



# UNDERSTANDING THE DETERMINANTS OF BLOCKCHAIN TECHNOLOGY ADOPTION STAGES AND SUPPLY CHAIN PERFORMANCE USING THE TECHNOLOGY-ORGANIZATION-ENVIRONMENT FRAMEWORK

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# UNDERSTANDING THE DETERMINANTS OF BLOCKCHAIN TECHNOLOGY ADOPTION STAGES AND SUPPLY CHAIN PERFORMANCE USING THE TECHNOLOGY-ORGANIZATION-ENVIRONMENT FRAMEWORK

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**ABSTRACT:** *With the recognition of the considerable benefits of blockchain technology, researchers have paid increased attention to its implementation in the Supply Chain. However, since prior research were conducted there is a dearth of studies considering blockchain technology adoption stages (evaluation, adoption, and routinization). To fill in this gap we developed an integrated model with special considerations related to the blockchain technology specificities to examine how technological, organizational, and environmental factors influence the three-stages of blockchain technology adoption process in the supply chain. This study provides a holistic view of blockchain technology diffusion in firms level with practical guidance for successful blockchain technology implementation in supply chain.*

**KEYWORDS:** *Blockchain technology, Supply Chain, Information technology, Technology-organization-environment, TOE framework, Adoption, Adoption stages,*

## 1 INTRODUCTION

Emerging from the world of crypto-currencies in 2008 (Nakamoto 2008), blockchain technology appeared as a new type of information system with several applications related to many fields such as healthcare (Farouk et al.,2020); food information security (Mettler 2016); e-government (Zhang et al.,2019) ; cybersecurity (Taylor Rodriguez Vance et al., 2019) and energy systems (Chen et al., 2019).

It is considered as a secure way to transact, that decrease the use of intermediaries and regulatory authorities like notary services, banks, and centralized middlemen (Zhang et al.,2019).

Blockchain technology can also have huge impact on operations and supply chain domain. Available research has cleared up the potential of blockchain technology to transform each of the SCM processes which improve its performance and decrease inefficient transactions. Amongst the advantages, blockchain technology could improve complex supply chain issues like transparency, traceability, security and product safety (Hader et al.,2020) and so forth. Thus, blockchain technology could be a driver of a supply chain long term growth and sustainability. Hence, enterprises are becoming more interested in blockchain technology to manage their supply chain. While recent studies have emphasized blockchain benefits in the supply chain field, some early use cases that materialize blockchain investigations have already started, those use cases are increasing over the years like any new technology or innovation.

Nevertheless, blockchain faces different obstacles in implementation by supply chain networks, organizations are still attentive as they weigh the benefits related to this technology against the obstacles to its adoption (Zhang et al.,2019). Therefore, many enterprises simply postpone their decision on blockchain technology adoption, pondering whether their current organizational conditions are ready for blockchain technology implementation.

To balance the benefits and barriers, the first task of adopting blockchain technology is to assess it. (Çolak et al.,2020) Nevertheless, a review of blockchain management literature leads to identify some gaps. Literature often cites blockchain technology case applications or the benefits of blockchain technology on the supply chain. However, there is a paucity of studies that work on blockchain technology evaluation in research and practice which leads to complexities that include inter-organizational consensus.

Therefore, we aim to fill this gap in blockchain technology literature by providing practical guidance for blockchain technology integration within supply chain at the company level. To achieve this, we set up the following research objectives:

- 1- To develop an integrated framework that enables a holistic perspective to investigate potential factors from the context of the TOE framework (i.e. technology-organization- environment) that can affect the entire blockchain technology adoption stages within enterprises
- 2- To generate a high-level proposition from the framework developed to enable future studies to develop specific hypothesis from propositions for their empirical tests. Former research has aimed to define model for

blockchain adoption in supply chain based on the TOE framework (Clohessy 2019). However, these authors do not make the crucial differentiation between the impact that the antecedents of blockchain technology could have on each of the stages of its implementation, as it is commonly assumed in the information systems that the effects of one technology antecedent may vary throughout its adoption process (Cruz-Jesus et al., 2019). By incorporating adoption stages in our conceptual model, we can explore how the proposed blockchain technology antecedents affect each of the three adoption stages individually from initiation to routinization, in enterprises. Examining this possibility and providing a clear vision about its adoption process at the firm level is both useful and one of the main contributions of this work for blockchain technology integrated supply chain literature

The paper is structured as follows: Section 2 provides an introduction to our theoretical base, followed by the conceptual development where we proposed eight propositions to illustrate how factors from three aspects that is, technology aspect, organizational aspect, environmental aspect, affect each of the stages of blockchain technology diffusion process in Section 3. Subsequently, section 4 presents a discussion about both theoretical and practical implications of our study. The concluding section 5 summarizes the most important insights and limitations and provides an outlook on future research.

## 2 THEORETICAL BACKGROUND

### 2.1 Technology Diffusion Process

This study draws from three streams of research: (1) technology diffusion process, (2) technology-organization-environment (TOE) framework, and (3) BC-SCM.

Technology Diffusion Process:

Innovation diffusion is described as a stage-based process of “spreading a new technology among potential adopters”. This process occurs over a sequence of steps which first starts by an awareness about the technology itself including the benefits and barriers to implement it in the organization. This step is followed by a formal decision to adopt the technology, and then implementation as a beginning of the integration, the technology (Ngah, 2017).

Most of studies in the literature divided the process of IT innovation adoption into three different stages. Although those stages do not have necessarily the same names in all works; like for example:

- 1- Perception, adoption, and implementation. (Koa et al., 2008)
- 2- Evaluation, adoption, implementation, and use. (Puklavec, B. et al., 2018)
- 3- Adoption, assimilation, implementation (Wu, Chen (2014).
- 4- Evaluation, adoption, and routinization (Junior et al., 2019)

Just to cite few, we notice that the three stages cited in the different studies are concordant.

Some researchers propose a six-stage model of adoption process (Sepasgozar and Bernold, 2012), which are:

- 1- Initiation: evaluating the technology and gathering related information
- 2- Adoption: Getting the enterprise resources commitment for IT implementation
- 3- Adaptation: train employees to use the technology and initiate IT and organizational procedures to tailor the solution to the enterprise needs.
- 4- Acceptance: motivate and encourage employees to engage in use of the solution
- 5- Routinization: ensuring that the technology is incorporated into work procedures and employee habits.
- 5- Infusion: Making the most of the technology by involving it in all processes to benefit from all its advantages.

However, in other papers a simple version of technology diffusion is suggested, for example in their work about the implementation of Green IT (Bose and Luo 2011), the diffusion process of software-as-a-service (SaaS) (Martins et al., 2016) and the assessment of broadband mobile applications (Chen and Gao 2017) .

The authors simplified the stages-adoption to three stages of initiation, adoption, and routinization.

As the adoption of BCT-SC (blockchain technology adoption in supply chain) significantly impacts business process change, collaborative relationships among partners. Hence, blockchain technology adoption can be viewed as an “IT innovation adoption”. Thus the theory of adoption stages seems to be relevant, it examines the BCT-SC adoption, which could be different in each stage according to the related antecedents, which makes our analyze useful to have a comprehensive understanding of BCT-SC through different adoption stages.

For parsimony, following the cited approach, we propose a three-stage model of blockchain technology adoption in supply chain.

Initiation is the first stage, where perceived advantages of BCT-SC are being assessed across all related process at firm level to complete the attitude towards the BCT-SC adoption.

BCT-SC adoption is the following stage, which consists in formalizing the adoption decision by evaluating the IT infrastructure and financial requirement for its integration. (Martins et al., 2016)

The last stage is routinization, which includes the implementation of BCT (blockchain technology) solution, and the preparation for use, by setting up trial versions for technology approval of stakeholders and supply chain members.

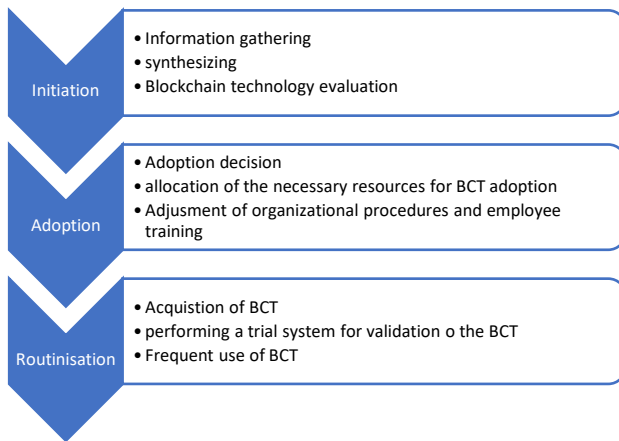


Figure 1: BCT adoption stages

## 2.2. Technology-Organization-Environment (TOE) Framework

To determine the factors that could impact the process of BCT adoption, we use the TOE framework, Developed by Tornatzky and Fleischer, its name comes from the three factors that this model claims to influence the stages of the technology adoption, i.e, technological, organizational, and environmental context.(Angeles 2012)

1. **The technological context:** it related to the organization's relevant technologies, as well as technologies used by trading partners and the potential technologies that the enterprise has the intention to adopt even if they are not set up in the enterprise. The relevant technologies could be material like for example the equipment and tools or immaterial as methods and data used
2. **The organizational context:** it includes the firm's equipment and resources such as the firm's size, administrative structure, business procedures, hierarchy, financial resources, human resources, turnover.
3. **The environmental context:** represents "the arena" in which the firm is operating, including its activity, its trading partners, and relations with governmental entities.

The TOE framework has been approved to be a suitable model for understanding IT integration factors. Hence it was used by IS researchers like for example: electronic data interchange (EDI), enterprise resource planning (ERP), e-business, e-commerce, green IT, hospital IS and Software-as-a-Service (Cruz-Jesus et al.,2019).

Even for the specific case of BCT, TOE already proved to be an interesting lens to have a holistic perspective of its requisition stages.

Lai-Wan Wong et al for example studied the adoption of blockchain in operations and supply chain management among Malaysian SMEs. To do that the authors grounded their conceptual model on the TOE framework, concluding that some BCT antecedents positively influence its adoption like for example competitive pressure whereas other factors like market dynamics did not prove to have any effect (Wong. Et al., 2020).

Simon Abrecht et al. proposed a theoretical model to shed light on BCT adoption in the energy sector. Their model combined some aspects of DOI (Diffusion of Innovation) with TOE framework to examine the dynamics relationships between blockchain technology and energy sector. Based on interviews with 22 experts in the domain of energy and blockchain they were able to determine constructs related to their theory and examines their influence on the use cases in question. (Simon et al., 2018).

They found that some energy services like for example grid services, microgrids and wholesale electricity trade are influenced by technological constraints whereas they noticed that they have a weak relationship with network-related and power-induced factors

Their model presents insights for decision makers in electric utilities and government administrations as they worked on the design of political and economic institutions for regulation of blockchain technologies.

However, they assumed that their study lacks generalizability because it is limited to the energy sector.

Gregor Schmitt et al. have performed an analysis of the advantages and barriers for organizations when smart contract which is a blockchain technology are integrated with Internet of things technology (IoT). Their study was grounded on interviews with researchers and industrial experts. The structure of their interview was structured following the TOE framework (Schmitt et al., 2019).

As a result, they determined 13 key-factors that affect the adoption within the TOE framework:

- Performance expectancy, Technology maturity, Perceived compatibility were identified as technological determinants
- Firm size, the attitude towards change, Organizational slack were among the organizational factors and
- Regulatory policy, Competitive pressure, Legal uncertainty were considered as environmental influencers

Thus, the TOE framework seems to be useful and interesting to understand BCT adoption process in the supply chain at firm level. Hence In the literature, multiple researchers have made it clear that technical context is not the only factor that influence BCT success and that organizational and environmental factors also impact BCT adoption success.

## 2.3. BCT application and its impact on supply chain performance:

BCT is defined as a fully distributed system that records and distributes transactional data between networked members. It is driven by rules that involved members have agreed to and secured by cryptography (Martins et al., 2016).

The chain refers to a sequence of data that involved actors maintain using a network. While the block represents the real time data that are updated by system actors.

In such a network, transparency is guaranteed, and traceability is enforced as the system maintain the entire history of transactions.

The benefits of BCT have been primarily examined in the cryptocurrency market over a decade ago. Nowadays multiple applications of blockchain technology are under study in multiple domains.

Thakur et al. (2020) also worked on the adoption of blockchain technology for land titling in India which demonstrated the interest as well as the barriers in the case of absence of internet infrastructure. (Thakur et al. 2020)

Damiano Di Francesco Mesa et al. in their work have surveyed five other applications of blockchain technology not related to cryptocurrencies which are : end-to-end verifiable electronic voting, identity management systems, access control systems, healthcare records management, decentralized notary and supply chain management. (Mesa et al., 2016).

For each of the cited applications, they analyzed the related issues and the potential opportunities brought by blockchain technology.

In the context of supply chain as proved in several studies, blockchain technology have the potential to remodel and enhance the performance of the processes of supply chain as it offers provenance of information which could reduce expected risks and also simplify the complexity of supply chains by limiting the use of intermediaries thus, cost reduction and valuable information protection.

(Wong. Et al., 2020) have also pointed out the benefits of blockchain technology in supply chain operations which are increasing efficiency and decreasing waste and costs.

### 3. CONCEPTUAL MODEL

Former studies have pointed out the necessity of customizing models borrowed to cater for the era of a specific technology. The same when we opt for the TOE framework to explore BCT adoption in supply chain at firm level, we pay attention to the specific context of blockchain technology and set up the parameters according to blockchain's specificity. Figure 1 shows our conceptual model. Each of the variables and suggested relationships is discussed in this section.

#### 3.1. Technological context

Firstly, we analyze the influence of the technological context on BCT adoption process in terms of organizational IT competence and BCT characteristics.

##### **Organizational IT competence:**

Organizational IT Competence refers to the “organization's ability for IT-based innovation “. Former studies have identified several determinants of IT competence, which are (1) IT Infrastructure includes technologies, systems and applications used by the organization. (2) Human IT resources refers to people working in the organization who have the skills to integrate and use technological solutions and lastly (3) IT partnerships. These factors have been identified as playing a crucial role at firm's level to evaluate, adopt and implement technologies and IT-based infrastructure. For example, it is proved that firms with a strong IT infrastructure and flexible human

IT resources could easily integrate new technologies with little risks and costs. Also, firms with a robust partnership between IS and business managers can facilitate the technology adoption by decreasing the hesitancy and skepticism from business units. Thus we believe that IT competence would be a crucial factor during the BCT adoption in SC at firm level especially when the technical immaturity was always the biggest obstacle for organizations to implement new technology in general and to conduct BCT activities in specific. Note that BCT entails a wide range of services (smart contracts, Public (permissionless) blockchains, Private (permissioned) blockchains ...) which requires technological abilities from the supply chain actors to take advantage of its advantages. The impact of IT competency, however, could be different among the stages of adoption process. Indeed, it can be considered as a method that support the preparation of the technology infrastructure, even if it was just to have a basic level of knowledge about the new technology. However, we consider that for the two first stages (initiation and adoption) a firm's IT competency may directly influence the way that the enterprise evaluates BCT. In fact, a strong IT infrastructure with a competent IT human resources and smooth IT-business partnership could promote the effective use of resources for evaluation and implementation of BCT.

Specially, IT competency may have a direct effect on the determination of the availability of resources for BCT technology implementation project and their allocation for the project. It is also assumed by researchers that technology competence helps to understand the technology and perceive clearly the benefits derived from the adoption of BCT. It could also determine the related activities like for example training programs and procedures update. However, we believe that Firm's IT competency doesn't affect directly the supply chain network actors personal motivation to admit and continuously use the BCT, which shows that it has a little effect on the last stage of BCT adoption which routinization.

Grounded on the above analyze we propose that:

*P1: Organizational IT competence will have positive impacts on BCT-SC initiation and adoption stages.*

According to a survey study done over the last 16 research resources about blockchain technology adoption. Table 1.1. summarize specific variables according to the number of times that were found to be significant in several blockchain studies based on TOE framework.

Based on this work we take into consideration the most relevant variables into this study.

Technological considerations	Organizational considerations	Environmental considerations
Perceived benefits 10	Organisational readiness <sup>1</sup> 12	Regulatory environment <sup>2</sup> 11
Complexity 10	Top management support 8	Market dynamics <sup>3</sup> 9
Compatibility 8	Organisational size 8	Industry pressure <sup>4</sup> 5
Data security 6	Business model readiness 4	Government support 5
Maturity 5	Technology readiness 3	Business use cases 3
Relative advantage 4	Innovativeness 2	Trading partner support 3
Disintermediation 4	Participation incentives 1	Critical user mass 1
Smart contract coding 2	Blockchain Knowledge 1	
Architecture 1		
Permissions (public vs private) 1		

<sup>1</sup>Includes value chain readiness; <sup>2</sup> Includes government regulation;

<sup>3</sup>Includes competitive pressure <sup>4</sup>Includes industry standards.

Table 1. Summary of significant blockchain adoption consideration. (Cleohessy et al., 2018)

### BCT Characteristics:

Grounded on a comprehensive literature review about the perceived characteristics of blockchain technology on the adoption has been widely studied.

According to Cleohessy et al. three characteristics of blockchain technology that is, perceived benefits, complexity and compatibility are significantly associated with its adoption (Cleohessy et al., 2018).

Based on this perspective, we posit that the perceived benefits, compatibility, and complexity of a certain blockchain influence its adoption process.

**Perceived benefit:** Drawing from the literature we define Perceived as the potential benefits derived from using a specific BCT in supply chain. Effectively when integrated in the supply chain processes, Firms that implement BCT could benefit from many advantages such as transparency, security, traceability.

According to a Malaysian study which aims to investigate the effects of TOE based variables, which conducted an empirical study over 194 SMEs in Malaysia (Wong. Et al., 2020). The results approved that perceived benefits has a significant relationship in determining blockchain

adoption and this is concordant with several studies on adoption considerations, especially with Wand et al. (2019) who confirmed through their work that perceived benefits would be considered as the main reason that blockchain is significant in supply chains (Cleohessy et al., 2018).

However, the benefits can be viewed from two distinctive levels, which are, organizational level and individual level. In fact, the expected advantages by organizations and employees may not be the same, that is why we believe that its impact may vary through BCT adoption stages as following:

- Organizational level: perceived benefits may have a positive impact on the adoption stage at this level because it can drive the firm's decision to adopt BCT and adjust its infrastructure to this new initiative.
- Individual level : we believe that individual level perceived- benefits may have a positive impact with the routinization stage because supply chain actors would be more encouraged to use blockchain technology when they will be aware of the usefulness of the system to their work.

Based on these arguments, we propose that:

*P2a: BCT perceived benefits at the organizational level will have positive impacts on BCT adoption stage.*

*P2b: BCT relative advantage at an individual level will have positive impacts on BCT routinization stage.*

**Complexity:** represents how much blockchain technology is challenging and difficult to use by supply chain actors. The complexity of BCT is considered as a big issue for potential adopters because it has a direct impact on how much human resources should be engaged and the extend of the effort that should be invested for adapting procedures and IT infrastructure especially in our case which treat the integration of BCT in the supply chain because it involves multi-party collaboration (Wong. Et al., 2020). Former studies have also pointed out the strong relativity between adoption intention and the extent of complexity of using a new technology (Cruz-Jesus et al., 2019). According to the Malaysian study they also found that complexity clearly create a big inhibitor for blockchain adoption in SC at firm level, with these arguments, the following proposition is formulated accordingly:

*P3a: BCT-SC complexity will have negative impacts on BCT adoption*

Furthermore, it is approved that since the technology is complex, its use by employees would be difficult and they will be confused and anxious which could impact negatively the time tasks take and job performance. Consequently the complexity of blockchain technology will in

turn adversely influences whether or not employees could achieve the routinization stage (Çolak et al., 2020). Based on these arguments, we propose that:

*P3b: BCT-SC complexity will have negative impacts on BCT routinization stages*

**Compatibility:** is defined as the ability of blockchain technology to be integrated with already existing infrastructure. Researchers believe that more the new technology is compatible in the firm's context, more the doubt about its adoption will decrease. (Chen; Gao., 2017). Several studies have documented that some enterprises considered only the benefits that the technology could bring but neglected whether the system was compatible with their business practices. As a result, is the case of blockchain technology adoption in supply chain could not achieve continuous usage by employees. However, by taking into consideration this compatibility issue, enterprises could achieve successful adoption and continuous use of blockchain technology by supply chain actors. Based on these arguments, we propose that:

*P4: Blockchain technology compatibility will have positive impacts on KMS adoption and routinization stages.*

### 3.2. Organizational context :

#### Top Management Support (TMS):

Considered by researchers as one of the organizational contexts that have more influence on IT outsourcing (Cruz-Jesus et al., 2019). Top management support (TMS) refers to how extent the adoption of a new technology "Blockchain in our case" is supported by managers of the firm.

This determinant has been pointed out by several studies of technology adoption especially when those technologies are disruptive and involved in the transformation of the business processes of the firm. Indeed, many researchers confirmed statistically that TMS is significant to support and evaluate technology adoption. Although in the context of supply chain management Hsiu-Fen Lin approved in their study about the determinants of electronic supply chain management system adoption, that TMS is a key determinant of the likelihood and extent of e-SCM adoption. (Lin, 2014) Considering BCT's characteristics, e.g. high financial costs, and the potential to revolutionize the way an organization manage its supply chain, it may especially depend on TMS.

However, Lai-Wan et al. in their empirical study about, BC implementation in SC at firm level Found that TMS is insignificantly related to BCT adoption which was not convincing according to them because they believe that BCT in Malaysia where the study was conducted is still in its infancy which mean that managers lacks of knowledge about the technology to support it but they would be more likely to have a positive behaviors and support it when they will be more knowledgeable about it. In fact BCT is a radical IT that alters IT existing business models and procedures (Wong. Et al., 2020).

Hence high BCT adoption requires TMS, because, the opinions and behaviors of top management can encourage supply chain actors to participate and resolve potential conflicts among SC stakeholders, especially when it comes to allocating needed resources and making adjustment of business procedures Hence, TMS support may be a significant driving force in the last stage of adoption (routinization). Furthermore, Top management's agreement toward influence the choice of a specific BCT adoption which may directly dictate how the firm perceives opportunities and barriers and eventually how it evaluates BCT application in supply chain... Hence TMS have an important influence throughout all the stages of blockchain adoption process in the supply chain.

Therefore, we propose that:

*P5: Top management support toward BCT will have positive impacts on BCT initiation, adoption, and routinization stages*

### 3.3. Enviromental context

#### Competitive pressure (CP):

According to Schuetz and Venkatesh (2019), environmental factors provide insight into how blockchain technology initiatives can overcome some of the challenges such as high monetary and time costs. The environmental factor considered in this study is the competitive pressure. (Schuetz and Venkatesh, 2020)

Competitive pressure refers to the degree of pressure felt by a firm from its rivals which is recognized by academics and practitioners as a crucial driver in the adoption of a new technology (Cruz-Jesus et al., 2019).

According to the empirical Malaysian study, the impact of competitive pressure on SME's appears among the most top four significant that determine the adoption of BCT in SC at firm level, which means that SME's goal to stay competitive in their business environment could be achieved by the acquisition of technological innovations. As mentioned earlier, one advantage of taking into consideration different adoption stages in our analyze is to differentiate influence through the adoption stages. Although CP has positive effects on evaluation and adoption stages, it can also bring negative impacts on the routinization stage. In fact, some organizations lack of technical and managerial skills to meet innovation technology requirement. Moreover Frederico Cruz-Jesus et al confirmed in their work that too much CP would push firms to change from a technology to another before effectively implementing the first technology in the firm .

Accordingly, we believe that too much CP impact negatively BCT routinization and might probably be an inhibitor. Thus, we suggest the following proposition:

*P6. Competitive pressure positively influences BCT evaluation and BCT adoption, but negatively influences BCT routinization.*

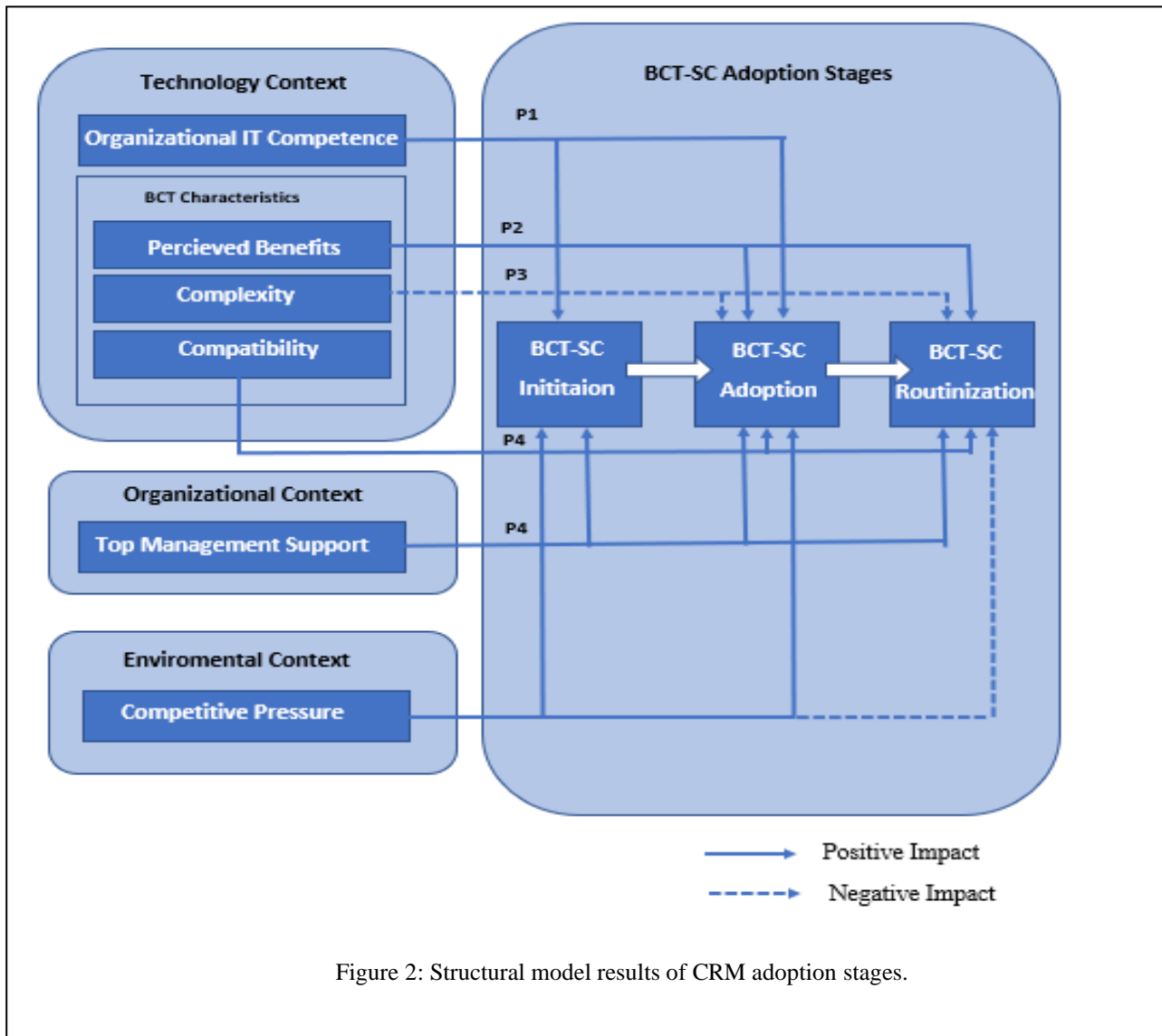


Figure 2: Structural model results of CRM adoption stages.

#### 4. CONCLUSION

This study proposes an integrated framework to examine how the technology organization, and environment) factors affect BCT adoption in SC at firm level. In particular, the study highlights the roles of technical characteristics of BCT, such as perceived benefits, complexity, and compatibility in explaining the impacts of those factors on each of the stages of BCT diffusion process in SC. Regarding their impacts there should be a variation among the way they impact BCT adoption stages. Our paper has several significant implications. First the work suggests a holistic view of BCT adoption process stages and variables that could affect the stages involved in the process.

Therefore, the analyse enables practitioners to understand the critical determinants of concern, in implementing BCT on SC in their enterprises. Through this study, we have proposed a conceptual model of BCT integrated Supply Chain adoption process through three stages.

We also adopted the TOE framework to frame the determinants that impact the three stages of BCT-SC diffusion within enterprises. The proposed framework will benefit enterprises who are planning to initiate a BCT and who are confronting difficulties in certain stages of their BCT-SC diffusion. Especially the framework points out areas for management attention in each stage of the BCT adoption process.

By offering a deeper understanding of their potential customers, our study model can also help BCT system



vendors who would like to take an edge over their rivals in supply chain sector. Moreover, this study will serve as a base for further empirical studies with the possibility of conceptual extensions. As the TOE Framework could be extended by exploring the potential influence of other factors. For example, another organizational determinant as firms' size or organizational readiness. Incorporating other significant factors into account will make our conceptual model more comprehensive and more predictive.

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