THE SIGNIFICANCE OF BLOCKCHAIN TECHNOLOGY IN THE FORMAL AND SHADOW SYSTEMS OF SUPPLY CHAINS. THE COMPARATIVE ANALYSIS

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ABSTRACT

The goal of the study is to compare the role of Blockchain technology in the formal and shadow systems of supply chains. Having conducted the survey-based research, the study shows that the strength of social relationships, established among the supply chain actors, significantly differentiate between the formal and shadow systems in supply chains. The obtained results also show that the supply chains with the domination of the shadow system demonstrate a more positive attitude towards the role of Blockchain technology as compared to the supply chains with a prevailing position of the formal system.

Keywords: Blockchain, shadow system, formal system, supply chain

INTRODUCTION

Under increasing uncertainty, induced by the unprecedented changes, the current business landscape is filled with a myriad of supply chains. To grapple with these challenges, managers of supply chains are urgently looking for new ways to survive and flourish in a completely unknown operating environment. At the forefront of the battle is the social layer of supply chains. This is because under stress, established systems may not account for unforeseen events such as ones brought on by the global pandemic, and thus social layers would be instrumental in responding to these unforeseen events. However, most previous studies neglect the social relationships formed by the actors in supply chains by focusing on the formal (legitimate) system that covers hierarchy, bureaucracy, formal routines, and rigid procedures, that are formally and intentionally established by the more powerful organizations in pursuit to accomplish their goals. In other words, the set of rules in the formal system govern how the firms should jointly carry out the primary tasks in line with the dominant schema, embracing information, energy, and actions, that are characterized by uniformity, conformity, and repetition [40]. Nevertheless, in supply chains, one may also identify the shadow system that covers social interactions developed among the supply chain actors. In other words, the shadow system is formed by the set of interactions among the actors, operating in the informal system of a supply chain, which actually falls outside that formal system. As consequence, the behavior of the supply chain can simultaneously possess the characteristics of a formal system (manifested by coherent patterns of behavior and connection), and social relationships, and spontaneity in the shadow system.

Supply chains can be thus depicted as a mixture, intertwining some portion of control, embedded in the formal system, complemented by social spontaneity manifested in the shadow system. Both systems require applying some advanced technological solutions, such as the Blockchain, to make them operate properly.

Blockchain technology has come to prominence through Bitcoin, as a distributed-ledger system [3] that is poised to dramatically change the way companies do business in supply chains. Despite its potential for supply chains, it has far received limited attention in the academic literature [11]. On the one hand, the technology operates on smart contracts that get executed automatically based on exchange rules and leave immutable transaction records. On the other, it creates a community of companies that share data, and trust that drives transactions among companies is built into the way the Blockchain technology is put together. (Please note there are two types of Blockchain technology - public Blockchain that drives cryptocurrencies such as Bitcoin and private Blockchain that drives supply chain activities). The goal of the study is to compare the role of Blockchain technology in the formal and shadow systems of supply chains. The study, therefore, makes an interesting observation that under the Blockchain companies do business in a trusted environment provided by the technology, yet they constitute a community that others may not gain access to unless given permission. Nevertheless, we argue that hat the Blockchain is a decentralized technology that can be peculiarly instrumental for the shadow system, as it is capable of supporting the dispersed, fragmented, and distributed supply chain actors. It means that no actor can claim ownership of overall supply chain data [16]. Not only does the Blockchain technology enable decentralized ledgers to be established, but it also encompasses incentive mechanisms to maintain those ledgers through collaboration, without the need to incorporate trusted third-party service providers [2], who would control centrally over the actors forming a supply chain.

In the following sections of the paper, two hypotheses are delivered supported by the literature review. Next, a research methodology, followed by the preliminary results, conclusions, and future research directions is demonstrated.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Each organization consists of two general layers: formal system and informal system [39]. The first one, often referred to as the legitimate system underlines that organizations tend to be run as if they developed linearly, and operated in a predictable way. Following [39] we argue that such a system in supply chains consists of links that are either formally and intentionally established by the most influential actor, or established by well understood, implicit principles that are widely accepted by all other actors in a supply chain [39]. On the other hand, the informal system, also described as the shadow system, is spontaneously and informally established by individual agents during interacting in the legitimate system. This results in emerging the shadow system which consists of informal social and political links, in which agents develop their own rules for interacting with each other in the course of their interaction [39]. In practice, there is usually some portion of formal and shadow systems in each organization. This is highlighted by [1] who argue that if the formal system is the skeleton, then the shadow system is the central nervous system. In a more precise way, the shadow system is the complex web of interactions in which social dimensions coexist in tension with the legitimate system [39]. The pivotal role of distinction between the formal and shadow systems can be peculiarly observed in supply chains, which rely on inter-organizational relationships. Following [24], we argue that the shadow system in supply chains is a labyrinth of webs, which shape the interconnectedness among organizations through relationships of companies, teams, and departments. It is thus a source of creativity, innovation, destruction, dysfunction, and differing perceptions of specific realities. The supply chain relationships can be, therefore, perceived to permeate throughout various firms and their multifunctional departments, activated in an *ad hoc* manner, frequently through communication shadow processes [22]). Consequently, rich connections typical for the shadow system can be characterized by the intense social relationships among the supply chain actors. Notably, this suggests the existence of repeated interactions, trust, reciprocity, integration, collaboration, personal ties, etc. [27] [42]. Accordingly, we argue that the social layer of supply chain relationships is the basic criterion to distinguish between the formal and shadow systems. Thus, we postulate the following:

H1: The strength of social inter-organizational relationships differentiates between the formal and shadow systems in supply chains.

The major distinction between the two types of systems is reflected in the centralization-decentralization continuum. More notably, in the legitimate system stability of centralization and bureaucracy plays a key role, while in the shadow system decentralization and individualism come to the fore [39]. Past studies argue that the organization's decision-making structure determines the information systems, such that the centralized decision-making process has a more centralized information system architecture, while a decentralized decision structure requires decentralized information systems [41] [13] [23]. Bringing these arguments into the field of supply chain management, we argue that widely adapted integrated ERP systems are specifically used to control operations in legitimate systems. The ERP systems impose constraints on information, metrics, and the underlying processes that should be performed in line with the 'one best way approach' [9]. In consequence, they leave little room for undistorted data sharing, spontaneity, decentralization, intuitive behavior, and emotions. On the other hand, Blockchain technology as the exemplary decentralized information system is of crucial importance for the shadow system. The development of information technology, such as the Blockchain, greatly contributes to increase the connectivity level among the firms and assist in enhancing real-time information sharing in the shadow systems [43]. With the advent of Hyperledger Fabric as the leading Blockchain framework (also referred to as The Blockchain 3.0 stage), the utility of this technology is widely exported to non-financial use cases. This makes Blockchain technology particularly relevant for creating the shadow supply chain where information about the flows of products, finances, and contracts can be updated and shared in a less expensive, faster, and more efficient way across the supply chain. In other words, the Blockchain has the potential to make data available across the distributed network of peer-to-peer actors [28]. The Blockchain has thus a potential to create new opportunities for constructing entirely new supply chain structures and forms of economic and social governance [15]. Likewise, the Blockchain is also perceived as a mechanism for improving trust in transactions [17] [36], fundamental for the social relations developed in the shadow systems. It is thus a key solution that can bring the digital technologies and social relationships closer together by transforming trust to support various ecosystems of supply chains [32]. Thus, we postulate the following:

H2: The supply chains with the domination of the shadow system demonstrate a more positive attitude towards Blockchain technology as compared to the supply chains with the domination of the formal system.

RESEARCH METHODOLOGY

Data Collection Procedure and Sample Characteristics

The research sample covered the supply chains composed of three companies: the product supplier, and the customer on one hand, and the logistics service provider on the other hand. The latter company served a wide spectrum of logistics services to connect both the product supplier and the customer. The smallest number of three companies form a structure of supply chain [25], and the triad itself is the basic unit of a network [8]. The investigated triads were formed by companies operating in several European countries. The sample breakdown by a country of origin is depicted in Figure 1.

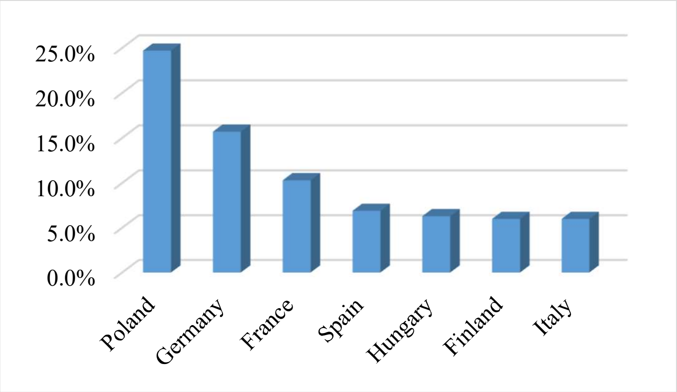

Figure 1. Sample Characteristics - country of origin.

It is worth mentioning that there is a high consistency among the country of origin indicated by the actors in a certain supply chain. In other words, all three investigated companies in almost all supply chains operated in the same country. Figure 2 depicts the sample breakdown by the size of companies, and role in the investigated triads.

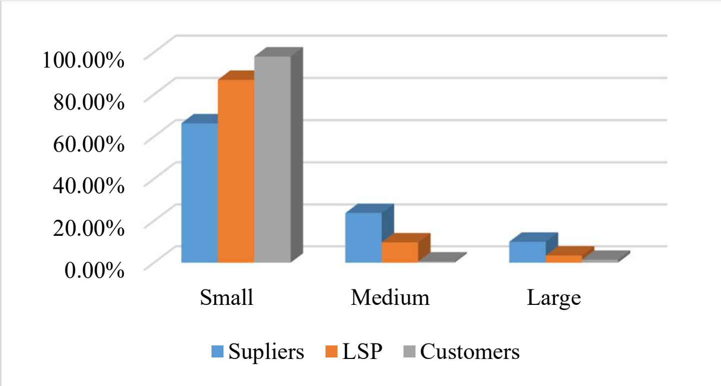

Figure 2. Sample Characteristics - companies' size and role in a triad.

As shown in Figure 2, the prevailing share of companies, taking different roles in the investigated triads, is represented by small firms, followed by the medium-sized, and large companies.

Due to the complexity of the data collection process, we performed a two-step approach, combining random and non-random methods of sample selection [29]. We particularly used a random method to select the companies as the primary contact in their triads. Depending on the roles of companies in triads, we received feedback from the group of 121 suppliers, 70 logistics service providers, and 159 customers. In the second step of the data gathering process, we employed a non-random method to select two other companies forming a certain triad [33]. These companies were indicated by a primary contact in their triads. For instance, the product supplier indicated the logistics service provider and customer, while the logistics service provider indicated both the supplier and the customer.

Survey and Measures

The questionnaire used in this research comprised a group of indicators examining the dimension of social inter-organizational relationships in supply chains, and Blockchain technology. All three firms answered the same set of questions but adjusted to their specific position in supply chains. The definition for individual measures included in the constructs was grounded in literature.

The social inter-organizational relationships among actors in supply chains: This construct is formed by the total of 22 variables (*see* Table 1) answered by each actor separately (supplier, logistics service provider, and customer) in the investigated supply chains, and, in particular, covers the issues of cooperation, loyalty, length of a relationship, trust, trustworthiness, reciprocity, communication, personal contact, and visits, openness, etc. [18] [6] [31] [38].

The Blockchain technology: This construct is formed by the measures that directly reflect willingness or actual use of the Blockchain technology (using the Blockchain-based platforms (e.g. OpenBazaar, OB1), using a digital ledger of transactions while connecting and trading with other partners in the supply chain, planning to implement the Blockchain technology in the near future, interest in the latest technologies (i.e. Blockchain) to support transactions with partners in the supply chain [12] [34] [4]. Apart from the variables directly linked with the use of Blockchain technology, the study also makes use of general measures manifesting the basic characteristics of Blockchain as a decentralized technology, namely:

storing the information, generated by the organization, in the non-human entity (e.g. electronic vehicles or sensors) that operates autonomously or within intelligent systems as human or another company proxies, legal ownership and property rights to data and records of supply chain partners, possessed by the company which belongs to the investigated supply chain or not, and to repatriate ownership of those data, granting or denying access by an individual person, who is not necessarily a part of the supply chain, to data and records, created by the investigated organization [20].

To measure all survey items, we used a six-point Likert scale, anchored at “strongly disagree” (=1) and “strongly agree” (=6) [10]. This type of scale eliminated the middle point of “neither agree nor disagree”, and thus reduced the possible deviation stemming from the respondents’ hesitation, which then enhanced the level of discrimination and reliability values [26]. As the responses for this study were collected from all three companies constituting a supply chain, data retrieved from each individual firm were averaged for the construct of using Blockchain technology. The responses for the construct of the strength of social inter-organizational relationships were captured for each company individually.

RESEARCH METHODS

To compare the formal and shadow system in terms of Blockchain Technology, a three-step statistical analysis was carried out. It first involved the Principal Component Analysis (PCA), followed by the cluster analysis, and the Kruskal Wallis one-way analysis of variance (one-way ANOVA). PCA was conducted to group the variables that differentiate the formal system and shadow system in supply chains. In the second step of the analysis, the factor scores for the characteristics of both systems, obtained through PCA were then applied to carry out the cluster analysis. It involved both a hierarchical cluster analysis (to determine the optimal number of clusters) and *K*-means cluster analysis [14]. The latter one was applied to conduct group profiling, and compare both systems in terms of Blockchain Technology.

Principal Component Analysis

PCA was conducted originally in three sets of 22 variables, which demonstrated the intensity of social dimensions in the investigated triads. The analysis was conducted separately for each set, yielded as a one-factorial solution with no rotation. The factor loadings above 0.55 were kept in the model. Each set included responses from one of three actors forming a triad. Consequently, three factors reflecting responses derived from the suppliers, logistics service providers, and customers were obtained. The first factor reflecting responses from suppliers included a total set of 15 variables, while the second construct, gathering responses from the logistics service providers, contained a total number of 5 variables. The third construct, encompassing responses from customers, included a total number of 6 variables. The detailed structure of the three factors is depicted in Table 1. Likewise, three components containing responses from suppliers, logistics service providers, and customers explain 41.38, 61.50, and 55.90 of the total variance, respectively. The coefficients of Cronbach’s alpha are satisfactory and indicate the level of at least .7 for each construct, and thus show the internal consistency of components.

Table 1. The results of PCA

Variables	Supplier	Logistics Service Provider	Customer
My relationships with both partners in the triad are long-term in nature	0.599		
My company has a strong sense of loyalty to both partners in the triad	0.620		
My company has cooperative relationships with both partners in the triad	0.634		
The employees of my company frequently visit both partners' places of business		0.695	
My company spends time getting to know people in both partners' companies		0.737	
My company frequently contacts both partners in the triad by phone, e-mail, letter, and/or fax			
The employees of our company usually meet both partners in a relaxed environment (e. g. dining out)		0.831	
My company usually gets together with both partners in the triad primarily to have fun		0.880	
The employees of my company take part in the family gatherings organized by the employees of partners in the triad		0.765	
My company does not mislead either partner in the triad	0.610		
My company keeps its word with both partners in the triad	0.633		
My company negotiates fairly with both partners in the triad	0.707		
My company is trustworthy of both partners in the triad	0.721		
My company does favors to its partners in the triad	0.559		
My company recognizes the performance improvements made by both partners in the triad by means of awards	0.553		
My company shares cost savings with both partners in the triad			
The communication guidelines are effective in improving the understanding that my company and both partners have of one another's businesses in the triad	0.727		0.617
The awareness of both partners' issues is effective in improving the understanding that my company and both partners have of one another's businesses in the triad	0.749		0.667
On-site visits are effective in improving the understanding that my company and both partners have of one another's businesses in the triad	0.672		0.785
Joint workshops are effective in improving the understanding that my company and both partners have of one another's businesses in the triad	0.593		0.771
Cross-functional teams are effective in developing relationships in the triad	0.628		0.809
The matrix-style reporting structure is effective in developing relationships in the triad	0.602		0.815

Cluster Analysis

In the second step of the analysis, three groups of factor scores were used as clustering criteria. First, a hierarchical cluster analysis was conducted to determine the number of clusters. This analysis was assisted by Ward's partitioning method and squared Euclidean distance to get clusters of approximately equal size [30]. Having compared the coefficients in the agglomeration schedule, the number of 2 clusters was yielded. Based on that, *K*-means cluster analysis was used to classify each supply chain to the proper group. The assignment of each case was dependent on the minimal Euclidean distance between each triad and the centroid of the group [5]. The statistical significance of the criteria for the obtained clusters is depicted in Table 2.

Table 2. ANOVA for the intensity of social dimensions indicated by each supply chain actor across two clusters

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
SC_Supplier	16.694	1	.955	348	17.482	.000
SC_LSP	128.698	1	.633	348	203.299	.000
SC_Customer	131.915	1	.624	348	211.467	.000

ANOVA shows that three factors used as clustering criteria are significant (at $p < .001$). This analysis has been supplemented by the boxplots graphically illustrating the intensity of social dimensions for two clusters – Figure 2.

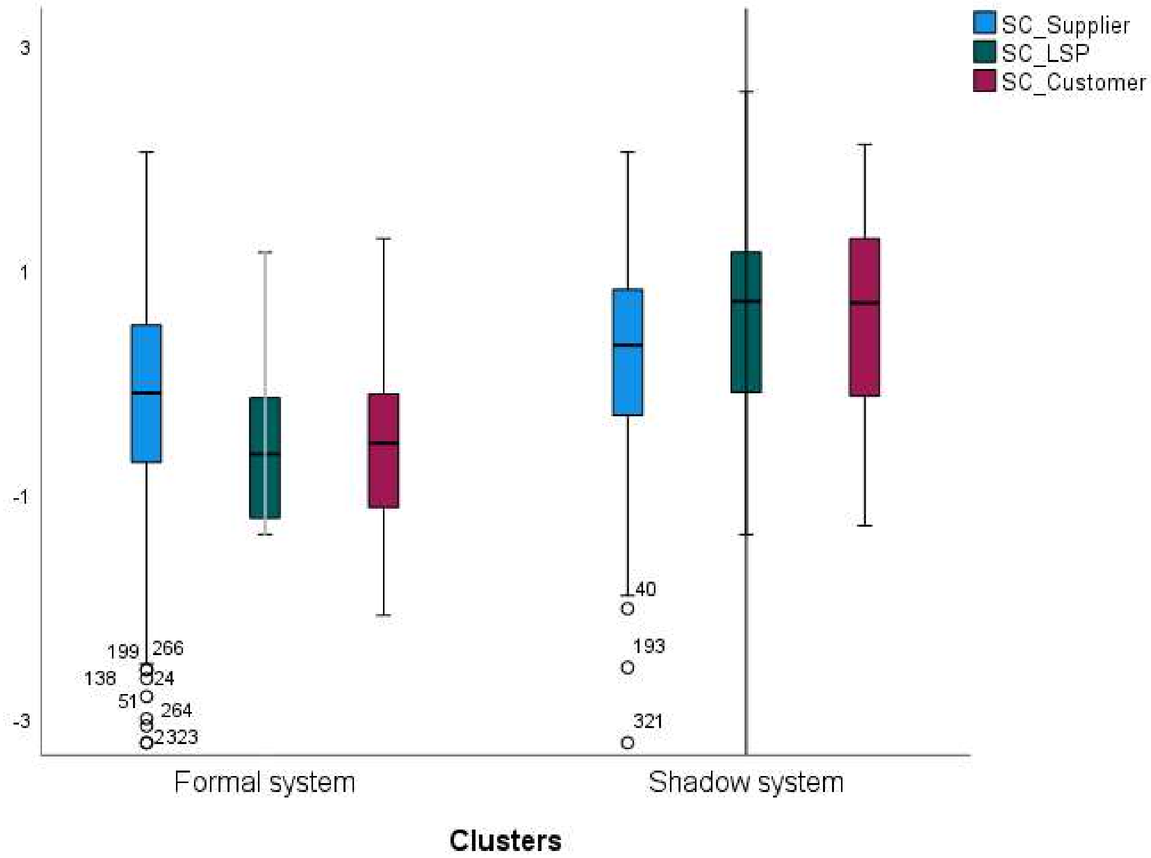

Figure 2. Boxplots for clusters depicting the strength of social relationships

Specifically, drawing on the median scores for three factors across 2 clusters, a bipolar classification emerges. Notably, cluster 1 gathers the supply chains with negative median scores for all factors indicating the social relationships, while cluster 2 contains the supply chains demonstrating the positive median scores for the factors. Consequently, cluster 1 is formed by the supply chains with the weak social relationships, and thus with the domination of formal system, while cluster 2 includes the supply chains with the strong social relationships, and thus with a prevailing role of shadow system.

PRELIMINARY RESULTS AND DISCUSSION

To profile the obtained clusters, we first tested whether the differences among clusters are significant for the use of Blockchain Technology. Table 3 depicts the Kruskal Wallis one-way analysis of variance.

Table 3. The Kruskal Wallis one-way analysis of variance.

Variable	Cluster	N	Mean Rank	Kruskal-Wallis H	df	Asymp. Sig.
	Ranks			**Test Statistics**		
Information that has been generated by my organization is stored in the non-human entity (e.g. electronic vehicles or sensors) that operates autonomously or within intelligent systems as human or another company proxies, but still generates information about the human/company data subjects, either directly or indirectly	FS*	179	169.80	1.190	1	.275
	SS**	171	181.46			
	Total	350				
Another company, whether it belongs to the investigated triad or not, has legal ownership and property rights to its own data and records, whether created by them, about them, or both, and to "repatriate" ownership of those data	FS	179	175.45	.000	1	.992
	SS	171	175.56			
	Total	350				
An individual person, who is not necessarily a part of my organization, is the one to grant or deny access to their own data or records, created by my organization	FS	179	172.84	.261	1	.609
	SS	171	178.28			
	Total	350				
My company uses Blockchain-based platforms (e.g. OpenBazaar, OB1), designed around a smart contract system, to connect and trade with the partners in the triad without any central authority or fees	FS	179	169.49	1.335	1	.048
	SS	171	181.80			
	Total	350				
My company uses a digital ledger of transactions (performed and stored in a digital form, thus supporting Big Data technology) while connecting and trading with other partners in the triad	FS	179	163.03	5.685	1	.017
	SS	171	188.55			
	Total	350				
My company plans to implement Blockchain technology in the near future	FS	179	164.61	4.334	1	.037
	SS	171	186.90			
	Total	350				
My company is interested in the latest technologies (i.e. Blockchain) to support transactions with partners in the triad	FS	179	159.44	9.408	1	.002
	SS	171	192.32			
	Total	350				

FS* - Supply chains with the domination of formal system
SS** - Supply chains with the domination of shadow system

As depicted in Table 3, the supply chains with a prevailing role of shadow system produce significantly higher mean ranks as compared to the supply chains with the domination of formal system. Specifically, the first group is more eager to store the information generated by the organization in the non-human entity and to grant or deny access to own data or records to the individual person, regardless of its participation in the investigated organization. Likewise, the supply chains with a prevailing role of shadow system have a more positive attitude to using Blockchain-based platforms (e.g. OpenBazaar, OB1), designed around a smart contract system, to connect and trade with the partners in the triad without any central authority or fees. Similarly, a comparison between two clusters shows that the supply chains with a prevailing role of shadow system have a more positive opinion on using a digital ledger of transactions (performed and stored in a digital form, thus supporting Big Data technology) while connecting and trading with other partners in the triad, and planning to implement Blockchain technology in the near future than the supply chains with the domination of formal system. Finally, the supply chains with a prevailing role of shadow system are more interested in the latest technologies (i.e. Blockchain) to support transactions with partners. Likewise, there are no differences between the supply chains with the domination of both types of systems in terms of legal ownership and property rights to own data and records.

The conducted analysis shows that the strength of social relationships established among the supply chain actors significantly differentiate between bipolar clusters – one cluster containing the supply chains with weak social inter-organizational relations, and thus a domination of formal system, and the other cluster including the supply chains with strong social relations, and thus a prevailing role of shadow system. The obtained distinction is quite clear as cluster 1 is formed by the entirely negative attitude of all three actors in the investigated supply chains towards the social relationships, while cluster 2 is established by the fully positive view on the social relationships reported by all three supply chain actors. In line with these results, cluster 1 can be described as the group of supply chains with the domination of formal system (Formal/legitimate supply chain system), while cluster 2 can be referred to as the group of supply chains with the domination of shadow system (Informal/shadow supply chain system). The obtained results thus lend support for *H1* which suggests that the strength of social inter-organizational relationships differentiates between the formal and shadow systems in supply chains.

Despite these results, it is also interesting to notice that four out of seven variables for the Blockchain technology significantly differ between two clusters (at $p < .05$). Specifically, the significant four variables directly refer to the Blockchain technology and include: using the Blockchain-based platforms, using a digital ledger of transactions while connecting and trading with other partners in a supply chain, planning to implement Blockchain technology in the near future, and interest in the latest technologies (i.e. Blockchain) to support transactions with partners in a supply chain. This result shows that although the rest of the variables indicate the features of Blockchain technology, it still remains insignificant. It may suggest that not all technologies possessing these characteristics might be instrumental for the formal and shadow systems of supply chains. In other words, they manifest more general features that do not necessarily determine the way both systems operate. On the other hand, the selective indication of a specific technology (e.g. Blockchain), clearly ensures it may have a significant impact on the formal and shadow systems of supply chains.

It is also interesting to observe that although the Blockchain is more important in the supply chains with a prevailing role of the shadow system, it still appears to play a significant role in the supply chains with the domination of the formal system. By the same token, while the classical ERP applications are more typical for the formal system, being a centralized technology with the limited ability to extend beyond the boundaries of an individual organization, integrating the Blockchain with the existing ERP technologies promotes a collaborative platform by joining a decentralized one-rule-enforced Blockchain network [11] [7]. Consequently, although the ERP applications are typical for formal systems, it is desirable to support them with Blockchain technology. The Blockchain becomes thus significant for the formal system. On the other hand, the Blockchain can be regarded not only as a technological tool but also as a sensitizing means that make us rethink entrenched premises regarding trust [37]. Trust shapes social relations in the shadow system and conveys a partner's positive expectations regarding the other supply chain actor's intentions or behaviors [21]. Blockchain technology is thus considered to be the enabler of trust [19], and *vice versa,* trust is addressed as a critical condition in the Blockchain services [35]. This may be evidence of the significance of Blockchain technology in shaping the shadow system in supply chains. In the light of these arguments, our results lend support for *H2* which suggests that the supply chains with the domination of shadow system demonstrate a more positive attitude towards Blockchain technology as compared to the supply chains with the domination of formal system.

CONCLUSIONS AND FURTHER RESEARCH DIRECTIONS

The research shows that the strength of social relationships established among the supply chain actors significantly differentiate between bipolar clusters – one cluster containing the supply chains with weak social inter-organizational relations, and thus a domination of formal system, and the other cluster including the supply chains with strong social relations, and thus a prevailing role of shadow system. The obtained results also show that the supply chains with the domination of the shadow system demonstrate a more positive attitude towards the role of Blockchain technology as compared to the supply chains with a prevailing position of the formal system.

Apart from providing insights into the role of Blockchain technology in the formal and shadow systems, the study also demonstrates some potential avenues of future research. First, it would be interesting to investigate the exact areas of both formal and shadow systems that can be significantly supported by Blockchain technology. This issue is of crucial importance, as the formal system may also draw certain benefits from implementing this technology, such as reducing errors, enhancing coordination, improving formal supply chain governance. Second, as the Blockchain is more important for the shadow system, it would be also worthwhile to empirically explore the effect of this technology for establishing self-organized supply chains, and its effect on the synergistic effect yielded by the supply chain actors. Third, as this study uses a bipolar clustering of the investigated supply chains, it would be interesting to explore different "shades" of the formal-shadow system typology. Having said that, the next step could be conducting research on the relationships between the level of formality/informality of supply chains, and the strength of using the Blockchain technology.

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