Towards an integrated model to explain the factors affecting collaborative innovation processes – insights from the agrifood sector

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Abstract

This study explores the relevant factors to involve multiple actors who develop and implement new technologies to build sustainable agrifood systems. By examining 11 cases, we found that technological, organization, environmental, behavioural and interorganizational factors (all mentioned in current literature) as well as collaborative business models (not mentioned in current literature) affect such initiatives. Based on this, we propose an integrated model. The agrifood sector is one of the first sectors in which a collaborative transition unfolds. As other sectors are likely to undergo similar transitions in the near future, lessons learnt from the agrifood sector can guide these transitions.

Keywords: Agrifood 4.0, collaborative innovation, collaborative business models

Introduction

Despite the existence of many sustainable farming practices (Rosenzweig et al., 2020), the actual uptake of sustainable farming practices remains limited. Limited uptake can, at least partly, be explained by the characteristics of the agrifood supply chain in which farmers operate. The agrifood supply chain is composed of a complex network of interrelated actors who produce, process, distribute and consume food. Power within the agri-food supply chains typically reside with multinationals and downstream buyers who apply intense pressure on farmers to lower their prices. Globalization, liberalization and the commodity nature of many food products further augment price pressures and leave farmers as price-takers with little financial strenght (Clapp, 2021). Hence, without the collaborative support of other actors, farmers struggle to respond to the environmental and social pressures exerted on them (Adams et al., 2016).

Although there is no clear path on how to implement sustainable collaborative innovations (SCIs) with multiple supply chain actors, several developments such as the adoption of agrifood

4.0 applications are predicted to play a major role (Bui et al., 2016). To develop and implement agriculture 4.0 applications, literature stresses the role of technological, organizational, environmental and behavioural factors (Maghazei et al., 2022; Tornatzky and Fleischer, 1990; Venkatesh et al., 2003). Two main frameworks provide guidance on how these factors affect the development and implementation of new technologies, namely the technology-organization-environment (TOE) model (Tornatzky and Fleischer, 1990) and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003). In addition, due to the collaborative nature, interorganizational factors may play a role as well (Chan et al., 2012). However, so far, literature has focused on the development and implementation of new technologies at the firm level, rather than on a multi-actor level (Chan et al., 2012).

Through a longitudinal multiple case study, we identify 15 factors which affect the development and implementation of SCIs. We relate these factors to the factors identified in the TOE model, the UTAUT as well as interorganizational factors identified in literature to propose an integrated model. While our findings confirm the TOE model, the UTAUT and interorganizational factors, we suggest an additional component: the collaborative business model. Beside the theoretical contribution, the knowledge of this paper can be used by practitioners to identify relevant factors for implementing SCIs.

The remainder of this paper is structured as follows. In the next section, we provide the literature background of our study. Next, we present the methodology followed by the results. Afterwards, we discuss the results and present the conclusion.

Literature review

In the next sections, we present the TOE model, the UTAUT and the interorganizational factors which affect SCIs. To do so, we integrate management literature with agricultural literature from journal as *Agricultural Systems, the Journal of Rural Studies, Nature Food and Sociologia Ruralis* who present rich insights into factors which affect agricultural SCIs.

The TOE model

The TOE model provides an organization-level perspective on the drivers and barriers that affect the adoption of new technologies. First, the technological context – the "T" of the TOE model – refers to i) the advantages that a technology can offer, ii) the technological readiness, iii) the ease of integrating the technology with existing business operations and iv) the compatibility with existing technologies and processes (Tornatzky and Fleischer, 1990; Zhu et al., 2006). Many digital agricultural technologies are not designed to meet the needs, requirements and competences of (small) farmers (Benyam et al., 2021). For instance , the lack of internet connections in rural areas limits the implementation of IoT-based agricultural technologies (Benyam et al., 2021). Likewise, the low technological readiness of some new technologies limits the implementation by farmers (Hofmann et al., 2020). In addition, limited interoperability between machines and devices from different manufacturers presents a major hurdle to adopt smart-farming technologies (Villa-Henriksen et al., 2020).

Second, the organizational context – the "O" of the TOE model – refers to the managerial structure of the involved organizations and the available technical and financial resources they possess (Tornatzky and Fleischer, 1990). Organizational size often plays a decisive role as large organizations typically have more slack resources and can therefore develop and implement new technologies faster (Zhu et al., 2006). In line with this, Adrian et al. (2005) show that farm size indeed impacts the adoption of precision agriculture technologies as small farmers cannot afford the significant fixed investments in capital and time. However, the structural inertia, hierarchical decision-making and complex organizational structures often found in large organizations may slow the routinization of technologies (Zhu et al., 2006). Furthermore, when multiple actors need to implement new technologies, the implementation may be slowed down due to the complexity and the interoperability with the different technologies which other actors may have (Zhu et al., 2006). The skewed power in agricultural chains, where the power resides with downstream buyers and farmers have little negotiation power (Clapp, 2021), may further complicate the development and implementation of new technologies as it may complicate the collaboration between farmers and other value chain actors.

Third, the "E" in the TOE model, refers to the environmental context – i.e., the arena in which the SCI is implemented. The arena includes aspects such as competitive pressure, market trends and regulatory demands (Tornatzky and Fleischer, 1990). Competition may drive firms to adopt technologies to develop a competitive edge (Zhu et al., 2006). Furthermore, market trends may affect the implemention of new technologies. For instance, Hofmann et al. (2020) argues that the rejection and scepticism of many consumers to genetically modified foods has slowed the diffusion of nanotechnology in the agricultural sector. On the other hand, environmental awareness of consumers arguably has a positive impact on the implementation of sustainable farming technologies. Furthermore, legislation may also have an impact on technology development and implementation. For instance, Hofmann et al. (2020) argues that complex regulation hampers the implementation of nanotechnology by farmers. The engagement of organizations such as the International Organization for Standardization for Economic Cooperation and Development, the World Trade Organization, the Food and Agricultural Organization and the World Health Organization can help to develop supporting regulations and harmonize these across jurisdictions (Hofmann et al., 2020). Finally, research shows that the lack of restrictions and requirements reduces the viability of food traceability systems, thereby reducing the implementation of such technologies (Li et al., 2021).

In sum, the TOE model provides insigths into essential, organizational level, factors which affect the development and implementation of new technologies in SCIs.

The UTAUT

While the TOE model refers to the organizational level, the user perception of the technology plays a decisive role in the diffusion of a technology too (Chan et al., 2012). Literature reports various technology acceptance models (TAMs) – see for instance Davis et al. (1989) and Venkatesh and Davis (2000). Based on eight TAM models and theories, Venkatesh et al. (2003) developed the unified theory of acceptance and use of technology (UTAUT). The UTAUT explains around 70% of the intention of the technology acceptance (Venkatesh et al., 2003) and is therefore considered a robust theory (Venkatesh et al., 2003, 2012). The UTAUT model consolidates four main constructs that have a significant impact on the adoption and usage of a technology, namely performance expectancy (the degree to which an individual believes that using the new technology will help him/her to attain benefits), effort expectancy (the degree of ease associated with the use of the new technology), social influence (the degree to which an individual perceives that important others believe he/she should use the new technology), and facilitating conditions (the degree to which an individual believes that organizational and technical infrastructure exists to support the use of the new technology (Venkatesh et al., 2003).

The factors of the UTAUT are found in agricultural literature. For example, with regards to the performance expectancy, Benyam et al. (2021) show that farmers base their decision to adopt digital technologies on the expected economic benefits that the technology offers. Furthermore, Li et al. (2021) show that the perceived ease of use contributed to the farmer's participation in a traceability system. The farmer's technology savviness and confidence towards learning eases the farmer's willingness to adopt a new technology (Adrian et al., 2005; Mastenbroek et al., 2021). In addition, in line with the UTAUT, Hofmann et al. (2020) suggests that different actors in the agrifood industry need to be involved in SCIs to facilitate the development of application protocols, train farmers and negotiate the regulatory landscape in order to scale-up the use of nanotechnologies.

Interorganizational factors

When embarking on SCIs, several interorganizational factors may be at play as well. First, trust plays an important role when implementing a new technology as, at this stage, it may create dependence on other actors (Chan et al., 2012). For instance, Rijswijk et al. (2021) show that technology providers often do not provide the 'right to repair machines' to farmers, which renders the farmers dependent on the technology provider. Furthermore, generating and sharing on-farm data may increase the farmer's accountability for eventual issues with product quality, the environment and animal welfare (Rijswijk et al., 2021). Finally, research shows that a lack of trust in policy makers often discourages farmers to collaborative with governmental bodies to develop and implement new farming practices (Osmond et al., 2015; Zhang et al., 2015).

In addition, including sustainable goals may result in economic-sustainable trade-offs of different actors (Boons and Lüdeke-Freund, 2013). Prosman et al. (2016) show that organizatons are more likely to adopt collaborative initiatives initiated by other parties when they benefit from it too.

Research aim

The aim of this research is to gain a better understanding of the factors which affect SCIs based on new technologies in the agrifood setting. In particular, we aim to propose an integrated model based on the TOE model, the UTAUT, interorganizational factors and potential other relevant factors for SCIs.

Methodology

Given the exploratory nature of our research, we adopt a longitudinal multiple case study approach (Eisenhardt, 1989a). The longitudinal multiple case study approach allowed us to gain in-depth insights into the factors affecting SCIs. The research followed a grounded theory approach (Strauss and Corbin, 1998) (i.e., the authors were not familiar with the TOE model and the UTAUT model prior to interpreting the results). We define the unit of analysis as the network of actors involved in the SCI.

To study the factors pertinent to SCIs, we selected eleven cases, so called sustainable innovation pilots (SIPs), from the Horizon2020 Ploutos project. The Ploutos project, embedded in the agrifood value chain, provides a fertile ground to address our research question: like the automotive industry was a frontrunner in lean manufacturing, the agrifood industry is currently a frontrunner with regards to SCIs. In fact, visions on sustainable agrifood systems by policymakers like the European Comission often include a myriad of actors such as farmers, farmer cooperatives, technology providers, food processors, retailers, research institutes and (local) governments (Bui et al., 2016; The World Bank, 2019). Hence, lessons learnt from agricultural SCIs may provide guidance for future SCIs in other sectors.

Data collection

The core of the data collection consisted of semi-structured interviews with the eleven SIPs. With each of the eleven SIPs, we had an interview which lasted approximately 1.5 hours. During these interviews, the different actors in the collaborative initiative were present, such as the farmer's cooperatives, the technology providers, and the research institutes. Table 1 provides an overview of each of the SIPs and the involved interviewees. Each interview was recorded and transcribed verbatim. Summaries of the interviews were sent back to the interviewees for verification. Moreover, we discussed the main findings of this research with the interviewees. Furthermore, observations during the project and written documentation such as project deliverables complemented the data collection and allowed us to achieve data triangulation.

Data analysis

Following the grounded theory approach, we applied an inductive coding approach to our data. First, to deal with the rich data, we applied a data reduction approach, where we coded the words, sentences and paragraphs which referred to factors which affected the SCIs of the SIPs. Based on the codes, we performed a within-case analysis by using the codes to develop case narratives. The within-case analysis allowed the researchers to become intimitaly familiar with the SCIs and the factors affecting them (Eisenhardt, 1989b). Next, we performed a cross-case analysis to inductively search for explanations behind the factors, i.e., whether the factors were case specific (e.g., a specific technology or objective). When factors were case specific, we excluded the factor from our analysis as we aim to idenfity factors which affect SCIs rather than specific cases. For instance, the SIPs working on traceability systems struggled with deciding on data sharing protocols. As this is pertinent to traceability, rather than pertinent to SCIs, we excluded data-sharing protocols as a factor affecting SCIs. The results of the within-case and cross-case analyses were discussed among the authors of this paper as well as with partners of the Ploutos project to ensure consensus on the interpretation of the factors. Where needed, data was re-coded until consensus was reached.

Table 1 – Overview of the SIPs

Case	**Country**	**Brief description of the objective**	**Organization of the interviewee (number of interviewees)**
SIP1	Greece	Supporting a frozen fruit value chain with small farmers, to optimize production, reduce environmental footprint and re-use data for certification and subsidies.	Agronomists of the farmer's union (1), technology provider (3), research institute A (2), research institute B (1), food processor (1)
SIP2	Italy	Better food-chain contracts for improved durum what production.	Farmer's union (4), agronomists (2), technology provider A (2), technology provider B (1), research institute (2)
SIP3	France, Greece, United Kingdom, Germany, Belgium	Empowering customers through crowdsourcing to take back control over their food and create healthy, sustainable, fair-trade products.	Retailer (3), technology provider (2), research institute (3)
SIP4	Spain	Traceability solutions covering the horticulture greenhouse value chain to improve operations, sustainable performance, and brand recognition.	Technology provider (2), research institute (3)
SIP5	Ireland	Smart farming on rural farms demonstrating its benefits in the wider agri-food community and co-creating new food products and services.	Regional agricultural hub (3), farmer's cooperative (1), farmer (1), technology provider A (1), technology provider B (1), research institute A (2), research institute B (1)
SIP6	Slovenia	Applying soil passports to reward landowners and users in combination	Technology provider A (3), technology provider B

		with a precision farming solution to increase soil health and .	(1), research institute (3), farmer's cooperative (1)
SIP7	Cyprus	Supporting wine producers to take advantage of the changes in labelling regulations and enhancing their sustainability performance.	Regional government (3), technology provider A (2), technology provider B (1), research institute A (2), research institute B (1)
SIP8	The Netherlands	Carbon farming to compensate farmers for climate friendly soil management.	Farmer's cooperative (1), technology provider A (1), technology provider B (1), research institute A (4), research institute B (1)
SIP9	Serbia and North Macedonia	Facilitating the transfer of surplus food from farmers to socially disadvantaged groups, by aligning logistics and processes.	Technology provider A (1), technology provider B (1), research institute (2)
SIP10	Italy	Increase sustainability in the grapevine sector by introducing payments for ecosystem services provision and parametric insurance to support losses from sustainable approaches.	Technology provider (2), farmer's cooperative (1), research institute A (4), research institute B (1)
SIP11	Spain	Improving the sustainability of Balearic agri-food chains with Smart Farming and by using the collected info to organize agri-food tourism.	Farmer's association (1), technology provider (1), research institute (3)

Findings

In the following sections, we subdivide the identified factors which affect SCIs based on the TOE model, the UTAUT, the interorganizational factors and remaining factors. Table 1 summarizes the 15 identified factors. Due to confidentiality reasons, we cannot relate the identified factors to the individual SIPs. Hence, we resorted to reporting only the number of SIPs who were affected by each factor.

The TOE model

With regards to the "T" – i.e., the technological context – of the TOE model, we identified several factors. First, verifying the technological benefits may be difficult (four SIPs). Multiple reasons explain the difficulty to verify the technological benefits: i) the sensors of the technology do not provide accurate enough data to verify it's benefits (one SIP), ii) yearly harvest cycles provide few moments to collect data (and due to high workloads during the harvest season, farmers may not collect the data) (one SIP), and iii) a lack of historic data (for instance because of crop rotations) to benchmark the performance of a new technology (two SIPs). Furthermore, low technological readiness played a role too. For example, the satellite technology used in one SIP only works on large fields. Furthermore, the interoperability between new and existing technologies (e.g., installing new technologies on old tractors) complicated the SCI in another SIP.

Regarding the "O" of the TOE model – i.e., the organizational context – we found that SCIs sometimes rely on a few key people in terms of workload (two SIPs), or the financial resources and network brought to the SCI (two SIPs). When these people leave the SCI, the SCI is at risk. Furthermore, we found that actors may be locked-in into existing value chain structures. For example, in one SIP, the actors were locked-in for two reasons. First, the meat industry has a monopoly on the management of offal (slaughter waste). As the meat industry does not want to manage local slaughter waste, farmers and local actors cannot start a short-food supply chain. Second, due to past investments and bank agreements (e.g., producing a certain quantity of milk), farmers are locked-in into existing business models. In addtion, in one SIP, a lack of time hampered the innovation process.

Finally, with regards to the “E” or environmental context of the TOE model, we found that unforeseen externalities impacted SCIs. For example, covid-19 lockdowns dried-up the available financial resources of the actors in one SIP, and high inflation harmed the economic business case of another SIP. Furthermore, in one SIP, the implementation of parametric insurance was delayed as the insurance company needed to wait for updated regulations by the national Ministry of Agriculture and the European Union.

The UTAUT

The factors mentioned in the UTAUT affect six out of eleven SIPs. Performance expectancy, or rather the lack thereof, seemingly played the most prominent role. For instance, in one SIP, some fields may need more pesticides or fertilizers than other fields based on i) micro-climates, ii) the crops cultivated in the previous seasons and iii) the crops cultivated in fields next to it (which can cause pest infestations). The farmers doubt that the technology captures these nuances. In another SIP, farmers do not trust a system that enables the windows of greenhouses to open automatically when the temperature reaches 20-21 degrees to avoid overheating. Instead, the farmers prefer to open the windows manually. Furthermore, in three SIPs, the complex user interfaces of new technologies required farmers to expand a significant amount of effort to understand and use the new technologies, hence creating resistance to the new technology.

Interorganizational factors

With regards to the interorganizational factors, lacking support of involved project partners formed a barrier in three SIPs. For example, in one SIP, changing management positions in the involved supermarket chain resulted in less support for the sustainable brand developed as part of the SCI. Furthermore, in another SIP, the involved actors feared that the reliance on data can result in becoming locked-in into business models of technology providers.

Remaining factors

Besides the TOE model, the UTAUT and the interorganizational factors, other factors affect the SCIs of the SIPs as well. For example, in one SIP, farmers found it difficult to quantify the economic business case of smart-farming solutions due to uncertainties about i) the price premium for more sustainable products, ii) the increased yields, and iii) the cost reductions related to reduced inputs such as pesticides and water. Four other SIPs were affected by similar factors. Furthermore, in two SIPs, the involved actors found it difficult to decide between alternative business models. For instance, in one of the SIPs, the business model could involve different partners (hotels, tour operators or local markets), different products (offering farm visits or local products), and different resources (whether to apply for a cerfication). Finally, one SIP was not capable to develop a positive economic business case as the expected income did not cover the cost of the sustainable practices, even not when considering indirect income streams such as increased crop quality, increased soil quality (meaning higher yields and lower costs related to fertilizers) and access to potential subsidies.

Table 2 – Factors affecting SCIs

Model	**Factors**	**Number of SIPs**
	Verifying technological benefits	4

TOE model – technological context	Technological readiness	2
	Interoperability with existing equipment	1
TOE model – organizational context	Dependence on individuals with key roles	3
	Lock-in into existing organizational structures	1
	Lack of time to dedicate to the innovation process	1
TOE model – environmental context	Unforeseen externalities	3
	Regulatory challenges	1
UTAUT	Performance expectancy of the technology	5
	Effort expectancy due to complex user interfaces	3
Interorganizational factors	Lack of support of project partners	3
	Risk of lock-in for (some of) the partners	1
Remaining factors	Estimating the business case	5
	Deciding between alternative business models	2
	Lacking business case	1

Discussion and conclusion

In this study, we aim to develop an integrated model of the factors affecting SCIs. Our results show that various aspects of the TOE model, the UTAUT and interorganizational factors indeed affect SCIs. Moreover, these factors confirm the factors already identified in (agricultural) literature such as the impact of technology readiness, regulation (Hofmann et al., 2020), interoperability (Villa-Henriksen et al., 2020) and the expected benefits of the technology (Benyam et al., 2021). However, our results provide nuances to existing literature by adding factors such as the difficulty to verify technological benefits and the dependence on individuals with key roles. As such, our findings both confirm and enrich the TOE model, the UTAUT and the interorganizational factors in agricultural SCIs.

Moreover, we identified remaining factors which we could not explain based on the TOE model, the UTAUT and interorganizational factors. The remaining factors have the '*collaborative business model*' as a common denominator. The impact of collaborative business models is a valuable finding which is only partly covered in literature. For instance, Zott et al. (2011) and Bankvall et al. (2017) argue that business models go beyond organizational levels and are embedded in the network in which firms operate. Furthermore, Rohrbeck et al. (2013) show that multiple organizations, that might differ in type and industry, can work together to create a collaborative business model. However, despite the seemingly important role of collaborative business models, literature does not yet consider collaborative business models as an important factor for developing and implementing SCIs.

Towards an integrated model for developing and implementing SCIs

By integrating the collaborative business model factors with the TOE model, the UTAUT and the interorganizational factors, we propose an integrated model as depicted in figure 1.

Future research should test the proposed model with larger samples to obtain insights into the relative impact of each of the factors. While doing so, one should control for several moderating factors – for example as done in the UTAUT (Venkatesh et al., 2003). Relevant factors may include the industry or sector, the type of the involved actors, the age of the involved actors, the available resources, and the objectives of the SCI.

Limitations and contribution

This study is not without limitations. First and foremost, all cases came from the agrifood sector. Despite the wide variety of SCIs implemented by the eleven SIPs, other sector may be affected by other factors. Secondly, although the initial unawareness of the TOE model and the UTAUT allowed the authors to conduct grounded research, we might not have observed all factors as we may not have asked relevant questions. This may explain the absence of some factors of the TOE model and the UTAUT. Indeed, we need to be careful to conclude that these missing factors do not play a role or only a marginal role. Therefore, we suggest future research to include these factors.

To conclude, the novelty of this study derives from investigating a sector which is a frontrunner in developing and implementing SCIs, namely the agrifood sector. Other sectors are likely to follow in the future and may learn lessons from the agrifood sector. Our research contributes to literature by proposing an integrated model based on the TOE model, the UTAUT and interorganizational factors, while adding the role of collaborative business models. The proposed model opens several avenues for future research. Moreover, we contribute to practice by helping practioners with identifying important factors which affect the development and implementation of their SCIs.

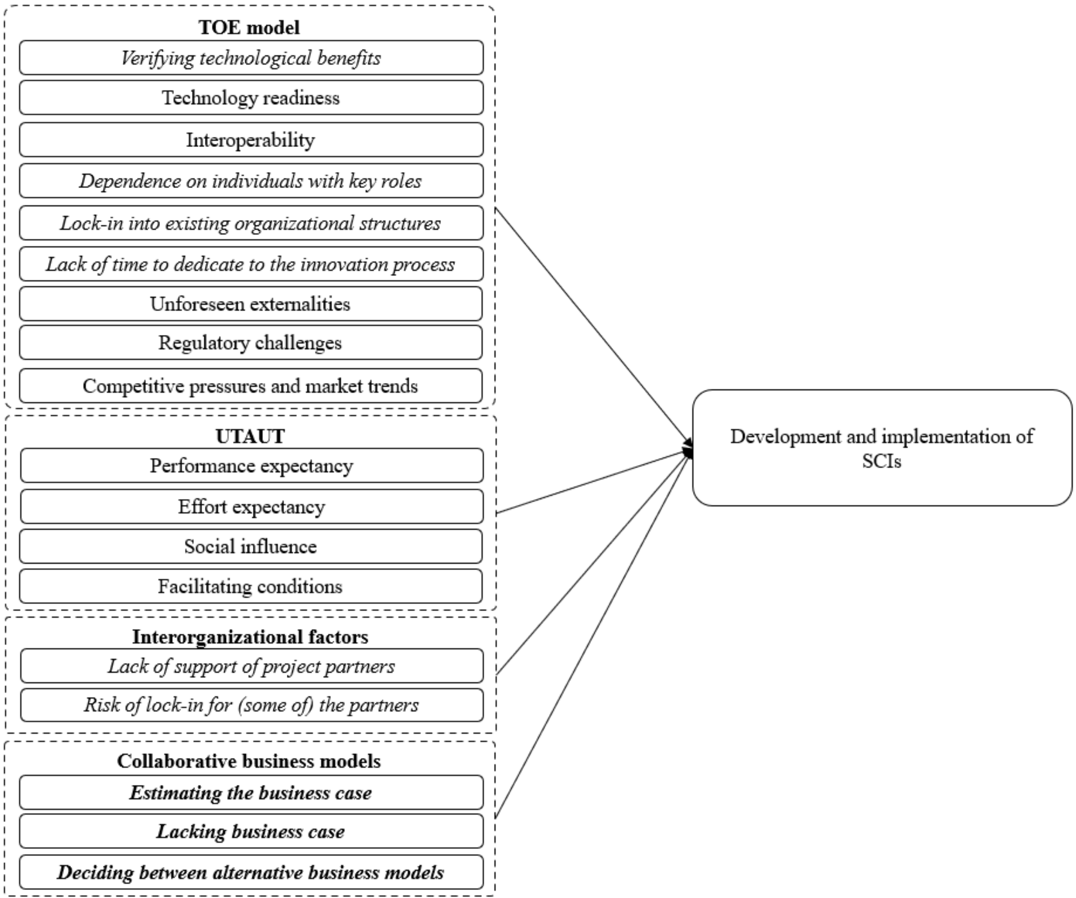

Figure 1 – Proposal of an integrated model for the development and implementation of SCIs (italic: adjusted factors from existing models; bold+italic: new factors identified in this research)

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