Impact of ambidexterity of blockchain technology and social factors on new product development: a supply chain and Industry 4.0 perspective

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Abstract

This study develops a technology and social capital process aided product innovation conceptual model based on dynamic capability and supply chain ambidexterity theory. The strategy of organisational ambidexterity in balancing technological and relational social capital factors between buyers and suppliers leads to a higher level of digital manufacturing capabilities and enhances buyers' innovation potential, considering the sustainable practices in their processes to cope with Industry 4.0 manufacturing processes and sustainability challenges. The study empirically validates the model using data collected from 379 French manufacturing companies. This is the first study that examines how buyers perceive the role of blockchain technology in exploring and exploiting innovation management in the Industry 4.0 era. The study advances understanding on the theory of ambidexterity of supply chains in buyer–supplier relationships. The study results show the positive effect between internal integration and blockchain technology as well as relational social capital factors in buyer–supplier relationships. The findings underscore the critical role of relational and technological capital in buyer–supplier relationships, specifically to act as a catalyst for exploiting internal capabilities to achieve the innovation targets. The unique findings state blockchain technology mediation is dominant in exploiting the internal capabilities and benefits buyers' innovation orientation.

Keywords: Buyer innovation, blockchain technology, supply chain ambidexterity, relational capital, Industry 4.0, sustainability.

1. Introduction

Significant environmental volatility and changing consumer behaviour are creating pressure on organizations to lean toward digital technologies in supply chains to address Industry 4.0 expectations and sustainability challenges (Garay-Rondero, 2019). In recent years, supply chain processes have been actively adopting advanced technologies such as Big data, artificial intelligence, the Internet of Things (IoT), and blockchain technology to deal with product and process innovation with the consideration of sustainability challenges. This study focuses on the association between new product development (NPD) process and Industry 4.0 technologies which, despite growing interest is still in the early stages of investigation in the literature (Wijewardhana et al., 2020).

Researchers emphasize that the NPD process can benefit from new technologies to provide smart products and stimulate innovation strategies, particularly in the context of the smart manufacturing process and related practices observed across extended supply chains (De Silva et al., 2019; Wijewardhana et al., 2020). The NPD process needs integration of substantial information related to product design such as digital design files, printing parameters, and process configurations alongside the collaborative efforts of various stakeholders including suppliers and their compliance with sustainability activities.

Industry 4.0 technologies will enable seamless transfer of information between multiple stakeholders in the supply network, however, there could be challenges in terms of security, traceability, and reliability of contracts between stakeholders in the manufacturing supply chain. The application of blockchain technologies is gaining momentum as they represent many benefits, particularly in inter-organisational relationships in terms of visibility, security, and traceability of operations (Schmidt and Wagner, 2019; Babich and Hilary, 2020). Companies can exploit these benefits to strengthen their relationships with a focus on the process of developing new products (Holland et al., 2018; Kouhizadeh and Sarkis, 2018). Nevertheless, blockchain's role in buyers' innovation has rarely been examined. To address this gap, this study explores the role of blockchain technology in collaborative supplier management in terms of enhancing the innovation capabilities of buying firms.

Buyers' innovation potential depends on several characteristics such as organisational culture, learning motivation, technology use, and resource allocation within and across firms (O'Reilly and Tushman, 2008). It is argued that organizations engaged in innovation processes must mobilize internal knowledge and knowledge spillovers from the extended supply network. Overall, innovation is a derivative of multiple partnerships with the art of pursuing and balancing both exploration and exploitation activities of buying firms and developing organizational ambidexterity (Tushman and O'Reilly, 1996; Gibson and Birkinshaw, 2004). According to O'Reilly and Tushman (2008), an ambidextrous approach enables companies to simultaneously undertake exploration and exploitation activities that sustain innovation over longer periods to satisfy sustainable performance.

Several studies emphasised the stronger relationship between sustainability focus, technology intervention and new product introduction (Nara et al., 2021; Bag et al., 2021). Moreover, technological intervention could help firms to understand environmental aspects by sharing their process-related information through Industry 4.0 technologies (Jabbour et al., 2018; Benzidia et al., 2021). However, understanding social practices from the supplier end need meaningful relationship management. Hence, social capital management at the relational level, where partners have a strong relationship founded on trust, respect, and mutual interest would benefit NPD and also depend on creating a favourable social environment from the sustainability perspective (Cousins et al. 2006). Relational social capital reinforces collaborative behaviour in the supply chain as a commonly shared value between the partners (Wu and Chiu, 2018). Relational social capital also builds a close and personal rapport between strategic suppliers who explore new knowledge that is useful for developing products and sustainable process innovations (Lawson et al., 2008; Chowdhury et al., 2017).

Additionally, to the best of our knowledge, no other study has investigated the combination of relational social capital and technological characteristics (blockchain integration) as an ambidextrous strategy that encourages buyers to develop a dynamic capability through exploration and exploitation activities to achieve innovation targets under Industry 4.0 and sustainability challenges. Hence, this study explores the purpose of ambidexterity to enable buyers pursue a balance of exploration and exploitation of knowledge spillovers and boost internal creativity and capabilities from the extended workforce to support buyers' innovation behaviour in dynamic environments.

Our empirical study, which extends the research on ambidexterity in a supply chain, makes the following contributions. First, in place of supply chain ambidexterity and dynamic capabilities theory, the study contributes to the literature on supply chains by developing a technology and social capital aided innovation model highlighting how firms can dynamically use explorative and exploitative strategies (also known as ambidextrous effect) to learn and enhance sustainable innovative abilities. Second, the study results offer insights to purchasing managers about managing the trade-offs between technological and relational social capital resources to improve their innovation ability. Third, purchasing managers can use our proposed model to understand the role of emerging technologies such as blockchain in the NPD process in conjunction with supplier activities and sustainability initiatives. Last, our study is among the first to measure an empirically ambidextrous supply chain strategy in the context of Industry

4.0 by testing the effect of blockchain technology and relational social capital in the context of developing innovation capacity.

This paper is organised as follows: Section 2 presents the theoretical framework of our study. Section 3 develops the hypotheses and conceptual model. Section 4 details the research methodology and explains the data sources and data analysis. Section 5 presents the empirical results, and Section 6 discusses these results. We conclude by presenting the study contributions and limitations and proposing directions for future research.

2. Theoretical framework

2.1. Supply chain ambidexterity and innovation

Ambidexterity is defined as an organisation's ability to simultaneously align and efficiently adapt to environmental changes (Raisch and Birkinshaw, 2008). Primarily, the concepts of ambidexterity has been applied to organisational learning. In his seminal work, March (1991) describes organisational learning as the balance between exploring new alternatives and exploiting existing capabilities. Exploration activities are associated with research, discovery, experimentation, and the development of new knowledge while exploitation activities consist of the refinement and extension of existing knowledge. Exploratory innovation is associated with the long-term vision of identifying and seizing new opportunities, uncertain advantages, and high risks of failure (O'Cass et al., 2014). Alternatively, exploitation innovation responds to market needs by improving the existing environment and by offering short-term security (O'Cass et al., 2014). Researchers have examined exploration and exploitation activities in the context of organizational learning such as strategic business alliances (Grant and Baden-Fuller, 2004), and new product development (Wei and Guo, 2014). The association of these two activities, that is, exploration and exploitation, has also been studied extensively across industries such as small and medium enterprises (Cegarra-Navarro and Dewhurst, 2007), manufacturing companies (Tamayo-Torres et al., 2011), biotechnology firms (Rothaermel and Deeds, 2004), higher education institutions (da Silva Souza and Takahashi 2019), and multinational companies (Luo and Rui, 2009). The existing literature has frequently focused on the balance between exploration and exploitation and has recommended that ambidextrous learning strategies must be further investigated (Kristal et al., 2010).

Broadly, the literature on ambidexterity in the context of supply chains lacks investigation and does not feature adequate empirical evidence (Blome et al., 2013). However, in an uncertain context, the adoption of collaborative supply chain practices involving exploration and exploitation practices can generate multiple benefits for the focal firm to develop new competencies with the support of external partners (Partanen et al., 2019). In recent years, few studies have explored the ambidexterity in supply chains and have provided insightful empirical evidence. For instance, Blome et al. (2013) and Gualandris et al. (2018) show that ambidexterity strengthens supply chain competencies and improves product innovation. Lee and Rha (2013) explain that supply chain ambidexterity is necessary for firms because it may mitigate the negative impact of supply chain disruptions and enhance firm performance. Aslam et al. (2018) recognise that the intertwining of dynamic capability and supply chain ambidexterity enable focal firms to simultaneously leverage the supply chain's exploitation (i.e. and new product development efficiency and exploration (i.e. flexibility) practices.

2.2. Integration of blockchain technology

The benefits of blockchain technology have been mostly discussed in the context of financial applications. However, blockchain technology shows potential for application across several other sectors (Kouhizadeh and Sarkis, 2018), and one such area of interest is supply chain operations (Chang et al., 2019). Kshetri (2018) states that blockchain technology generates several benefits in supply chains such as risk reduction, cost optimisation, responsiveness, reliability, sustainability, and flexibility. Babich and Hilary (2019) highlight a conceptual discussion on the strengths and weaknesses associated with the technological functionality of blockchain in operations management. Chod et al. (2020), examine the application of blockchain technologies in financing supply chains and supporting operational capabilities. Schmidt and Wagner (2019) argue that blockchain reduces transaction costs by limiting opportunistic behaviour, and environmental and behavioural uncertainty in the supply chain. Other than cryptocurrency, a supply chain is one of the most popular areas of blockchain use, as evidenced by the development of various chains, including HyperLedger, VeChain, Modum, and Waltonchain (Frizzo-Barker, 2020). For example, Walmart and IBM have deployed the IBM Food Trust application as a collaboration platform for Walmart's vegetable suppliers to strengthen the traceability and security of the food supply chain (Bumblauskas et al., 2020; Köhler and Pizzol, 2020).

In the Industry 4.0 era, inter-organizational relationships are supported by a combination of technologies, as the relationship between the supply chain stakeholders requires a certain level of transparency and security of the data exchanged within the supply chain (Treiblmaier, 2018; Wamba and Queiroz 2020). Blockchain is a promising solution that could be integrated with other inter-organizational technologies and can potentially alleviate trust, traceability, and collaboration issues between supply chain actors (Saberi et al., 2018; Kayikci et al., 2020). Typically, blockchain improves the reliability of historical supplier data and helps companies to enhance the supplier selection process (Kouhizadeh and Sarkis, 2018) and improve the purchasing function (Tönnissen and Teuteberg, 2018; Rane and Thakker, 2019). In addition, firms can reduce their product development cycles by facilitating real-time data sharing for any modifications or data errors (Kamble et al., 2018; Saberi et al., 2018; Subramanian et al., 2020).

Blockchain technology is predicted to have a strong influence on new process and product development in the Industry 4.0 era. Papakostas et al. (2019) consider that blockchain associated with computer-aided design (CAD) guarantees protection of sensitive files (e.g. product prototypes and designs) and information that is exchanged between stakeholders during the design phase of new product. Rahmanzadeh et al. (2020) developed a blockchain decision model implemented in Visual Studio 2010 software to help organisations protect intellectual property rights by recording and storing ideas and innovations for future use. A few other studies also stated the potential use of building information modelling on a CAD platform by highlighting the potential of blockchain in the design and smart contracts of innovative projects that require collaboration based on stakeholder trust (Dounas and Lombardi, 2018; Lemeš and Lemeš, 2019). Blockchain also represents a potential for complementarity with other technologies such as Big data and enables companies to assess customer attitudes and preferences. Therefore, such complementarity can support the NPD process by generating personalised and intelligent data (Choi et al., 2020; Pólvora, et al., 2020).

On a technical level, blockchain improves the quality of existing technologies, such as the IoT, cloud, RFID, GPS, and machine-to-machine learning (M2M) (Reyna et al., 2018), which many companies strongly rely on to manage their processes (Kshetri, 2018). For Zhang et al. (2018), blockchain’s smart contracts can automate implementation agreements, a possibility that was mostly theoretical until the introduction of blockchain. Different types of blockchain architecture are used to collect and process transactions with different organisational or transactional parameters (O’Leary, 2017). This integration could be achieved by taking a hybrid technological approach for exploiting the advantages of blockchain and existing technologies (Reyna et al., 2018). In addition, notwithstanding the potential of blockchain, companies face several challenges such as interoperability, data storage, regulatory and legal variability, protection of anonymity, and contractualisation (intelligent contracts) in their quest to succeed in creating flexible and accessible interfaces (Reyna et al., 2018).

2.3. Relational social capital

Prior studies have focused on the social dimension of inter-organisational aspects (Cousins et al., 2006), including buyer–supplier relations (Dyer and Singh, 1998; Autry and Griffis, 2008). Min et al. (2008) defined social capital in the supply chain as a set of social resources embedded in the relationships within a supply chain network. Nahapiet and Ghoshal (1998) have identified three types of capital—cognitive, structural, and relational. These three types of capital are mobilized frequently in a buyer–supplier relationship (Carey et al., 2011; Chowdhury et al., 2017). In this research, we focus only on relational social capital as a human variable to understand how partners in a supply chain must strengthen their collaborative behaviour to foster knowledge sharing and improve process innovation (Cousins et al., 2006; Lawson et al., 2008; Carey et al., 2011; Tsai et al., 2013). For Wang and Wei (2007), collaborative behaviour reduces conflict between clients and suppliers, and thus helps them to establish relationships based on human values from the end to end supply chain. Collaborative behaviour can be based on the principle of relational social capital, as a means of transferring knowledge and developing innovation (Cousins et al., 2006; Lawson et al., 2008; Carey et al., 2011). In line with the literature on organisational behaviour, all relations do not afford mutual benefits, as noted by Cheng (2011). Some companies express reticence towards collaborative relations fearing their partners' opportunistic behaviour, such as symmetrical power and dysfunctional conflicts (Min et al., 2008). Integrating behavioural values such as trust and commitment between partners is key to facilitating collaboration with suppliers in the NPD process. In the absence of trust, exploiting a knowledge base is impossible (Delbufalo, 2017) including overlook of human rights abuse. Similarly, the obligation and commitment involved in relational social capital ensures respect for agreed-upon standards of interaction and establishes mutual trust in relationships (Kang et al., 2007; Wang, 2014). As mentioned earlier, in the Industry 4.0 era, companies must create a trust-based environment, primarily emphasising transparency during trade. Trust is even more necessary in the NPD process where sensitive and strategic data are exchanged. One of the most important characteristics of Industry 4.0 is the lack of experience of suppliers in developing or adopting IT infrastructure that meet specific buyer requirements including sustainability concerns. Thus, it is important to collaborate with suppliers to design a flexible interface that is adept at integrating various heterogeneous applications focused on Industry 4.0 and sustainability concerns (Luthra and Mangla, 2018; Beaulieu and Bentahar, 2021).

3. Conceptual model and hypotheses

How do some companies succeed in being more innovative and in securing a competitive advantage over their counterparts? The resource-based view (RBV) provides a suitable framework to answer this question and holds that a company's position depends on the market results derived from the accumulation of resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). This formalisation of RBV has led to acquiring a 'unique' firm-specific resource base. Therefore, RBV does not clearly explain the process by which the interaction of resources helps a company to maximise its competitive potential, particularly in a highly dynamic and disruptive market (Benzidia and Makaoui, 2020). Possessing resources is a necessary condition, but it is not sufficient to guarantee competitive advantage. For these reasons, the dynamic capability view (DCV) has emerged to extend the concept of RBV to accommodate the dynamic market perspectives and to build flexibility into the capability development process. O'Reilly and Tushman (2013) suggested that dynamic capability is a relevant theoretical framework for advancing understanding on ambidexterity in supply chains. Previous research has shown that dynamic capabilities are required to develop business innovation (Zhang et al., 2017; De Silva et al., 2019). Our model assesses the ability of companies to integrate the dynamic capabilities of the supply chain ambidextrously to ensure exploration and exploitation capacity.

3.1. Exploitation using internal integration technologies and innovation capacity

Internal integration refers to the unified process in which different business units and functional areas of a company must collaborate to achieve a goal (Flynn et al., 2010). Zhao et al. (2011) consider internal integration as a company's capacity to share data between various functions using information technologies. Companies can employ software such as ERP, computer-aided design, or web-based applications that facilitate real-time, transparent circulation of flows among internal functions, such as procurement, logistics, R&D, and production.

Companies working on innovation projects must establish integration processes that are not only adept at improving communication and coordination but must also adopt a cooperative framework (Wong et al., 2013). Gillani et al. (2020) stated that in the Industry 4.0 era, the efficiency of internal digital technologies associated with CAD applications enable smart manufacturing to improve the company's innovation performance.

Several business units, such as design, procurement, production, marketing, and distribution can be integrated into NPD (Narasimhan and Kim, 2002). Moreover, the purchasing function is integrated into the innovation process, including design to production to industrialisation (Benzidia, 2013). Inter-functional teams coordinate to exploit firm-specific internal resources more efficiently (Wong et al., 2013). Stakeholders can share knowledge and simultaneously make decisions that are necessary for developing products and processes for performing tests, conducting evaluations, and establishing prototypes (Koufteros et al., 2010). The level of integration within an organisation depends on the project's influence on processes and product innovation. For example, complex and novel projects require a high level of coordination, planning, and cooperation to ensure the success of innovations (Gao et al., 2015). Internal integration also deals with the hazards and constraints encountered during the development of innovative products. An integrated organisational response improves a product's development cycle and the company's responsiveness, thereby allowing the product to reach the market faster (Droge et al., 2004). For these reasons, we propose the following hypothesis:

H1: Internal integration positively affects a buyer's innovation capacities.

3.2. Exploitation of internal integration and integration of blockchain technology

Previous research has highlighted the importance of cross-functional integration to facilitate the diffusion of new external technologies to enhance buyer–supplier relationships (Rai et al., 2006; Angeles, 2009; Ranganathan and Dhaliwal, 2011). Maiga et al. (2015) confirmed the strong association between the integration of internal and external information systems. The integration of inter-organizational infrastructure will remain unsatisfactory if its own systems are not integrated (Zhou and Benton, 2007). Integrated and interoperable IT systems such as enterprise resource planning (ERP) enable firms to achieve better integration of e-business supply chain processes (Rai et al., 2006). According to Angeles (2009), internal interconnection is the catalyst for the successful deployment of the radio frequency identification (RFID) technology within interlinked supply chains and helps to achieve supplier cooperation. Ranganathan and Dhaliwal (2011) cited lack of internal IT integration as the main reason why many B2B projects failed to succeed in digital web-enabled supply chain initiatives. Ramamurthy and Premkumar (1995) highlighted the importance of interoperability of IT systems between internal business units for the dissemination of EDI technology. Thus, companies with a high level of internal integration supported by IT applications will more likely succeed in blockchain integration between buyers and suppliers. This leads us propose the following hypothesis:

H2: Internal integration positively enables integration of blockchain technology.

3.3. Exploration using internal integration and relational social capital

The existing literature has studied the impact of the internal integration or coordination of various organizational functions/processes on external relationships/stakeholders (Das et al., 2006; Ellegaard and Koch, 2012). However, these studies tended to focus on the transactional side and paid little attention to the association between internal integration and relational social capital of suppliers. According to Zhao et al. (2011), companies' internal processes are fragmented and disconnected and lack sufficient resources to resolve potential conflicts with suppliers. Horn et al. (2014) explain that companies rely on cross-cutting integration to cope with external actor issues, particularly in an international context.

Exploration using internal integration based on collaboration between buyers and other business units in a company allows buyers to improve integration with strategic suppliers. This close relationship makes it easier for a company to absorb and exploit new knowledge inflows required for innovation (Bierly et al., 2009). Whipple et al. (2015) draw on the resource-based theory to demonstrate the positive relationship between internal capacity and external social capital. More precisely, they highlight that lack of investment in 'internal competence' reduces the benefits of relational success significantly. Drawing on various studies, we develop a hypothesis to address the gaps and propose an empirical study on the association between internal integration supported by IT applications and relational social capital to improve the innovation capabilities of buying companies. This leads us to the following hypothesis:

H3: Internal integration positively affects a supplier's relational social capital.

3.4. Exploration using relational social capital and innovation

Recent studies have advanced understanding on the importance of developing robust social interactions with suppliers for fostering an innovation culture (Autry and Griffis, 2008; Lawson et al., 2008; Carey et al., 2011). March (1991) interprets that the development of relationships with external partners depends on the strategy to explore and exploit new opportunities. Innovation development is the result of existing relational social capital, which reinforces firms' vision and common objectives.

Relational motivation implies that companies must share tacit information to improve their understanding on product design and processes (Blomqvist et al., 2005). Cousins and Menguc (2006) posit that improving relational social capital ensures security in buyer–supplier relations, which reduces constraints related to information sharing, especially confidential information that is likely to improve product innovation. Carey et al. (2011) proposed a model that stipulates trust and reciprocity in relationships as fundamental assets of relational social capital for strengthening legal contracts and creating an environment that fosters innovation. Strong mutual trust promotes willingness to invest in collective learning and reduces knowledge dissemination control as well as transaction costs (Adler and Kwon, 2002).

Relational social capital fosters personal relationships with strategic suppliers who are capable of supplying added value and innovative solutions that can adapt to consumers' needs (Lawson et al., 2008; Chowdhury et al., 2017). Therefore, we formulate the following hypothesis:

H4: Relational social capital is positively associated with improved buyer innovation.

3.5. Exploitation of blockchain technology integration and innovation

Several studies feature the importance of supplier integration in new product/services development (Wong et al., 2013; Lii and Kuo, 2016). However, a few researchers studied the impact of e-integration of suppliers on innovation (Barczak et al., 2007; Barczak et al., 2008). Blockchain technology is a new form of integration that companies can employ to improve their innovation strategies (Kouhizadeh and Sarkis, 2018). Some researchers show that blockchain could provide a solution to the complexity in supply chains by creating a digital framework capable of integrating processes and allowing real-time management of transactions between the various actors in the chain (Kamble et al., 2018). Blockchain technology could also improve the use of the vast amount of data generated by the Industry 4.0 applications (Rahman et al., 2019). The contribution of blockchain in innovation processes can take several forms. First, blockchains are used to store voluminous information, which is often sensitive and related to the new product design and development process and environmental concerns, allowing it to be shared by several partners with total security and better develop the intelligent manufacturing systems (Leng et al., 2020). Second, blockchain technology improves the efficiency associated with NPD, reliability of information analysed, and the trust between partners (Rahman et al., 2019). Lastly, easier interaction and more sharing of pertinent product and environmental information with suppliers fosters collaboration in innovation and enables a company to access the additional knowledge required to develop new products (Bibby and Dehe, 2018). During the innovation process, blockchains are used to improve both data collection time and quality, precisely track sources, employ real supplier data, and store information (Kouhizadeh and Sarkis, 2018). Klöckner et al. (2020) concluded that blockchain technology can help companies overcome intellectual property and data security barriers associated with the design phase by preserving various types of historical records related to 3D printed parts and securing authentication of prototypes.

Based on these reasons, we propose the following hypothesis:

H5: Integration of blockchain technology positively affects a buyer's innovation capacities.

--Figure 1---

4. Research methodology

4.1. Sampling and data collection

We used a survey for testing our hypotheses and the proposed conceptual model. The questionnaire helped to measure the extent of the phenomenon in all the French companies by collecting precise information on buyers' perceptions and experiences through blockchain intervention and relational exchange of information. The questionnaire also enabled us to analyse the characteristics of the phenomenon studied in this research.

By using standard scales similar to recent studies (Wamba and Queiroz 2020; Jakhar et al, 2019), this study contributes to the existing literature on the potential role of blockchain technology in enhancing the innovation capacity of companies and social capital in exchange of formal and informal information across partners.

Before conducting a field study in France, we tested our questionnaire with a group of purchasing professionals to verify its validity and to make necessary modifications. This stage helped to check if the respondents could easily understand the translated items. In particular, the principal component analysis resulted in consistent and logical factors and, following the test, only minor modifications were made. The survey population comprised of buyers from French organisations across sectors. In its final form, the questionnaire was distributed electronically to purchasing managers who proactively participate in the meetings of the firm's innovation teams. In addition, we only included responses from organisations that use e-procurement. We also ensured that only one respondent from each firm answered the questionnaire. The rate of return was 23.6% or 379 responses from organisations that automate their purchasing process. Table 1 provides the demographic profile of respondents.

The choice of purchasing managers is justified by the central role of the purchasing function between the internal business units and suppliers, particularly in the NPD process (Benzidia, 2013; Constant et al., 2020). The contribution of the purchasing function is also substantial to the team in charge of innovation because it allows to align internal services, in particular R&D and marketing (Picaud-Bello et al., 2019). The role of purchasing function in the development of innovative projects, supported by IT, has contributed to the digitization of this function and enhanced its strategic positioning within organizations. In addition, the emergence of Industry 4.0 technologies, namely IoT, Big data, and Cloud computing, offer purchasing managers opportunities to renew their technological assets and support organizations in their innovation strategies. However, in NPD projects, companies always seek to secure and share knowledge and information, and hence the need to invest in technologies with higher security.

---Table 1---

Table 1 shows that a significant majority of the respondents worked in private companies (71%) and most belonged to manufacturing industries (70%), with a preponderance of large companies. The participants' average age was 35 years, and they had five years of work experience in procurement. Over 84% of the respondents had completed purchasing and procurement training, and 10% had completed training in IT tools. In the context of the e-procurement system used by the sample companies, over 83% employed an ERP program, 57% had established a data exchange system (i.e. EDI), and 41% used the tools of a purchasing editor software or e-marketplace. Some companies combined several tools. Despite the current lack of use, all the sample respondents were aware of the benefits of blockchain technology and the ongoing pilot initiatives worldwide.

4.2. Measurements

Based on the conceptual model, our questionnaire covered each dimension. The survey questionnaire items were adapted from previous studies and improved through interviews with purchasing managers and reviews by academic researchers to assess the face and content validity. All the items were subject to internal validation and a pre-test. To measure the degree of agreement or disagreement with the questions asked, we used a 5-point Likert scale, ranging from ‘1 = strongly disagree’ to ‘5 = strongly agree’. The operationalised variables are presented in Table 2.

--Table 2--

5. Analysis and results

We tested our research model applying the structural equation modelling (SEM) technique using the AMOS 23 software. Our research required developing and validating several measurement instruments. Gerbing and Andersen (1988) illustrated the need to clean data using exploratory factor analysis (EFA) applying SPSS 23, followed by confirmatory factor analysis using AMOS 23 to appraise the reliability and validity of the measurement instruments.

We measured several univariate and multivariate statistics that represent skewness, kurtosis, and the Mardia methodology. According to the guidelines for severe non-normality (absolute skewness value > 2; absolute kurtosis value > 3) proposed by Westfall and Henning (2013), the normality assumption of all the variables was satisfied: the standardised values were between -0.709 and -0.169 for skewness and the standardised values were between -0.319 and 0.416. The Mardia measure of multivariate skew equalled 118.43, whereas a value lower than 3 is recommended to conclude that there are no multi-normality problems (Bentler, 1995). Therefore, to estimate the model parameters, we used a robust correction method developed by Satorra and Bentler (1994). This method enables to have the stability of the estimate by the maximum likelihood method (MLM). Thus, the statistics corrected have been favoured and the final fit of the EFA was satisfactory.

The data analysis was organised into two stages. The first stage evaluated the model's measurement quality and the second stage involved an examination of the model's structure to test the research hypotheses.

5.1. Robustness checks

5.1.1. Testing for response and non-response

Survey research in supply chains can represent non-response problems (Wagner and Kemmerling, 2010). To detect potential non-response bias in our sample, we compared early and late responses using key variables, starting with the hypothesis that the opinions of participants who respond later are similar to those of non-respondents (Armstrong and Overton, 1977). The final sample was divided into two groups according to the date each company received the questionnaire. Thus, the early and later sub-samples were identified as having 231 and 148 respondents, respectively. The two groups were compared using diverse organisational characteristics for correlations with the *t*-test, including industry type and firm size. In addition, the *t*-tests performed on the responses of these two groups revealed statistically no significant difference ($p > 0.05$), indicating that no systematic non-response bias was present for the data collected. In addition to early and late wave test, as recommended by Wagner and Kemmerling (2010), we did a priori test to confirm the non-respondent bias using demographic variables such as firm size and firm type with the population characteristics of the manufacturing sector in France and confirmed there is no significant difference between the sample and the population characteristics.

5.1.2. Common method bias

Given that the survey data were obtained from single informants, to resolve any common method bias (CMB) that may have occurred, we adopted a priori approach to attenuate such biases. Our questionnaire-based survey respondents were senior managers highly skilled in using e-procurement with the knowledge of product and innovation strategies of the firm. We preselected each respondent through closed-ended questions based on their knowledge of blockchain operations. If any respondent believed that he/she was not the best person to answer any specific question, we requested that they ask the most informed person to provide the answer instead. To avoid any misunderstanding of the questions, the respondents were provided with an explanatory introduction about the nature of our research and a glossary of the key terms of our study. We allowed respondents to answer the questions anonymously, stipulating that there were no wrong or right answers. This also reduced the potential cause of CMB due to decreased motivation (Podsakoff et al., 2003). In the accompanying letter, we highlighted the potential scientific contributions and the advantages of the project. Statistically, we also performed Harman's single-factor test provided by Podsakoff et al. (2003). This test is a commonly used method to detect CMB and is recommended in operations management literature (Craighead et al., 2011). We used SPSS 23.0 to conduct a factor analysis, using the factorisation of the main components of the measuring elements. A single-factor solution without rotation for the 16 elements indicated that the total variance explained by these elements was 42%. We also performed a second test applying the correlation marker technique (Lindell and Whitney, 2001). This test consists of using an unbound variable to extract the correlations caused by the CMB. In addition, we calculated the significance value of the correlations using the procedure suggested by Lindell and Whitney (2001). There are small differences between the obvious variables (between manifest variables as measures for the latent method variable). The analysis shows that various latent variables in our sample are not significantly correlated, with correlation coefficients close to zero.

We supplemented the previous tests that suggested collinearity using the full collinearity test by Kock (2015). According to Kock and Lynn (2012), collinearity typically occurs when the variance inflation factor (VIF) is greater than 3.3, indicating that the model presents a common method variance (CMV). The values of VIF must, therefore, exist below the threshold of 3.3 (Hair et al., 2017, Kock, 2015). This indicates that the model has no CMV.
Based on these results, we conclude that CMB may not have a significant impact in this study.

5.2. Measurement model

We considered the measurement properties of the constructs and tested their reliability, convergent, and discriminant validity. Individual item reliability is examined by observing the item-to-construct loadings. A factor loading of 0.70 or above indicates that 50% or more of the variance in the item is shared with the latent construct, while a factor loading of less than 0.5 should be dropped (Anderson and Gerbing, 1988). All the items' loadings were above the 0.70 threshold. As Table 3 indicates, the Cronbach's α values ranged between 0.772 and 0.901, and the composite reliability for all the constructs was above the 0.70 level (Nunnally and Bernstein, 1994), indicating adequate reliability.

---Table 3--

We examined convergent validity by calculating the average variance extracted (AVE) and the composite reliability (CR) of each latent variable. We obtained satisfactory results on the convergent validity of our model. The AVE of each latent variable was equal to or above 0.5 (Fornell and Larcker, 1981), and the composite reliability (CR) of all the three latent constructs was greater than 0.70.

Discriminant validity was evaluated by examining the factor contributions of the items to their respective theoretical constructs. To establish discriminant validity, CR, AVE, maximum shared variance (MSV), square root of AVE, and maximum reliability (MaxR(H)) were measured. All the respective values of MSV are lower than AVE, while CR is higher than AVE, and MaxR(H) is greater than 0.8 (Hu and Bentler, 1999). We verified that factor contributions for each construct were higher than the factor contributions crossed between each item and the other constructs. We also checked that the square root of the AVE for each construct was greater than the relevant inter-construct correlations (Fornell and Larker, 1981) (Table 4).
Based on our results, the overall measurement model provided an acceptable fit to the data ($\chi 2/df$ = 1.716; goodness of fit (*GFI)* = 0.950; comparative fit index (*CFI)* = 0.986; Tucker Lewis index (*TLI)* = 982; incremental fit index (*IFI)* = 0.986; root-mean-square error of approximation (*RMSEA)* = 0.060; standardized root-mean-square residual (*SRMR)* = 0.0332). All the fit indices fulfilled the recommended thresholds given by Hu and Bentler (1999). Therefore, it can be concluded that the model fits the data well and can be used to explain the research hypotheses.

---Table 4--

5.3. Results of structural equation modelling

We used structural equation modelling to estimate the relationships between the constructs. We applied the maximum likelihood estimation method. The fit indices for the structural model indicate an acceptable fit to the data (Hu and Bentler, 1999) ($\chi 2/df$ = 227.486/97 = 2.345; *GFI* = 0.931; *IFI* = 0.973; *TLI* = 0.967; *CFI* = 0.973; *RMSEA* = 0.060; *SRMR* = 0.0332). As presented in Table 5 and Figure 2, the structural model results indicate that all the hypotheses are supported.

---Table 5---

---Figure 2---

5.4. Mediation effects analysis

Structural equation modelling analysis demonstrated that two variables mediate the influence of internal integration on innovation: blockchain technology and relational social capital. To test these effects, we employed the procedure developed by Baron and Kenny (1986), where a four-step approach examines the effects of mediation.

First, the relationship between internal integration and innovation must be significant.

Second, the relationships between internal integration and the mediating variables (blockchain and relational social capital) must be significant. Third, the relationship between the mediating variable and innovation must be significant. Finally, after controlling for the mediator, the relationship between internal integration and innovation should become non-significant (i.e. full mediation) or weaken (i.e. partial mediation). Tables 6a and 6b present the estimates obtained from the regressions.

---Table 6a---

---Table 6b---

5.5. Control variables

In this study, firm size and type of industry are the control variables. Firm size was measured by the number of employees and industry type was measured based on nine categories. The statistical results suggest that firm size ($\beta = -0.06$; $t = -1.76$) and industry type ($\beta = 0.001$; $t = 0.10$) did not have a significant effect on buyer's innovation capacities.

6. Discussion

The analysis of the study results shows that internal integration of firm capabilities enabled blockchain technology integration with supplier operations to share product and process information across firms. Our study results are similar to previous studies which consider internal integration as one of the mean factors in effectively using external technology and diffusion of innovation (Angeles, 2009) and consequently reinforcing the collaborative process involving suppliers (Zhang et al., 2018).

In addition, in line with other studies such as Horn et al. (2014), our results substantiate a direct and significant connection between internal integration and relational social capital. These results support the concept that mastering an internal process using effective communication contributes towards the development of relational capacity between buyers and suppliers through formal and informal channel of data collection. This internal step, supported by IT applications, produces strong relational alignment and is an effective mechanism that reduces social control and builds trust between buyers and suppliers.

The study results confirm a positive and significant impact between internal integration and buyer's innovation capacity. Companies can benefit from technological advantages that ensure better inter-functional integration that is necessary for realizing the benefits of digital manufacturing, primarily for teams involved in innovation projects (Svahn et al., 2017). Our results indicate that working in collaboration with other business units ensures improving the capacity to not only exploit and coordinate internal resources but also to remove functional obstacles easily, especially in the Industry 4.0 era. This result implies that inter-functional integration has beneficial effects on digital design and manufacturing (Gillani et al., 2020) and the time necessary to develop and commercialise products (Dröge et al., 2004). Nonetheless, the results indicate that this impact remains relatively weak. Therefore, concluding based on our results that inter-functional integration is the only factor that affects companies' innovation development would be an exaggeration. This weak impact could be explained by the fact that some companies tend to concentrate only on internal resources and ignore emerging opportunities and the potential of external integration in building innovation capacity (Wong et al., 2013). In addition to a direct effect, our results indicate that internal integration contributes to innovation through relational capital and blockchain technology integration. In summary, internal integration could constitute a solid antecedent of increased innovation, if supplier relations are strong to address sustainability concerns in the longer run.

In addition, our results confirm the positive and significant impact of relational social capital on a company's innovation capacity. These results supplement the growing research trend of drawing on relational social capital to improve buyers' innovation (Cousins et al., 2006; Carey et al., 2011) and explain why purchasing managers spend time creating an environment of proximity with suppliers to strengthen mutual trust and reciprocity. Based on our analysis, we assume that manufacturing companies must create a relational environment to understand the social issue from the sustainability perspective with suppliers to meet Industry 4.0 requirements including environmental perspective from the sustainability dimensions and innovative product development (privacy, security, etc.).

Our results confirm that relational social capital ensures partial mediation between internal integration and innovation, in turn suggesting that shared values and the ability to maintain a sustainable social connection with the supplier network reinforces the effect of internal integration on innovation.

Our survey establishes the significant impact of integrating blockchain technology with a buyer's innovation capacity. This result extends the previous study, which highlights the ability of the blockchain to interface with other applications (e.g. IoT and RFID) as the infrastructure necessary for the technology security and tracking environmental concerns of the supply chain (Zelbst et al., 2019), which in turn can influence the innovation process (Leng et al., 2020). For example, this capacity concerns regular exchanges and innovation meetings with suppliers and technological roadmaps connecting business, innovation, and purchasing strategies. It is an important finding, because the effect of blockchain in NPD and innovation remains insufficiently studied, especially in the Industry 4.0 and sustainability context.

In addition, incorporation of blockchain technology partially mediates the relationship between internal integration and innovation. These results confirm that blockchain technology is perceived by stakeholders as a determinant of innovation mechanisms. The mediating impact of blockchain technology is greater than the effect of relational social capital. This finding is unique since blockchain is recognised today as a new technology that guarantees quality of transparent and secure transactional exchanges including environmental information from the sustainability perspective with suppliers (Schmidt and Wagner, 2019).

7. Concluding remarks

7.1. Theoretical contributions

Our results on the ambidextrous effect of technological integration and relational social capital for developing new products contributes to the existing literature in the following ways.

First, blockchain is increasingly being used for developing new products and innovation activities. However, most studies on blockchain technology and innovation focus on computer science and engineering research (Rahmanzadeh et al., 2020). Our study contributes to the literature blockchain by understanding purchasing managers views on the role of blockchain in supply chain integration, process information and innovation development.

Second, while the concept of ambidexterity has been widely studied in previous innovation research (Blome et al., 2013; Wong et al., 2013), this study makes a new theoretical contribution and offers a new perspective on innovation ambidexterity through a combination of relational social capital and blockchain integration to develop buyers' exploitation and exploration capacities.

Third, on a relational social capital level, lack of trust is one of the main impediments to inter-organisational collaborations, especially in the context of increasingly complex supply chains. This concern is prominent when it involves transfer of knowledge between partners (Lawson et al., 2008; Carey et al., 2011). To attenuate this problem, we have applied a collaborative behaviour approach to explain how to establish trust rapidly and to encourage partners to develop innovative projects.

Fourth, we contribute to research on product innovation by providing empirical proof on how internal integration affects innovation that could resolve challenges related to sustainability. Our findings broadly align with previous research that considers internal integration as a catalyst for external integration (Koufteros et al., 2005). Similarly, this research corroborates studies that identified internal integration as an antecedent to the external dissemination of technology (Ranganathan et al., 2004). However, prior empirical research has not analysed the role of internal integration as an antecedent to relational social capital and its effect on innovation. This study offers a major theoretical contribution that seems promising and initiates a future scientific debate.

Fifth, this study contributes to the literature on the NPD based on the perspective of dynamic capabilities by drawing on internal and external resources. The results are consistent with other research studies (Zhang and Wu, 2017). Nevertheless, to our knowledge, this is the first attempt to identify the process by which a company transforms the potential advantages of interaction between its internal resources and the combination of technological and relational resources through dynamic capabilities. Thus, the theoretical approach of dynamic capability provides new perspectives regarding collaborative supply chains in terms of the usefulness of resources that are mobilised for the successful development of new products.

7.2. Managerial contributions

The results also offer some managerial implications for innovative projects in supply chain management. The observations indicate that the potential use of blockchain integration technology positively influences the effectiveness of the NPD process, which is a strong argument to encourage managers to enter into new collaborative projects with their suppliers to cope with sustainability challenges. Procurement managers can combine blockchain with the existing integration tools to improve strategic information exchanges for innovation, including sustainability challenges with their supplier network. The possibility of technically coupling blockchain with other technologies (e.g. CAD, 3D, IoT, and cloud computing) provides further motivation to encourage managers to invest in these technologies and to make them accessible to users. This combination requires that prototype and design files can be sent in real time to accelerate the development process of new products.

This result falls under the continuity of studies that highlighted the role of advanced technologies such as Big data, 3D, cloud computing, and IoT which hold significant capacities in terms of sharing, storage, data analysis, and play a dominant role in the innovation process (Yang, et al., 2017). In addition, the accessibility of advanced technologies escalates the need for transaction security, which is a major concern in buyer-supplier relationships. The deployment of blockchain technology is, therefore, a serious promise for future generation companies because it offers complementary opportunities to existing applications in terms of security and transparency and allows buyers to accelerate the NPD process. Moreover, in the Industry 4.0 era, blockchain is a new paradigm with a core benefit of higher productivity in digital manufacturing and addressing sustainability concerns. Consequently, blockchain could help companies integrate other product lifecycle management systems such as production, maintenance, and recycling in a secure and connected way.

Our finding that blockchain improves innovation capacity is important because companies always try to build a relationship of trust with suppliers before committing to developing new products. In addition, building relational social capital will address the social dimensions of sustainability. Thus, our empirical results offer a valuable contribution that investment in

blockchain technology not only offers security in information exchange but also improves collaboration between the various actors engaged in implementing innovation developing a long term policies.
Our results explicitly abound the importance of purchasing to manage alliances between different actors and functional alignment in the success of NPD, especially in the Industry 4.0 era and sustainability conerns. Companies must, therefore, align purchasing with the development objectives of exploratory and exploitative innovation. In addition, our results encourage companies to invest heavily in technologies or collaborative platforms to facilitate the implementation of purchasing 4.0 processes and lead innovation projects reliably and transparently.

The results also suggest that relying solely on external integration technologies to develop innovation is not prudent. Managers must carefully align their internal technological resources and evaluate the capacity of their inter-functional relationships in terms of sharing and disseminating information (De Sousa Jabbour et al., 2018). Innovative projects require close collaboration between internal teams across various business units, such as purchasing, marketing, R&D, and quality. For instance, the quality of information sharing can be supported by tools such as ERP, Big data, and RFID to foster NPD processes that cope with emerging sustainability challenges. Thus, companies must take proactive measures to improve internal integration to improve the development of new green products through the technological and relational integration of suppliers (Benzidia et al., 2021).

Lastly, we believe that with the increasing demand for new-generation technologies (e.g. artificial intelligence, IoT, Big data, smart cities) and the results of our research could encourage software vendors to develop new extended blockchain applications that cover not only innovation processes but all supply chain operations in an integrated manner to address sustainability challenges in the Industry 4.0 era (i.e. a software suite).

7.3 Limitations and future directions

These results must be interpreted with certain caution as they present limitations that can be resolved through additional research. We have mobilised collaborative behaviour from an external perspective to provide a basis from which client–supplier relations can develop a relational consensus and the capability to share information through internal technological resources. The dynamic capability theory offers an innovative framework of understanding.

Managers can also evaluate other pre-adoption factors on the development of collaborative blockchain mechanisms or from a technology dissemination perspective (Hastig and Sodhi, 2020). This research could also be extended and linked with other earlier studies (Kim and Garrison, 2010) to measure individual or collective behavioural intention based on the technological acceptance model developed by Davis (1989). Lastly, the theory of information technology assimilation (Armstrong and Sambamurthy, 1999) could be employed to study how the use of blockchain technologies fits into the organisational level to reduce the gap between adoption and usage and to accelerate the innovation process.

In our research, we focus solely on the buyer perspective and attitude towards innovation to address sustainability challenges in the Industry 4.0 era. Consequently, integrating the viewpoints of both buyers and suppliers into the same field of investigation to apply a mirror approach to understand the concept of supplier integration *via* blockchain would be interesting. Monitoring the relationship over time through a longitudinal study would also be pertinent to comprehend evolution in buyer-supplier relations.

In addition, our results are based on a study that surveyed buyers, and we did not make use of convenience samples. The final study involved a sample of 379 buyers. The data collection efforts ensured pertinence of this sample and a final response rate of 23.6%, which is satisfactory for a questionnaire distributed to professionals. Nevertheless, the sample size is relatively small for making multi-group analysis through structural equation modelling. Preferably, this type of analysis must involve a larger sample.

Although the model follows the literature according to which the buyer's innovation is affected by internal and blockchain technology integration as well as relational social capital, a certain level of endogeneity can also explain the association of these variables (i.e. the most innovative companies can use technologies and organizational processes to integrate both internally and externally). In our study, we did not verify endogeneity bias arising from the simultaneous and reciprocal effects of the variables.

Although the present study has improved our understanding on the potential of blockchain technology for the development of collaboration and innovative products, no distinction was made between the types of innovative projects, such as the level of innovation to address sustainability challenges and complexities. An additional study could distinguish between these two forms of innovation to more closely examine the balance of blockchain technology integration and socialisation.

Our study has examined the link between blockchain and innovation by focusing predominantly on the upstream process of the chain with the assumption of capturing environmental process information during the record of activities in the stamped blocks. Future studies can consider the ability of blockchain in the end to end supply chain to improve innovation in the Industry 4.0 era by involving other collaborators and processes throughout the product lifecycle and develop smart and sustainable factories. On the similar vein, we indirectly captured the betterment of social practices across the supply chain through relational practices. Further qualitative studies can investigate in detail the employee welfare activities and other societal benefits.

Our results demonstrate the ability of the blockchain to secure data and exchanges by mobilizing heterogeneous technological systems. Consequently, supply chain management will become increasingly visible, sustainable, and intelligent.

Lastly, our conclusions are specific to France, and could be different for emerging countries depending on their technology infrastructure and business-to-business (i.e. e-business) context. Future studies can validate our conclusions in other emerging countries on a larger scale. If we can conduct a similar study in another country, we believe that we must consider the level of acceptance of this new technology, sustainable practices as well as the level of innovation in companies.

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Appendix 1

Primer to shortlist the participants

I confirm that I am aware of blockchain technology characteristics.

I believe blockchain is compatible with our electronic e-procurement applications.

Our company is currently using blockchain technology in supplier integration.

Purchasing managers contribute to the new joint product development process between focal company (buyer) and suppliers.

Please indicate your current e-procurement tool (s): EDI – ERP – E-marketplace - purchasing editor software - e-marketplace – Other "please precise"

Internal integration using advanced technology (Adapted items derived from Flynn et al., 2010; Narasimhan and Kim, 2002; Lii and Kuo, 2016)

Please indicate your level of agreement with the following statements about the degree to which your inter-departmental are integrated with the support of IT/SI.

Q1. Our inter-departmental teams participate in the development of new products
Q2. Data are well shared with other internal departments
Q3. Our inter-departmental teams participate in the improvement of processes
Q4. Real-time integration and connection among all internal functions from raw material management through production
Q5. Our IT/IS support is well integrated among internal functions

Relational social capital (Adapted items derived from Dyer and Singh, 1998; Lawson et al., 2008)

To what extent do the following statements describe your firm's relationship with suppliers?

Q1. The relationship is characterized by close interaction at multiple levels.
Q2. The relationship is characterized by mutual trust at multiple levels.
Q3. We build a long-term relationship with suppliers
Q4. We develop a new projects with some suppliers
Q5. The relationship is characterized by high collaboration

Blockchain integration (Adapted items derived from Flynn et al., 2010; Narasimhan and Kim, 2002; Lii and Kuo, 2016)

Please indicate your level of agreement with the following statements about the ability of blockchain integration in the process of developing new products with supplier.

Q1. Improves communication with suppliers by strengthening the security of data exchanged in terms of customer preference of the buying firms' product information.
Q2. Improves exchanges of information with suppliers about product demand and feedback (customer request)
Q3. Improve the exchange of information of strategic suppliers in the design phase

Perceived Innovation (Adapted items derived from Wong et al., 2013; Chowdhury et al., 2017)

Please indicate your level of agreement with the following statements about the future innovation process ability for new products of your company

Q.1 Our company is able to accelerate the new product development process
Q.2 Our company is able to improve the capacity development process for product innovation
Q3. Our company is able to develop the process for new product features into the market quickly.

Figures

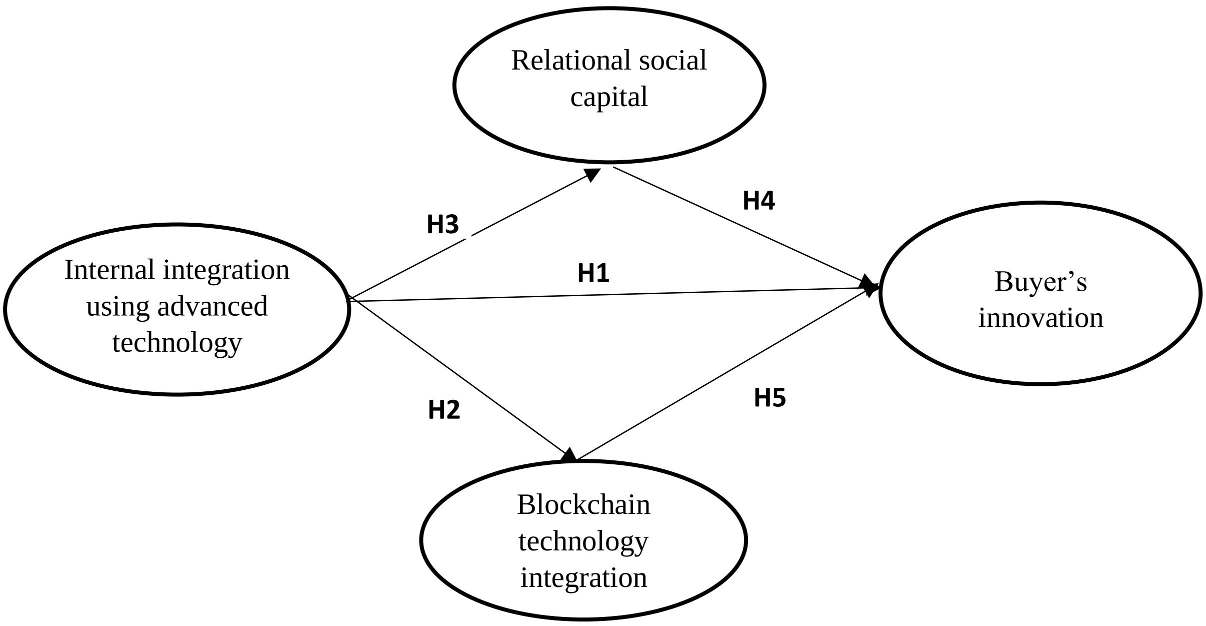

Figure 1: Technology and social capital process aided product innovation conceptual model

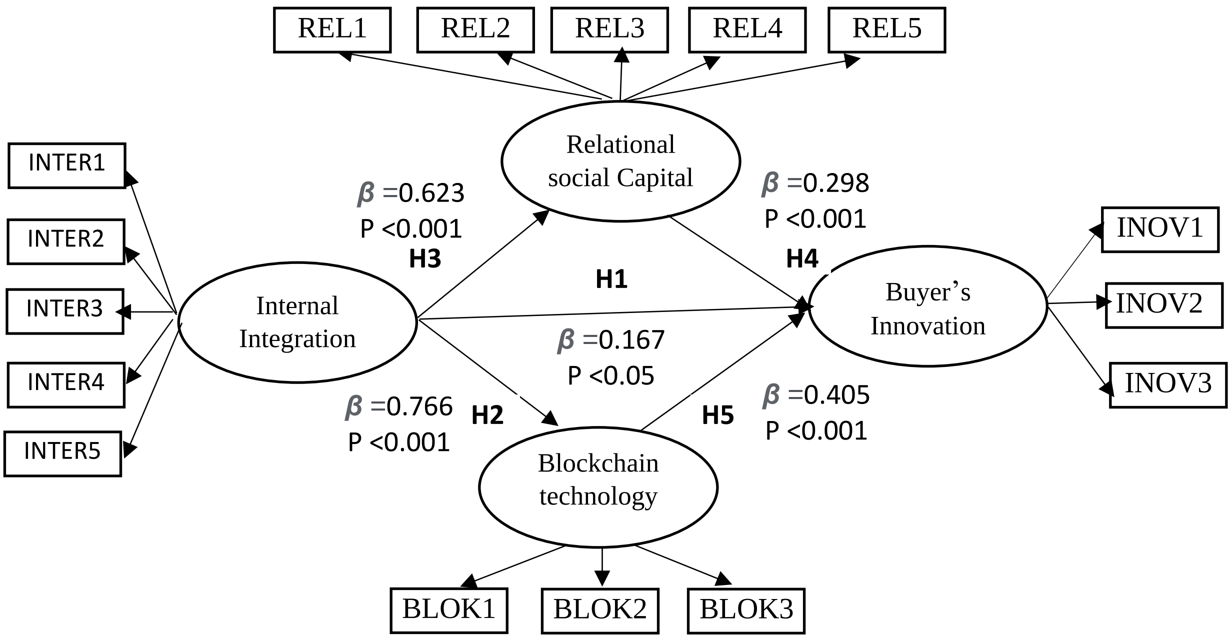

Figure 2: Structural model with path coefficient estimates

Table 1. Breakdown of respondents

Demographic variable		%
Firm type	Private organisation	71%
	Public organisation	17%
	Semi-autonomous public	10%
	Other	1%
Industry type	Manufacturing	67%
	Other manufacturing enabled services	33%
Firm size	Less than 20 employees	4%
	21–500	26%
	500–5000	41%
	More than 5,000 employees	29%

Table 2. Constructs/Items

Construct & Derivation	Indicator	Validated Measures
Internal integration using advanced technology (INTER), adapted from Flynn et al., (2010); Narasimhan and Kim (2002); Lii and Kuo (2016)	INTER1	Inter-departmental teams participate in the development of new products
	INTER2	Data are shared with other internal departments
	INTER3	Inter-departmental teams participate in the improvement of processes
	INTER4	Real-time integration and connection among all internal functions from raw material management through production
	INTER5	Information system integration among internal functions
Blockchain integration (BLOK), adapted from Flynn et al., (2010); Narasimhan and Kim (2002); Lii and Kuo (2016)	BLOK1	Improves communication with suppliers by strengthening the security of data exchanged in terms of customer preference of the buying firms' product information
	BLOK2	Improves exchanges of information with suppliers about product demand and feedback (customer request)
	BLOK3	Improve the exchange of information of strategic suppliers in the design phase.
Relational social capital (REL), adapted from Dyer and Singh (1998) and Lawson et al. (2008)	REL1	Close, personal relationship with suppliers
	REL2	Relationship of mutual trust with strategic suppliers
	REL3	Improved collaboration with strategic suppliers
	REL4	Development of new projects with some suppliers
	REL5	More durable relationship with strategic suppliers.
Innovation (INOV), adapted from Wong et al., (2013); Chowdhury et al. (2017)	INOV1	Reduce the speed of new product development process
	INOV2	Able to improve the capacity development process for product innovation
	INOV3	Develop the process for new product features into the market quickly.

Table 3. Results of confirmatory factor analysis

Construct	Items	Factor Loadings	Alpha	Composite reliability (ρc)	AVE
Internal integration (INTER)	INTER1	0.855	0.922	0.95	0.69
	INTER2	0.772			
	INTER3	0.857			
	INTER4	0.901			
	INTER5	0.817			
Blockchain integration (BLOK)	BLOK1	0.833	0.876	0.88	0.70
	BLOK2	0.857			
	BLOK3	0.828			
Relational social capital (REL)	REL1	0.836	0.921	0.92	0.71
	REL2	0.874			
	REL3	0.866			
	REL4	0.784			
	REL5	0.874			
Innovation (INOV)	INOV1	0.879	0.909	0.91	0.77
	INOV2	0.881			
	INOV3	0.870			

Table 4. Results of correlation testing—discriminant validity

Construct	CR	AVE	MSV	MaxR(H)	Internal integration	Blockchain integration	Relational capital	Innovation
Internal integration	0.95	0.69	0.56	0.93	**0.83**			
Blockchain integration	0.88	0.7	0.56	0.88	0.75	**0.86**		
Relational social capital	0.92	0.71	0.5	0.93	0.6	0.71	**0.84**	
Innovation	0.91	0.77	0.53	0.91	0.64	0.73	0.65	**0.81**

The square root of AVE is on the diagonal.
The correlation is significant at the 0.01 level (two-tailed).

Table 5. Summary of hypothesis testing

Structural paths		Standard coefficient β	t-values	Hypothesis test
Internal Integration	→ Relational capital	0,623***	11,434	H1: Supported
Internal Integration	→ Blockchain integration	0,766***	13,245	H2:Supported
Internal Integration	→ Innovation	0,167*	2,046	H3: Supported
Blockchain integration	→ Innovation	0,405***	5,456	H4:Supported
Relational social capital	→ Innovation	0,298***	5,456	H5:Supported

*** P<0.001 *P <0.05.

Table 6a: Multiple regression analysis for the mediating effects of relational capital

Multiple regression steps	**1**	**2**	**3**	**4**
Dependent variables	**Innovation**	**Innovation**	**Innovation**	**Innovation**
Independent variables	*t-value (Beta)*	*t-value (Beta)*	*t-value (Beta)*	*t-value (Beta)*
Internal integration	14.296*** (0.593)	13.232*** (0.563)		8.069 *** (0.371)
Relational social capital			8.581*** (0.394)	
F value	204.365***	175.095***	158.689***	
R-square	0.35	0.317	0.455	

*** < 0.001

Table 6b: Multiple regression analysis for the mediating effects of blockchain

Multiple regression steps	**1**	**2**	**3**	**4**
Dependent variables	**Innovation**	**Innovation**	**Innovation**	**Innovation**
Independent variables	*t-value (Beta)*	*t-value (Beta)*	*t-value (Beta)*	*t-value (Beta)*
Internal integration	14.296 *** (0.593)	18.247 *** (0.685)		5.38 *** (0.279)
Blockchain integration			8.84 *** (0.458)	
F value	204.365***	332.960***	162.171***	
R-square	0.35	0.468	0.46	

*** < 0.001