications; 2014.

[31] McCracken G. The long interview. Newbury Park, CA: SAGE; 1988.

[32] Patton MQ. Qualitative research & evaluation methods. Third. Sage Publications; 2002.

[33] Namey E, Guest G, Thairu L, Johnson L. Data reduction techniques for large qualitative data sets. In: Guest G, MacQueen K, editors. Handbook for team-based qualitative research. Lanham MD: AltaMira Press; 2008. p. 137–62.

[34] MacQueen KM, McLellan E, Kay K, Milstein B. Codebook Development for Team-Based Qualitative Analysis. Cult Anthropol Methods. 1998;10(2):31–6.

[35] Shenton AK. Strategies for ensuring trustworthiness in qualitative research projects. Educ Inf. 2004;22(2):63–75.

[36] Merriam SB. Qualitative research and case study applications in education. San Francisco: Jossey-Bass; 1998.

[37] Kagermann H, Wahlster W, Helbig J. Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group. 2013