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Assimilation of Tracking Technology in the Supply Chain

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Abstract

While tracking technology has become increasingly accessible, firms still struggle with deploying these technologies into the supply chain. Using the complementary perspectives of transaction cost and institutional theory, we develop an understanding of how supply network, product, and environmental characteristics jointly impact tracking technology assimilation. We empirically test our model on a global dataset of 535 supply chain executives and decision makers. The results suggest that assimilation is frequently initiated by an external stakeholder in a firm's supply chain and that firms must develop strong collaborative ties with their partners in order to take full advantage of this technology.

1. Introduction

Supply chain decision making is increasingly reliant upon access to real-time data. With a better understanding of inventory location and demand information, a supply chain manager may effectively replace product flow with information flow, at a considerably reduced cost. The most beneficial, real-time supply chain data is now most likely generated and delivered by some form of tracking technology. The ability to track products and assets through the value chain has become increasingly important in a wide range of industries [14]. Motivated by operational efficiency standards, competitive pressures, heightened customer expectations, and government regulations, both public and private organizations are searching for ways to reduce risks by gaining data driven visibility into the physical location, condition, and context of their products and assets [27, 78]. In the food industry, for example, there is an emerging trend to track food from "farm to fork" [46]. This visibility enables manufacturers and retailers to not only monitor conditions (e.g. location and temperature) of perishable shipments, but also determine the overall food mileage. In the health and life sciences industry, pharmaceutical companies are increasingly relying on tracking technologies to reduce the risk of counterfeit drugs [7] and the Federal Drug Administration recently approved a bill to use tracking technology to track the safety and efficiency of the nation's blood supply [105]. More generally, tracking technology can generate significant amounts of data that can be used to enhance workflow management, fleet performance, security, productivity, driver behavior, quality, and customer service, and reduce fuel and insurance costs [67].

Despite these enormous transformational benefits, not every implementation of tracking technology has met organizational expectations [64]. Previous studies have shown that information technology (IT) innovation diffusion rarely occurs in a smooth and linear fashion [38, 43]. Indeed, tracking technology assimilation levels vary greatly across organizations and industries, with full implementation within the supply chain difficult to achieve. A trucking company appears to be a natural candidate for adoption as tracking technologies can generate valuable data to help make their operations more efficient, while also providing significant real-time information to their customers. However, a customer may not have the capability to interpret the information provided by the technology, limiting the benefits such that they are outweighed by the costs. Alternatively, a company transporting hazardous materials may be required to process tracking information effectively to ensure secure delivery of goods, increasing the likelihood that they are able to overcome the hurdles associated with assimilation. Further, as the scale of the supply network grows, more data is available, increasing both the difficulty to process the information and the potential benefits associated with accurately interpreting this data. This may be both a detriment to and a stimulator of tracking technology adoption.

Together, these observations suggest that the diffusion of tracking technologies is not only determined by the characteristics of the organization, but also the supply network and product characteristics, as well as the broader institutional context in which organizations are embedded. Yet, these factors have traditionally been examined in separate models and on a subset of tracking technologies. We conducted a thorough review of prior research focused on the assimilation of tracking technology in the supply chain, with the results presented in Appendix A. This table indicates trends and gaps in literature. The overwhelming majority of literature has focused solely on individual types of tracking technology, primarily radio-frequency identification (RFID). The most common theory used is diffusion of innovation (DOI), with most papers focused on the adoption stage of tracking technology. DOI theory considers how communication channels, the social system and the innovation itself influence technology adoption [91]. This paper builds off of this theory, similarly applying the various stages of assimilation. However, while DOI theory considers the social system, it is limited in dissecting the various institutional pressures that a company may feel. Further, in considering the social system, it does not have a particular focus on the supplier-customer relationship, and the transactions that may define that relationship, found in every supply chain. Similarly, DOI theory is not able to evaluate the impact that the product that is center to these transactions has on technology adoption.

Given these limitations, this paper applies two complementary theories that allow for an analysis of how the supply chain system within which a firm operates influences tracking technology adoption. Transaction cost theory posits that, given a set of available options, organizations will select the technology that is the most efficient [113], thereby minimizing the various costs associated with a transaction. A supply chain facilitates the transactions between multiple networked parties, such that the characteristics of the chain and the products that move through it impact transactional costs. By providing a perspective on what firms do to limit these costs, transaction cost theory allows for an assessment of how supply chain and product characteristics influence the adoption of tracking technology. Alternatively, institutional theory posits that not all business decisions are as economically rational, with decision making strongly influenced by norms, values, and traditions external to the organization [77]. The supply chain system surrounding a firm includes not just its partners, but competitors and regulators as well. The influence that each of these has on the process by which a firm adopts a new technology may be examined with institutional theory.

While both of these theories are complete in and of themselves, each has been shown to fill in the gaps of the other, together providing a considerably more comprehensive perspective [90]. Transaction cost theory indicates that a firm will always choose the technology that maximizes efficiency; however, institutional theory can account for those situations in which the firm must implement an alternative technology requested by a customer. Alternatively, institutional theory is not as effective when considering early adoption of a new technology, as institutional pressures often take time to develop. Transaction cost theory encompasses those instances when an efficiency seeking firm implements a new technology that it expects will reduce costs. By applying both theories, we may study the influence of the complete supply chain system on a firm's decision to adopt tracking technology.

In terms of knowledge gaps within existing literature, this paper is the first to use transaction cost economics theory in a tracking technology context and to look at all tracking technologies combined at any stage of assimilation. Only two other papers look at tracking technology assimilation at the three stages of initiation, adoption and routinization, and both focus on RFID. Bridging the gaps in past research, this study develops an integrated model of these factors and jointly investigates their influence on the phases of tracking technology assimilation.

The findings of this study contribute to our understanding of IT innovation assimilation and data-driven decision capabilities in a supply chain context in several ways. First, we show that the complementary perspectives of transaction cost and institutional theory provide a strong framework to study technology assimilation. We use three fundamental contexts - product characteristics, supply network configuration and institutional environment - that shape IT innovation assimilation in supply chains. Second, we focus our study of IT assimilation on tracking technologies, an emerging supply chain IT sector of utmost importance and value to data driven decision making. We identify three dimensions that distinguish the data that tracking technologies may provide from traditional IT innovations - namely context, reach, and periodicity. Third, drawing on transaction cost and institutional theory, we develop a stage model of tracking technology assimilation and empirically test it on a global dataset of 535 supply chain executives and decision makers. Our findings provide evidence of the differing importance of product, supply network, and environmental characteristics on tracking technology usage in today's data driven supply chain.

From a practitioner's perspective, the study contributes to our understanding of emerging technology management in a global supply chain context and tracking technologies in particular. First, the results strongly suggest that assimilation is frequently initiated by an external stakeholder in a firm's supply chain, whether that is a competitor, customer or government regulator. This suggests that managers must be aware of the decisions and preferences of institutional stakeholders. Further, while competitors and regulators may influence initiation, they do not have an impact on the routinization of tracking technology, suggesting that the industry as a whole still has not determined how to most effectively utilize the data provided by tracking technology. The results also strongly suggest that firms must develop and foster strong collaborative ties with their supply chain partners in order to take full advantage of this data. Lastly, this research has implications for tracking technology vendors and solution providers, suggesting that they can help firms overcome some of the inertia by providing insight into methodologies for best utilizing data delivered by tracking technology.

2. Background

It is widely recognized that IT plays an important role in managing the flow of products and assets through the supply chain. IT enables supply chain participants to: share information, including demand and inventory data, ordering policies, and future demand forecasts [45]; reduce supply chain risks [24]; communicate and collaborate more effectively [101]; and design more efficient supply chain structures [26]. These capabilities have in many instances led to significantly reduced transaction costs and positive operational and financial performance impacts [15].

One emerging group of IT - broadly termed tracking technologies - promises to fundamentally transform supply chain management by providing detailed real-time information and seamless insight into the flow of products and assets throughout the value chain [56]. Early types of tracking technologies included on-board computers, universal product code (UPC) barcodes, and satellite-based communication and global positioning systems (GPS). More recently we have seen the emergence of cellular/mobile networks, wireless local area networks (WLAN), RFID chips and smart-tags. Information provided by tracking technology can include location, speed, acceleration, temperature, humidity, product information (price, dimensional information, physical characteristics, etc.) and vehicle status (tire pressure, engine diagnostic information, hard braking, etc.).

These tracking technologies offer several unique value propositions by providing information along three dimensions - context, reach, and periodicity - as shown in Figure 1. While other technologies may be limited along at least one of these dimensions, tracking technology is suited for all three. Abowd et al. [1] define context as information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application. While many different conceptualizations of context-awareness, or situatedness, exist [13], context is typically considered the location, identity, and state of individuals and physical objects. Tracking technologies generate this rich contextual data on supply chain resources and assets at both the point and time of action. In the food industry, for example, there is an emerging trend to track food from "farm to fork" [46]. This visibility enables manufacturers and retailers to monitor contextual information such as location and temperature of perishable shipments, as well as the overall food mileage. By collecting and analyzing this data, gaps in the food chain are revealed, allowing food companies to reduce spoilage and improve health and safety issues for their end-consumers [70].

These capabilities fundamentally transform a firm's information reach and periodicity. Reach is defined as the radius of information insight and access a firm has into its supply chain. In the supply chain context, tracking technologies have extended a firm's reach from localized to virtually pervasive. A company viewing the location of materials in-transit is better prepared to reschedule manufacturing activities based on expected availability of parts. By extending the reach of this technology, analyzing information regarding the delivery of materials to their suppliers empowers a company to better forecast and avoid future supply chain failures.

Tracking technologies are also increasing the periodicity (i.e. frequency) at which relevant supply chain information is collected and provided. Advanced sensor-based tracking technologies, for instance, can collect an enormous amount of data and provide it continuously and in near real-time [19]. This periodic information allows a firm to visualize the supply chain as the constantly shifting process that it is. Problems with product flow through the supply chain are easier to identify the more frequently contextual information is collected over time. Traumatic events that may damage sensitive electronic products while in transit occur in a split second, information that would may be missed without continuous data collection.

Tracking technologies enable firms to shift from receiving local, periodic, and static snapshots of their operations to viewing a fully instrumented and contextualized supply chain. Assuming that supply chain partners are willing to share the information provided by tracking technology, this data can be used immediately in realtime or to build a dynamic model that more accurately reflects supply chain events. While traditional, aggregated supply chain data is useful, the information provided by tracking technology allows for an unprecedented level of detail. For example, when analyzing last mile delivery in an urban supply chain, tracking technology can indicate where customers are located that require the longest service time or where delivery vehicles have the most trouble finding parking [112]. Big data analytics techniques may use the information collected through tracking technology to build supply chain models that will reduce inefficiencies, allow for more accurate forecasting and improve service. The new capabilities offered by tracking technology can have significant economic and operational consequences, demanding a re-examination of the underlying requirements and conditions as well as existing theories and frameworks of IT assimilation.

3. Theory and Hypotheses

There is a general consensus that tracking technology usage is largely driven by efficiency requirements, competition, customer demands, and regulation. From a theoretical perspective, tracking technology assimilation thus requires an examination using both economic and institutional lenses. Transaction cost theory analyzes a firm's decision making from an efficiency seeking perspective. It posits that any organizational design exists because it is more efficient than the set of available alternatives [113]. However, pressures from competitors, customers or the government may constrain that set of alternatives, with institutional theory positing that decision making is strongly influenced by norms, values, and traditions external to the organization [77]. Institutional theory is based on the premise that not all business choices are the result of rational economic decisions [32, 86, 94]. Each of these theories, while complete in and of itself, does have inherent weaknesses that are addressed by the other theory and together they provide a strong framework for the study of tracking technology assimilation.

Roberts and Greenwood [90] present a detailed argument that transaction cost and institutional theory are complementary, showing that institutional constraints motivate organizational decision making that is driven by the efficiency seeking transaction cost engine. Within the context of organizational design adoption, they argue that from a transaction cost perspective, while bounded rationality is accounted for, organizations consider only alternatives that maximize efficiency, likely disregarding institutional bounds that may limit those alternatives. The institutional environment may significantly influence how the firm views the decision and which alternatives are considered. A similar argument can be made within the context of tracking technology adoption. While a firm may wish to adopt technology A, which is the alternative that maximizes visibility within their supply chain, government regulations may mandate that they use technology B, which increases visibility beyond current conditions, but not to the extent of technology A. Through transaction cost, this firm would not have observed technology B as an efficiency maximizing alternative; only by also considering institutional constraints can we see why technology B was selected.

With a focus on immediate alternatives that maximize efficiency, transaction cost alone may have difficulty interpreting the evolution of technology assimilation as organizational circumstances change. Hill [51] finds that a firm displaying opportunistic behavior while seeking efficiencies may not consider the long-term implications of their decision making. They describe Chrysler in the 1990's, pressuring their suppliers on price, finding short term benefits but generating deep hostility among supply chain partners, ultimately resulting in declines in efficiency, quality and profit. When undergoing technology assimilation, a firm will naturally consider the economic benefits. However, without also considering the impact assimilation has on the firm's supply chain partners, these benefits may be short lived. Institutional theory complements transaction cost theory by providing a perspective on the dynamic influence of these important relationships that might not be accounted for otherwise.

Conversely, while transaction cost has shortcomings based on its static perspective, institutional theory is limited in explaining technology assimilation when the technology is first developing. As Leblebici, Salancik, Copay, and King [65] indicate, institutional pressure generally evolves over time, with norms established through multi-organizational acceptance or government regulation. However, technological innovation often outpaces the establishment of these norms and it is difficult to theorize how a new technology is selected based on institutional forces. Early adoption of technology is more commonly driven by technical considerations, rather than institutional ones [32].

While tracking technology is no longer in its infancy of development, it is an evolving technology where institutional forces may not be able to explain the entire assimilation process and transaction cost is a necessary complement.

As the intention of this study is to provide a multi-stage perspective on organizational assimilation of tracking technology, using only transaction cost or institutional theory would likely be insufficient. However, with the combined technical and institutional perspectives that these theories provide, a more thorough analysis is facilitated. With a focus on decision making driven by efficient alternatives, transaction cost theory allows for a consideration of the supply chain benefits that tracking technology presents. As technology assimilation is a dynamic process, institutional theory provides a flexible lens, while indicating the environmental constraints that limit the process. These theories together provide a comprehensive platform to study organizational change [82, 103, 12], but they have not been applied to an analysis of technology assimilation.

3.1. Supply Chain System and Assimilation Process

Prior to developing the framework that utilizes these two theories, we construct a suitable conceptualization of a supply chain system that considers the technical benefits to the member firms and the institutional environment within which the firms operate, while allowing for a dynamic adoption process. Generally, a system can be defined as the set of actors, the network of relationships between these actors, and the institutions that guide their behavior [8]. The system lens is particularly relevant to understanding the structure and dynamics of supply chains [9]. Building on Porter's linear value chain framework [85], Stevens [99], for instance, describes a supply chain system whose constituent components include material suppliers, production facilities, distribution services, and customers interconnected via a feed forward flow of materials and products and a feedback flow of money, knowledge, and information.

In the context of tracking technology assimilation in supply chains, we argue that three inextricably connected socio-technical contexts define the system for the firm (shown in Figure 2). The *supply network* is defined by the interorganizational network structure of firms, the nature and extent of collaborative relationships with supply chain partners, both customers and suppliers, and the technological infrastructure and processes that facilitate information flow between them [9]. The *product* context describes the nature of the products that flow across the supply network. These contexts are embedded in a broader *environmental* context, consisting of three institutional actors: competitors, regulators and supply chain partners [32]. In order to understand how firms react to the technical benefits of tracking technology, while navigating the institutional constraints placed on them, a joint consideration of all three contexts is necessary.

The firms operate within this system as they undergo the dynamic process through which tracking technology is adopted. Tracking technology assimilation is defined as the degree to which tracking technologies support and enable relevant business activities and become widely routinized in supply chains [37]. Consistent with prior work, we conceptualize three phases of tracking technology assimilation. *Initiation* is defined as evaluating the potential benefits of tracking technology to improve a firm's performance in supply chain activities such as operational efficiency improvement, product loss prevention, regulatory compliance, coordination improvement, and cost reduction. *Adoption* is defined as making the decision to use tracking technology for value chain activities (i.e. allocating resources and physically acquiring the technology). *Routinization* is defined as the phase in which tracking technology is used as an integral part in a firm's and its partners' value chain activities. Previous studies have identified different phases of IT innovation assimilation - ranging from initiation and awareness to adoption and basic deployment to widespread use and organizational routinization [39]. There is a particular clear demarcation between the initiation, adoption, and routinization phases, such that a firm can only be in one phase at any time and it is clear which phase that is. While a firm may consider an IT innovation, it may fail to actually adopt it. Similarly, while a firm may adopt an IT innovation, it may ultimately not be used (widely) across the organization.

3.2. Research Model

A conceptual research model is built to understand tracking technology assimilation, composed of the three socio-technical contexts that characterize the supply chain system and the three distinct phases of assimilation, as shown in Figure 3. This model combines transaction cost and institutional theory. Williamson [111] states that transaction cost is primarily concerned with the rational systems branch of organization theory. Transactions represent the microcosm, or logical unit of analysis, of the supply chain system. Rather than treating each transaction separately, viewing the supply chain as a system enables a clustering of related transactions within the system. Transaction cost thus provides the theoretical foundation for the inner oval of our supply chain system shown in Figure 2. Alternatively, institutional theorists posit that decision making is strongly influenced by norms, values, and traditions external to the organization [77]. Institutional theory thus describes the outer oval of the supply chain systems in Figure 2.

The costs associated with moving a product through a supply network are defined by transaction cost theory [5]. Scholars posit that a firm will explore every opportunity to increase efficiency or reduce its transaction costs, including the *enforcement costs* that ensure the transaction is completed as stipulated [36]. In order to complete a transaction, products and information must successfully flow through the supply network. The characteristics of this conduit, as well as the amount of information shared through it, can thus affect the cost of each transaction. Williamson [110] defines transaction costs as the "economic counterpart of (physical) friction." This friction increases as the number of transfer points rises and more supply chain partners touch a product, creating the potential for information asymmetry, or uncertainty, throughout the supply network [69]. Under these conditions, a supply chain partner may exhibit "opportunistic behavior," resulting in unfair advantages and an increase in transaction costs [110].

To avoid opportunistic behavior, decrease uncertainty, and lower transaction costs, a firm is likely to utilize resources, such as tracking technology, to reduce the amount of friction and information asymmetry. As defined earlier, tracking technology allows for the collection of data along the dimensions of context, reach and periodicity. By providing information more frequently and with a greater reach, tracking technology allows for unparalleled integration that can significantly reduce transaction costs. Further, by collecting full contextual information regarding a product, tracking technology protects a firm from opportunistic behavior. The firm will now know if the temperature of a perishable good rose above an acceptable limit in transit or if a product was late because the driver chose a poor route. Using a transaction cost framework, one can posit that supply network and product characteristics which facilitate the collection of data through tracking technology are most likely to lead to a perceived or realized reduction in transaction costs (note that the impact on transaction costs is *perceived* during the initiation stage and *realized* during the adoption and routinization stages).

While the transaction cost lens can be used in the technical context of the physical product and supply network to define the drivers for technology assimilation, the information provided may be incomplete. A firm may be compelled to initiate tracking technology to improve efficiencies within the supply chain; however, tracking technology usage may not be sufficiently developed for firms to see the long-term efficiency gains that may be realized through full assimilation. Rather, it may be the institutional environment that is currently driving usage to routinization, with customers or regulators applying pressure. Research has shown that a firm's environmental (i.e. institutional) context plays an important role in the level and extent of IT diffusion [104]. DiMaggio and Powell

[32] identify three distinct institutional pressures that influence a firm's actions and structure. Mimetic pressure refers to the pressure on a firm to imitate what another organization is doing based on how successful they perceive the other organization to be. Coercive pressure refers to the pressure applied to a firm by organizations that they are dependent upon and by the expectations of the social environment. Normative pressure refers to the pressure on a firm to operate within the legitimate norms as defined by the collective expectations of organizations within the field.

Numerous studies have shown the considerable influence that environmental pressures have on IT assimilation [18, 97, 104]. Given the significant amount of data that tracking technology can provide within a supply chain, assimilation is likely to be driven by these pressures. As more firms successfully assimilate tracking technology, mimetic pressure to follow these firms will grow, customers and regulators will exert coercive pressure to gain access to the data provided by the technology, and normative pressure will build as it becomes expected that the technology is used in every supply chain.

3.3. Supply Network Context

A supply network is the construct of nodes (e.g. firms) and links (e.g. relationships) through which resources (primarily products, but also materials and information) in the supply chain move [8, 9]. The characteristics of the supply network influence how effectively supply chain information is transmitted through the network. A supply network that is tightly interconnected, whether through technology, relationships or geography, magnifies the opportunities for tracking technology enabled information to reach and be used in various parts of the network, allowing for a reduction in transaction costs. These characteristics may impact the ease with which tracking technology is assimilated within the supply chain, with this research focusing on three foundational aspects: technology integration, collaboration intensity, and structural complexity [9].

3.3.1. Technology integration

Technology integration is defined as the "degree of inter-connectivity among back-office information systems and databases inside the firm and those externally integrated with suppliers' enterprise systems and databases" [115]. When enterprise information systems are not tightly integrated across the supply network, information flow and knowledge exchange is impeded, leading to greater information asymmetry and higher transaction cost [101].

The extent of technology integration plays a significant role in tracking technology assimilation. Consider two firms, one with significant technology integration (Firm A) and one with minimal integration (Firm B). Both firms will perceive benefits during the initiation stage. For Firm B, tracking technology may be a driver or enabler in becoming technologically integrated, with the perception that new data will be made available that can be used to reduce transaction costs. Alternatively, Firm A is already cognizant that IT can lead to improvements in strategic information flow, opportunities to make data driven decisions and ultimately reduced transaction costs [62], expecting that tracking technology will further all of these gains.

At the adoption stage, where tracking technology resources are initially scattered throughout the network, transaction costs may be reduced for Firm A as even limited information provided by the technology is more easily shared with supply chain partners. When this firm is at the routinization stage and tracking technology is producing the most transactional data within the supply network, technology integration enables this data to flow efficiently and the greatest benefits may be realized. For Firm B, the information provided by tracking technology can not readily flow through the network at either stage and transaction cost reductions become more difficult to realize moving from adoption through to routinization. Therefore, we propose the following:

H1: Technology integration is positively related to tracking technology adoption and routinization.

3.3.2. Collaboration intensity

Collaboration intensity is defined as the degree to which supply chain partners synchronize decisions and share information and goals [96]. A supply network that exhibits considerable collaboration is one in which firms are operating in tandem with the same uniting purpose. As with technology integration, a greater degree of collaboration intensity allows firms to respond more easily to economical and technological changes [35], leveraging data collection and market knowledge creation to gain a competitive advantage [75]. Ultimately, if supply chain partners are not willing to share the information provided by tracking technology, the overwhelming majority of benefits of the technology may not be realized, stifling adoption throughout the supply chain.

Again, consider two firms, one with a high (Firm A) and one with a limited collaboration intensity (Firm B). Both firms perceive benefits in the initiation stage. Firm A's supply chain partners are likely to share similar goals and the perceived reduction in transaction costs associated with tracking technology can motivate all partners to initiate usage. Because Firm B does not collaborate closely with its supply chain partners, it is likely to perceive a benefit from tracking, expecting the information provided by the technology to protect against opportunistic behavior.

During adoption and routinization, however, the realized benefits from tracking technology are likely to differ between these firms. By collaborating with partners, Firm A has improved their ability to engage in innovation throughout the supply chain [58]. "Tapping joint creativity capacities, joint organizational learning, knowledge sharing, [and] joint problem solving between supply chain partners" [16] allows a firm to introduce a new technology much more quickly. Allocating resources throughout the network as part of the adoption process is simplified in a collaborative environment, as Firm A receives more cooperation from supply chain partners open to sharing in this new technology. Without collaborative partners that also adopt tracking technology, Firm B is not likely to realize the protection from opportunistic behavior that was expected upon initiation.

Similarly, a collaborative environment eases the wider integration of the technology as part of the routinization process, allowing for a more immediate realization in the reduction of transaction costs. Collaborative partners may be more likely to work in conjunction with Firm A to spread the use of tracking technology through the supply chain, utilizing the information for a common benefit. As with adoption, Firm B may find resistance from supply chain partners unwilling to undergo the potentially complicated and costly routinization process. Therefore, we propose the following:

> *H2: Collaboration intensity is positively related to tracking technology adoption and routinization.*

3.3.3. Structural complexity

We define structural complexity of a supply network as the combination of vertical (e.g. number of tiers) and horizontal complexity (e.g. number of suppliers in each tier) [23]. With the global expansion of supply networks, visibility and operational insight into every tier of a supply chain becomes more difficult to achieve, leading to an increase in transaction costs.

Consider two firms, one with a complex supply network (Firm A) and one with a simple network (Firm B). For Firm B, assimilating tracking technology to any stage may not be necessary to reduce transaction costs. Choi and Krause [22] show that with a reduced supply network, and repeated transactions with the same set of suppliers, transaction costs are inherently reduced. Firm A may not have the capability to build trusting relationships with all suppliers, potentially requiring a tool that can aid in guarding against opportunistic behavior. With the promise of increasing information flow and integrating the network at the initiation stage, the perceived benefits of tracking technology may be significant.

At the adoption stage, implementing tracking technology resources in certain segments of the network is still feasible for Firm A, regardless of the complexity of the network. The information provided by tracking technology can decrease opportunistic behavior, thereby reducing transaction costs [10]. However, as the number of suppliers and customers in the network grows, it becomes increasingly challenging to ensure that all supply chain partners are able to effectively utilize the data provided by tracking technology. As the firm moves to routinization, the complexity of the network becomes a detriment as there are more partners with whom to share information. Therefore, we propose the following:

H3: Structural complexity is positively related to tracking technology initiation and adoption.

3.4. Product Context

The product is the central element of the system that flows through and (conceptually) connects the supply network. It has been shown that product characteristics impact how the product moves through the supply chain, both in the production stage and in delivery to the end customer [55]. These characteristics also dictate how useful tracking technology may be in translating contextual product status into data that can be disseminated through the supply network to external partners or regulators. For this study, product-related descriptors were chosen that consider both physical and economic characteristics. The physical complexity of a product in the supply chain is commonly described by the associated handling risk. The economic complexity of a product may be defined by how difficult it is to predict the demand for the product. Therefore, demand uncertainty and handling risk were used as the product characteristics.

3.4.1. Demand uncertainty

Demand uncertainty is defined as the stability of the market that the supply chain serves and the difficulty with which demand may be predicted [44]. A higher level of demand uncertainty implies a higher transaction cost because parties involved in the transaction will spend more time and effort in monitoring the transaction process [72]. The transaction cost perspective has been used to posit that demand uncertainty positively influences vertical integration [109] and vendor managed inventory (VMI) [33], but in both cases the empirical study finds no clear connection.

While VMI allows the supplier to have visibility into consumer demand, tracking technology generates significantly more supply chain related data. As more firms move to eliminate inventory from their supply chains in order to reduce costs, the main hurdle is demand uncertainty. Stockouts are a regular occurrence with uncertain demand, often because a firm does not know how much inventory is on hand or where it is in the supply chain. From a transaction cost perspective, this increases the enforcement costs that are incurred when ensuring that a transaction is successfully completed. By frequently providing product information from across the entire supply chain, tracking technology allows for costly inventory to be replaced with data while allowing for more orders to be successfully processed. Inventory and enforcement costs are simultaneously reduced.

The literature relating demand uncertainty to technological innovation is conflicted. In many instances, demand uncertainty has either a negative or even no influence on a technology decision [83], making a hypothesis difficult to draw. However, given that tracking technology can provide more data in an uncertain environment than any previously evaluated technology, allowing for a potentially significant reduction in transaction costs, we expect that it will have an influence at all three stages of assimilation. Therefore, we propose the following:

H4: Demand uncertainty is positively related to tracking technology initiation, adoption and routinization.

3.4.2. Handling risk

Handling risk is defined as the level of risk associated with storing, handling and transporting the product [92]. Products that are perishable, fragile, hazardous, or flammable all may require close tracking in order to avoid costly consequences. Supply chains are particularly vulnerable to disruptions when products have high handling risk [98].

As with demand uncertainty, increased handling risk leads to a higher transaction cost because a firm will spend more time and effort in monitoring the transaction process. A high reliability organization (HRO) is a firm that has successfully navigated the risks it regularly faces, using complex processes to manage sophisticated technologies that minimize those risks [93]. When transporting a high risk product, a firm is likely to operate as or mimic an HRO. These firms are driven to use technology in order to guard, preserve or otherwise monitor a sensitive item, thereby increasing reliability and reducing the transaction costs associated with handling these products.

No other technology does more to protect sensitive products throughout the supply chain, providing continuous contextual data that allows a firm to respond to or prevent events that could result in product loss or worse. A technology that promises to limit a firm's exposure to high risk events is thus likely to be quickly assimilated. Therefore, we propose the following:

H5: Handling risk is positively related to tracking technology initiation, adoption and *routinization.*

3.5. Environmental Context

The supply network and product are embedded within a broader environmental context composed of customers, competitors and regulators, exerting institutional mimetic, coercive and normative pressures. Consideration of the environmental context is particularly pertinent when examining tracking technology, with its ability to extend context, reach and periodicity. Observing the success that a competitor has in assimilating tracking technology may drive a firm to do the same. The richness and complementary value of contextual data afforded by tracking technology may be enticing to customers. With the impact that tracking technology may have in monitoring hazardous materials, regulators are very keen to determine the most effective use of the technology. Pressures from the institutional environment are likely to drive tracking technology assimilation provided the numerous associated benefits.

3.5.1. Competitive pressure

Competitive pressure is defined as the degree to which direct competitors of a firm have implemented tracking technology, potentially resulting in a competitive disadvantage for the focal firm [60]. In order to adopt a new technology, a firm must find that the benefits outweigh the costs. However, evaluating this balance involves considerable uncertainty and the firm cannot know for certain if the technology will be worth the risks until after assimilation is complete. When institutional peers adopt this new technology and show it to be a functional component of their business, the risks associated with adopting the new technology are not quite as daunting for the focal firm.

Mimetic and normative pressures may be exerted by a competitor, with Teo et al. [104] finding that both lead to greater intention to adopt financial electronic data interchange (EDI) systems. The normative pressures have a considerable impact, likely through strong professional organizations that support the use of this technology. Liu et al. [73] also find that normative pressures are positively related to adoption intention of Internet-enabled supply chain management systems. They find that the prevalence of these systems stimulates information sharing that allows for the establishment of norms to further promote their use. With numerous industry forums on tracking technology, practitioner research and discussion on developing industry standards, a firm is likely to experience normative pressure from competitors, whether directly from one or more firms or through professional organizations composed of competitors. Through the prevalence of trade publications, a firm may regularly be informed on the importance of tracking technology and how their competitors are effectively using it.

Similarly, intense market competition has led to mimetic pressure that stimulated the adoption of IT innovations. Chwelos et al. [25] and Iacovou et al. [54] both find that the competitor is the single most significant influence on EDI adoption. It is probable that mimetic pressure to initiate tracking technology has a comparable effect. A transportation provider not offering some form of tracking is very likely to be questioned as to why their competitor has tracking technology, but they do not. In an industry with low barriers of entry and competitors that are often indiscernible from one another, foregoing a service that many offer is tantamount to failure.

While initiation and adoption are likely to be driven by competitor pressure, that pressure may not be sufficient for full routinization. In analyzing business-to-business (B2B) e-marketplaces, Son and Benbasat [97] find that mimetic and normative pressures positively influence the intention to adopt. However, these pressures do not influence extended use. Similarly, Karahanna et al. [57] show that normative pressures are stronger in the pre-adoption stage than post-adoption. As a firm moves past adoption of tracking technology, the risk associated with assimilation decreases and the normative and mimetic pressures associated with competitive pressure do not have the same direct influence. While the pressure to offer a technology that many of your competitors have may be considerable, routinization of that technology is likely not as commonplace among competitors, diminishing the pressure at that stage. Therefore, we expect that competitive pressure influences tracking technology initiation and adoption, but not routinization.

H6: Competitive pressure is positively related to tracking technology initiation and adoption.

3.5.2. Customer pressure

Customer pressure is defined as the pressure that a firm feels to provide any type of customer service [60]. Characteristics defining the relationship between a firm and its customers, such as the level of dependence between supply chain partners and the economics driving the relationship, can dictate the level of technology assimilation [28]. There is a considerable volume of literature showing that customer pressure drives initiation and adoption of technology, including EDI [49], electronic trading systems [60] and RFID [63]. To define the extent to which a customer influences a firm's behavior, coercive and normative pressures are generally used to represent the considerable power of this influence [32]. The initiation of Internet-enabled supply chain management systems is driven by coercive and normative pressures from supply chain partners [73], while Ke et al. [59]

find the same result for the adoption of this technology.

As coercive pressure is applied on a firm by an organization that the firm is dependent upon, finding a dependent relationship is generally synchronous to finding coercive behavior. With the supplier-customer relationship inherent in every supply chain, dependence is prevalent. Coercive pressure is often applied when a customer demands that their supplier adopts a new technology, as Wal-Mart famously did when integrating RFID into their supply chain [4]. In a move that was considered primarily beneficial to Wal-Mart, suppliers of the world's number one retailer had no choice but to bear the costs. While a supplier may resist coercive pressure, many supply chains are sufficiently competitive that the supplier must concede to the pressure or the customer may find another supplier who will. The supplier may also be in a position where all customers apply a common pressure. This is particularly true when the customer base has created a normative standard.

Normative pressure is developed as organizations collectively create expectations for how a firm should operate. While coercive pressure entails direct pressure from a customer on a firm, normative pressure from a customer base may have a greater impact. A firm may deflect coercive pressure through negotiation or discontinuing a relationship; however, normative pressure cannot be as readily dismissed. Realizing the importance of protecting the supply chain from counterfeit goods, the pharmaceutical industry has made RFID usage the norm [7]. If a firm operating within this industry resists tracking technology adoption, the set of customers willing to enter into a relationship with them is rather limited. When a customer base has created a normative expectation that tracking technology should be used, there is little that a firm may do except follow the norm.

While literature has shown that the effect of competitive pressure is ambiguous at the routinization stage, the combined coercive and normative pressures applied by a customer have a clear influence. A firm has very limited recourse when a customer applies pressure to adopt tracking technology, at any stage of assimilation. Therefore, we propose the following:

> *H7: Customer pressure is positively related to tracking technology initiation, adoption, and routinization.*

3.5.3. Regulatory environment

Regulatory environment is defined as the degree of government influence and support felt by the focal firm to monitor the movement of goods transported [115]. The coercive pressure of the regulatory environment on IT innovation assimilation has been well recognized [2]. The regulatory environment has also had a clear influence on the supply chain. Not surprisingly, the events of 9/11 have led to the revision of regulations dictating how goods may be moved through the supply chain, such as the Hazardous Materials Transportation Act of 1975 as amended by the Homeland Security Act of 2002 [52], which, among other things, raised the security standards of those transporting hazardous materials. Note that this study focuses on a supportive regulatory environment that has rules and regulations facilitate or aid organizations in compliance (with the firm given flexibility of choice with regards to adoption), rather than an environment in which the firm has no choice but to obey the mandate.

The pressure created by the regulatory environment is comparable to that applied by the customer in that it is generally considered to be both coercive and normative in nature [94]. To that extent, many of the findings in literature are similar and often complementary. As government regulations are primarily in place to protect the people and tracking technology can be a very useful tool to maintain the safety of goods within a supply chain, it is likely that the regulatory environment will create new coercive measures to encourage tracking technology assimilation. As these measures become a part of the social environment, a firm that does not adopt tracking technology may appear disinterested in safety, creating ill will from customers or the general public. Further, executives may find that government regulations provide justification to initiate new technologies that keep the firm competitive and in tune with customer expectations. The initial cost of tracking technology may be easier to justify when the coercive pressure of a mandate to begin assimilation is applied [53].

Normative pressure in the form of directives that regulate innovation were effectively used for both the initiation and adoption of IT usage between government entities [50]. Similarly, normative pressure was applied through the establishment of a set of standards, driving IT adoption [3]. As normative pressure is defined by the collective expectations of organizations in a field, the regulatory environment may influence what the norm is by directing those expectations. Government regulations pushing for tracking technology usage in the pharmaceutical industry helped to establish the norm that is then applied through customer pressure. While this is more of an indirect normative influence on tracking technology adoption, it is a voice that most firms listen to in coming to a legitimate norm.

However, King et al. [61] conjecture that regulatory intervention is necessary for sustained IT innovation, but that it is not necessary for the diffusion of this innovation. It is further posited that regulatory agencies play an important role in the development of standards for IT innovation, but these standards may result in counterproductive consequences. With numerous tracking technologies available, it may be difficult for supply chain partners to find a common platform on which to communicate. If a governing body assists in establishing this platform, ease of communication increases and the risk associated with initiation and adoption of the technology diminishes. However, if the standards are too confining, innovation is stifled, the benefits are potentially curtailed and routinization becomes less likely. Therefore, we propose the following:

H8: A supportive regulatory environment is positively related to tracking technology initiation and adoption.

4. Methodology

4.1. Data

Prior to developing a large-scale, cross-industry survey, the research model and hypotheses were evaluated using a focus group. The focus group consisted of 12 supply chain and transportation vice presidents or managers from a variety of industries, including food distribution, petroleum distribution, manufacturing, third party logistics (3PL), and tracking software development. The focus group was held on one day with two three-hour sessions. Both authors co-led the discussion, which was seeded with questions and issues pertinent to the research model and hypotheses. The investigators resolved any disagreements on content classification by discussion and consensus. The research model and the associated hypotheses as presented in Section 3.2 were all supported by the focus group.

In collaboration with the Council of Supply Chain Management Professionals, the Supply & Demand Chain Executive magazine, and the RFID Journal, the survey presented in Appendix B was disseminated, with participants meeting the following three criteria: (1) the participant is a director, executive, or strategic decision maker in his or her organization, (2) the participant has supply chain management responsibilities, and (3) the participant has had at least 5 years of supply chain experience. These criteria were selected to ensure that respondents had both the appropriate level of decision-making authority in their organization as well as relevant work experience to comment on strategic and operational supply chain decisions. In case of multiple respondents per organization, only the most senior executive's name was retained. While using a single respondent from each firm has its limitations, these are overcome to some degree by identifying senior executives that are most "informed" with IT adoption and usage and related variables within each organization. This approach is therefore in line with other survey studies that have used the "key informant" method [87]. The web-based survey was administered over a period of three weeks with two reminders sent after week 1 and 2, respectively. A link to the survey was sent by email to executives in 2,500+ member organizations. 102 emails were returned due to incorrect contact information; 67 responses were incomplete. In total, we received 535 usable surveys, resulting in a response rate of 18 percent. Table 1 shows the sample characteristics.

To control for the different stages of assimilation, two binary decision gates were used to determine whether the respondent's organization had initiated and adopted tracking technology. If the answer was 'no' to initiation, then the respondent was not included in the survey. If the answer was 'no' to adoption, then only their responses to the initiation stage were included. If the answer was 'yes' to adoption, then the responses to the adoption stage were considered, as well as the extent to which tracking technology was routinized. This approach is in line with prior work in multi-stage technology adoption studies (see Zhu, Kraemer, and Xu [115]).

Several procedures are employed to control for common method biases given that we have a single respondent. First, we designed the survey to use as many formative constructs as possible to reduce the cognitive complexity a respondent is exposed to answering a scale item [34]. Second, Harman's one-factor test is conducted in a principal components factor (PCF) analysis [48]. The PCF analysis shows that each construct explains roughly equal variance. It can be concluded that there is no strong evidence suggesting the presence of common method bias in this study.

Non-response variance was assessed by comparing early respondents with late respondents in terms of three key organizational characteristics of the sample. The rationale for the test was that late respondents were likely to have similar characteristics to nonrespondents. The three characteristics used for this test were number of employees, annual revenue, and supply network scale. T-tests showed no significant different between the two groups of respondents in terms of number of employees (t=1.22; p=0.201), annual revenue (t=1.24; p=0.224), and supply network scale (t=0.87; p=0.313) at the p=0.05 significance level, suggesting that non- response variance was not a problem. Table 2 shows descriptive statistics of the sample.

4.2. Instrument Development

The survey instrument is developed through successive stages of theoretical modeling, statistical testing, and refinement [100]. A comprehensive review of the literature as well as expert opinion form the basis for instrument development. Survey items for the constructs described are developed from commonly accepted theoretical definitions. Based on recommended approaches to item measurement development and to support cumulative research, constructs are operationalized or adapted for this context using validated items from prior research as much as possible [108]. Measures are defined and described in the following subsection. A small sample of (eight) senior executives (three of whom were part of the focus group) and four academicians in operations and information management evaluated a pretest of the survey. The pretest participants commented on the clarity of the instructions, readability and understandability of the individual items, and the overall organization of the survey. Based on their feedback, minor wording and flow changes were made to the instrument.

4.3. Measures

4.3.1. Dependent variables

The three stages of assimilation found in Zhu et al. [115] are adapted for this context. The IT innovation initiation stage commonly involves the pressure to change, the gathering of relevant information, and the evaluation of its potential benefits [91]. *Tracking Technology Initiation* is evaluated by measuring how the potential benefits of tracking technologies are rated before the firm begins using them. Eight items are used: operational efficiency improvement, product loss prevention, regulatory compliance, cost reduction, productivity gain, coordination improvement, supply network visibility gain, and customer service improvement. Similar to Zhu et al. [115], *Tracking Technology Adoption* is measured through an aggregated index of whether the firm has used tracking technology in any of seven value chain activity areas. Each value chain activity area contains several items. The seven activity areas include inbound logistics, outbound logistics, fleet management, sourcing and procurement, warehousing and inventory management, customer service, and sales and marketing. This approach is consistent with previous work [39]. *Tracking Technology Routinization* is measured through the extent of organizational usage of tracking technology to support value chain activities [17]. It is therefore operationalized similarly to Zhu et al. [115] and adapted to the tracking technology context.

4.3.2. Independent variables

Technology Integration is measured using four items indicating the extent that a firm's internal databases and information systems are electronically integrated with the Internet and the extent to which their databases and information systems are connected to suppliers and customers [115]. *Collaboration Intensity* is measured using five items based on conceptualizations by Bensaou and Venkatraman [11], Frohlich and Westbrook [42] and Simatupang and Sridharan [96]. Items include the extent of information sharing, decision synchronization, goal sharing, and self-management of the supply chain. *Structural Complexity* is measured using the definition of vertical and horizontal complexity found in Choi and Hong [21]. Vertical complexity is measured as the number of tiers and horizontal complexity as the number of firms per tier, all log-transformed to reduce data variance. *Demand Uncertainty* is measured using three items that indicate the extent to which demand for products is difficult to predict, shows significant variability, and cannot be accurately forecast. *Handling Risk* is measured using five items adapted from Rushton et al. [92]: (a) product fragility, (b) specialized handling requirement, (c) perishability, (d) hazardousness, and (e) climate-controlled environment requirement. These items represent the physical transportation characteristics that determine handling risk. The operationalization of Khalifa and Davison [60] is adapted to measure *Competitive Pressure*. Six items are used to reflect the extent to which a firm is affected by its competition. Similarly, *Customer Pressure* is measured based on five items using an adapted scale from Khalifa and Davison [60]. Lastly, *Regulatory Environment* is measured using five items, adapted from Zhu et al. [115], reflecting the degree of government influence and support experienced by the firm to track the movement of goods.

4.3.3. Control variables

Several variables are controlled for that comparable studies have found may influence IT assimilation. Organizational size is frequently shown to be an important indicator of IT innovation adoption [91]. Large organizations are more likely to adopt tracking technologies as they tend to have more financial and human resources to assimilate innovation effectively and economies of scale to leverage the investments [104]. There are many different ways to measure organization size [66]. In this study, organization size is measured through two metrics - a firm's *employee size* and *annual revenue*. We also control for the scope of supply network operations as firms with global supply networks may have a greater need for tracking technologies than those with local ones. Similar to previous studies, we a use a dummy variable to control for *supply network scope*. We also control for product ownership. Firms that ship their customers' products may be more inclined to use tracking technologies in order to provide superior customer service and protect themselves against possible litigation. A dummy variable is therefore used to control for *product ownership*. It has been shown that there can be global differences that influence IT innovation assimilation. For instance, firms in developed regions may be more likely to assimilate IT innovations than emerging or developing regions. In accordance with other studies, a dummy variable is used to control for *geographical* *location* of a firm.

5. Analysis and Results

The research model is tested using Partial Least Squares (PLS) with SmartPLS 2.0 [89]. PLS, developed by Wold [114], is a component-based structural equation modeling (SEM) method that has no distributional assumptions and is flexible to the inclusion of both formative and reflective measures in a model [31]. The basic PLS algorithm, as outlined in Lohmöller [74], is described in Algorithm 1.

Algorithm 1 PLS Algorithm

Iterative estimation of latent variable scores, consisting of a 4-step iterative procedure

while convergence is not obtained or the maximum number of iterations is not reached **do**

  outer approximation of the latent variable scores,

  estimation of the inner weights,

  inner approximation of the latent variable scores, and

  estimation of the outer weights.

end while

Estimation of path and loading coefficients.

Estimation of location parameters.

In addition, it has been shown that component-based SEM does not face the same statistical identification challenges found in covariance-based approaches to formative modeling [84] and maximizes the explained variance of endogenous variables in the structural model [20]. For data analysis, SmartPLS is chosen over LISREL due to its ability to handle both reflective and formative constructs [106].

5.1. Assessment of Measurement Model

Since this model contains both reflective and formative constructs, the analysis has to apply appropriate assessment techniques for each type. Validation of reflective constructs is well documented; in contrast, there are only few well established validation guidelines for formative constructs [84]. The internal consistency of each reflective construct is assessed by Cronbach's alpha and composite reliability [47]. Table 3 presents the results. All Cronbach's alpha and composite reliabilities exceed the criterion of 0.70 established by Nunnally [80], ranging from 0.772-0.937 and 0.828-0.949

respectively. Convergent validity is established by examining the significant factor loadings on each construct. Unidimensionality and convergent validity ensures that all items measure a single underlying construct [6]. Convergent validity thus exists when items load significantly on their designated latent construct [95]. The standardized Confirmatory Factor Analysis loadings present evidence of convergent validity.

Discriminant validity is the degree to which measures of different scales of the survey instrument are unique from each other [107] and, especially, tautologies between scales increases the chance of a lack of discriminant validity. Even if there are no clear tautologies it is possible that an item in one scale is reflecting the value of a construct of another scale. Comparing the chi-square value of a model with a perfect correlation with that of an unconstrained model can test discriminant validity. A significant difference between the constrained model chi-square and that of the unconstrained model indicates that the two constructs are distinct [107]. All of the tests indicated strong support for discriminant validity criteria at a p-value less than 0.1. Thus these scales satisfy the discriminant validity criterion. We also used the criteria established by [41] to compare the inter-construct correlations with the square root of the Average Variance Extracted (AVE). Table 3 shows that all of the constructs exceed the absolute value of inter-construct correlations and thus meet this criterion. Discriminant validity of the formative constructs is assessed using the approach suggested by [88] by examining item-to-item and item-to-construct correlations. Intra-construct item correlations are found to be greater than inter-construct item correlations. In summary, these results suggest that the instrument has acceptable measurement properties and can be used to test the research model and associated hypotheses.

This study has six formative constructs. It has been shown that formative measures do not need to exhibit internal consistency or reliability [20, 84, 88] and that multicollinearity among formative indicators can actually result in non-significant items [29], as multiple indicators may identify the same aspect of a construct [84]. Rai et al. [88] suggest that the variance inflation factor (VIF) is a useful statistic to examine such problems, with values below 3.3 indicative of the absence of multicollinearity [30]. VIF values for our formative measures range from 1.3-2.0, confirming the absence of multicollinearity.

5.2. Assessment of Structural Model

Based on Fichman and Kemerer [37], three models are estimated: Model 1 includes only the theoretical variables as predictors, Model 2 is a controls-only model, which provides a benchmark for assessing the additional impact of theoretical variables, and Model 3 is the full model. Table 4 shows the standardized path results of the three models.

The three dependent variables - tracking technology initiation, adoption, and routinization - in the model have an R^2 of 39%, 32%, and 38% respectively, which are considered acceptable. A comparison of Models 2 and 3 shows that the model shows an incremental increase in variance explained of 23% for initiation (F=44.8, p<0.005), 20% for adoption (F=39.8, p<0.01), and 26% for routinization (F=42.1, p<0.01). In contrast, the inclusion of control variables in addition to the independent variables only explains 5% for initiation (39%-34%), 1% for adoption (32%-31%), and 5% for routinization (38%-33%), as shown by a comparison between Models 1 and 3.

Within the supply network context, technology integration has significant and positive paths between adoption (p<0.01) and routinization (p<0.05), but no significance to initiation, thus supporting *H1*. A significant and positive path is also found from collaboration intensity to adoption (p<0.005) and routinization (p<0.01) supporting *H2*. Significant and positive paths are also found from structural complexity to initiation (p<0.1) and adoption (p<0.05), thus supporting *H3*.

Within the product context, significant and negative paths are found from demand uncertainty to initiation (p<0.05) and adoption (p<0.05). The direction of influence is opposite than hypothesized, therefore rejecting *H4*. Handling risk has significant and positive paths to initiation (p<0.05) and adoption (p<0.1), but no significance on routinization. *H5* is thus only partially supported.

Within the environmental context competitive pressure has a strong significant and positive path only to initiation (p<0.005). Thus, *H6* is only partially supported. Customer pressure has strong significant and positive paths to initiation (p<0.005), adoption (p<0.001), and routinization (p<0.01). These results provide strong support for *H7*. Finally, significant and positive paths are found from regulatory environment to initiation (p<0.1) only. Thus, *H8* is only partially supported.

Among the control variables, employee size is positively related to initiation and adoption (p<0.01 and p<0.05, respectively), indicating that larger firms are more likely to assimilate tracking technologies. Similarly, revenue is positively associated with initiation (p<0.05). This finding is not surprising as larger firms are commonly believed to have more slack resources for committing required investments. We also find that supply network scope is positively related to initiation (p<0.05) and adoption (p<0.1) suggesting that firms with global supply network operations are more likely to initiate and adopt tracking technologies than those with more local supply networks. This might be because global supply networks are more complex and often involve more firms, requiring greater supply chain visibility. We did not find any significant effects for product ownership and geographic location at any stage of tracking technology assimilation.

6. Discussion

In an increasingly competitive and global business environment firms are confronted with enormous operational challenges - improving their supply chains, meeting customer needs, and complying with regulatory mandates - all at lower costs. Tracking technologies promise to help overcome these challenges by delivering data with insight into the supply chain, but assimilation levels vary greatly by organizational contexts. Understanding these contexts from the perspective of a broad supply chain system requires an expansion beyond a singularly focused research model.

Most existing studies in innovation adoption and assimilation have used a single theoretical lens. However, there has been an increased call by management scholars to use multiple theoretical frameworks to aid in the exploration of complex and potentially paradoxical phenomena [71, 81]. Given the multi-phase nature of tracking technology assimilation and the broader stakeholder context in which it takes place, a single theoretical lens is not sufficient to capture the systemic issues. Using the complementary perspectives of transaction cost and institutional theory allows for identification of the influence of product, supply network, and environmental characteristics on the global assimilation of tracking technology.

6.1. Research Implications

6.1.1. Supply network context

Within the supply network context, both technology integration and collaboration intensity strongly influenced tracking technology adoption and routinization. Firms with higher levels of technology integration can more easily reap the benefits from tracking technology-centric data as it couples with other systems. For example, geographic specific information (e.g. location, proximity) can be jointly used with inventory levels, demand requirements, and customer preferences. Tracking technologies are unlikely to become an integral part of a firm's value chain activities if information sources are not linked and cannot be fully accessed and leveraged [76, 68]. Similarly, collaboration can facilitate and accelerate adoption and routinization of tracking technology initiatives. This is in line with other approaches such as vendor managed inventory, efficient consumer response, and collaborative planning, forecasting and replenishment, whose success is contingent upon the level of collaboration found within the supply chain.

Structural complexity is the only supply network characteristic that does not have an influence on routinization, but only on initiation and adoption. Structurally complex supply chains are characterized by many suppliers, hand-offs and transfer points. Supply network visibility and control becomes exceedingly difficult in such configurations. Firms initiate tracking technology to gain increased visibility and flow of information, reducing opportunistic behavior and transaction costs. However, increased structural complexity turns into a hurdle when routinizing tracking technology, as it becomes much more difficult to ensure that each supply chain partner embraces the technology. The benefits associated with tracking technology may be outweighed by the costs of routinization.

6.1.2. Product context

Both product characteristics - demand uncertainty and handling risk - play a role during the initiation and adoption stages of tracking technology assimilation. However, contrary to our belief, we found that demand uncertainty had a strongly negative influence on initiation and adoption. One explanation for this may be that while tracking technology primarily eases the flow of information, it does not necessarily reveal previously unavailable information that can assist in forecasting demand. Considering that past research studying demand uncertainty and the development of information accessibility has shown no significant connection between the two [109, 33], one may conjecture that more data does not necessarily help when managing a supply chain of products with uncertain demand.

Rather, the findings indicate that a firm with more easily predictable demand is most likely to initiate and adopt tracking technology. Fisher [40] finds that moving a product that has predictable demand allows for the development of highly efficient supply chains, characterized by reduced inventory levels, decreased stockouts and reduced overall costs. Uncertainty in a supply chain creates a volatile environment that requires a great deal of focus, with the implementation of a new technology left as a secondary task. On the other hand, a supply chain with less uncertainty may allow managers to focus on improving operations through innovative technologies.

At the initiation and adoption stages, handling risk was shown to have an influence on tracking technology assimilation. However, this product characteristic was not sufficient to drive a firm to routinize the technology. Novak and Eppinger [79] show that increased product handling complexity leads to vertical integration and a shift to internal control. Similarly, as complexity in the supply chain increases due to a product's sensitive nature, a firm may be wary to trust external partners to correctly monitor and handle the product, relying more on internal systems. This internal focus can inadvertently limit the extent to which tracking technology may be fully integrated through the entire supply chain. A firm may initiate and adopt tracking technology to protect a high risk product, but routinizing the technology can be difficult without cooperation throughout the supply chain.

6.1.3. Environmental context

It is not necessarily surprising that institutional factors such as competitors and regulators push firms to initiate tracking technology usage. However, it is interesting that only customer pressure has a significant influence on adoption and routinization. Contrary to our hypothesis, competitive pressure and regulatory environment only influence initiation. While firms are initiating tracking technology based on what the competition is doing, the results indicate that they have not seen the technology provide data that is used in such a way as to give their competitors an advantage. In order to pressure a firm to invest the resources in adoption of tracking technology, the results indicate that competitors need to show that the benefits outweigh the risks. Similarly, normative pressures are not sufficient as an industry standard for tracking technology has not been established.

The coercive and normative pressures of the regulatory environment also do not have the influence that might be expected. Firms are considering tracking technology with the knowledge that mandates regarding the use of the technology are on the horizon. However, the results indicate that there appears to be a "wait-and-see" approach, as firms are reticent to make the investment to move beyond initiation until regulations specifically dictate how they must incorporate this technology. Further, the regulatory environment has not yet created a set of norms that allow for a firm to safely invest in tracking technology with the knowledge that supply chain partners are investing in the same technology.

Based on DiMaggio and Powell [32], who found that technical, not institutional, considerations drive early adoption of technology, the seeming lack of norms indicates that tracking technology is still evolving and industry has not determined what the expectations are for its use. Customer pressure is the only factor that has an influence on tracking technology at every stage of assimilation. This is a reflection of the fact that the supply chain industry is very much customer service oriented. The customer drives the supply chain and clearly has an influence on decision making throughout. However, the lack of influence from competitors and regulators at the latter stages is telling. Firms are still making decisions at these stages based on technical considerations, which might reflect a lack of long-term vision for why the technology should be used [51].

6.1.4. Implications for Big Data Management

By providing unparalleled information along the three dimensions of context, reach and periodicity, the fundamental purpose of tracking technology is to generate useful data in the supply chain. The usefulness of this data is dictated by how well it is managed, with the entire life-cycle of big data management proving to influence how supply network, product and environment drive tracking technology assimilation. Routinization of tracking technology is less likely if it is difficult for the data to be efficiently collected, curated, stored and used for analytical purposes. Effective big data management requires strong partnerships and connectedness throughout the supply chain. The three factors in this study that have an influence on routinization of tracking technology are also those that identify supply chain partnerships and connectedness: technology integration, collaboration intensity and customer pressure.

For instance, integration, curation, and quality management of multiple types of sensor data can become a significant challenge. Organizations assimilating tracking technologies must find ways to ensure that different resolutions of physical assets at different time scales and metrics are appropriately mapped. One potential issue for multi-sensor temporal data is to determine whether time stamps are accurate and synced. An integrated data warehouse that stores and provides continuous consistency checks can be valuable in this case. This is reflected in the strong influence of technology integration on routinization.

Similarly, a challenging issue is not just mapping of same-type data, but connecting related data streams. For instance, some data may be needed in streaming form (e.g. location of physical asset, temperature levels) while others may only describe the overall state (e.g. security breach). When multi-faceted data is connected, relationships, associations, and patterns can be identified that could lead to improved performance management, risk resolution, and incident prediction. Again, technology integration is pivotal to unifying this multi-faceted data.

With appropriate data engineering, such as cloud-based infrastructures, tracking data can be made available – either in raw or transformed form – to different stakeholders (e.g. customers, suppliers) and enterprise functions (e.g. human resources, finance, marketing). This, however, raises important ownership and privacy-related data issues. Organizations must thus have appropriate data governance and control policies in place. In an increasingly global business environment, country-level data residency requirements may complicate ways organizations along a supply chain can freely share data. It may also raise issues of who owns the data and where it should be stored. Without a collaborative supply chain or customer influence, it may be difficult to overcome these concerns to effectively manage the big data generated by tracking technology.

6.2. Managerial Implications

The findings of this study have important implications for firms considering or currently pursuing tracking technologies. First, our study indicates that the institutional environment - and in particular customers and competitors - may play a significant role in the initiation of tracking technologies. In an increasingly service-oriented environment, firms are seeking ways to improve their operational effectiveness, provide new value added services to their customers, and differentiate themselves from their competitors. Our study highlights that managers should be aware of the decisions and preferences of institutional stakeholders. This also suggests that managers should potentially move beyond the conventional "wait-and-see" philosophy many firms have for an unproven and potentially immature technology and become more responsive.

While competitors and regulators may influence initiation, they do not have an impact on the routinization of tracking technology. This finding suggests that the industry as a whole still has not determined how to most effectively use tracking technology or the data provided by the technology. Firms are not realizing enough of an advantage with tracking technology to push competitors to adopt or routinize. Further, it appears that regulators have not settled on an industry-wide standard for firms to follow. This may be an indicator that no one technology can offer everything that a supply chain manager needs, with more work to be done in the development of tracking technology itself.

The results also strongly suggest that tracking technology is not a silver bullet and, by itself, cannot connect all the dots in a firm's supply network or provide an explicit interpretation of the data generated by tracking technology. As supply chains grow in complexity, firms must be aware of their supply chain configuration, which includes knowledge about the number and location of supply chain participants, hand-offs and transfer points. At the same time, firms must develop and foster strong collaborative ties with their supply chain partners, since implementation often requires a joint effort. In order to reap the full benefits, managers must shift from legacy thinking and invest in integrated technology infrastructures that tie in traditionally disconnected enterprise information systems. Failure to do so will limit its assimilation.

Lastly, this research has implications for tracking technology vendors and solution providers.

The results suggest that vendors can help firms overcome some of the inertia by providing insight into the business value of the data provided by tracking technology, making them aware of the challenges during the assimilation process, and emphasize the importance of an integrative, collaborative approach to deploying solutions across their supply networks. While some firms may have in-house expertise, vendors can provide implementation support that will facilitate assimilation. On the other hand, the results also inform vendors which product and supply network characteristics matter, thus enabling vendors to provide targeted solutions for each organization type.

6.3. Limitations and Future Research

As is the case with most studies, our study also has some limitations, each of which present fruitful areas for further research. The use of multiple theories to develop a research model can be beneficial, but is also challenging to integrate. While each theory has its own merit, multiple theoretical lenses could provide paradoxical concepts that need to be carefully fused. While we tried to do this, we acknowledge that other theoretical explanations may fill unintended gaps. For example, based on our interpretation, neither theory predicts that demand uncertainty is negatively correlated to tracking technology adoption. Our results, however, show that this is the case. Future research should consider alternative theories on market behavior and economics that may shed more insight. Further, a potential limitation of our analytical approach is the possibility of hierarchical relationships between our theorized factors. While we made every attempt to validate our constructs and used well-established analyses techniques, alternate statistical approaches may provide additional complementary insights.

Our study also examines assimilation of tracking technology as a group of technologies. While the assumption that firms adopt more than one type of tracking technology is arguably appropriate, it can be argued that not all tracking technologies are equal. Some may be considered more important than others given organizational needs. Firms may also adopt tracking technologies in a particular order. Future research might therefore explore if there is a particular sequence or precedence in which tracking technologies are adopted. Similarly, while we ensured that our respondents are experienced and qualified to answer tracking technology assimilation questions for their respective firms, we are cognizant that recollection bias may have occurred. For instance, firms cannot be at all stages at once, so some level of recollection of the assimilation process was required. To overcome this issue our survey used a 5-point Likert scale, instead of 7-point scale where applicable [102]. However, the problem of decreasing capacity of recollection may still exist.

Also, the context of this study is an understanding of global assimilation of tracking technology. While we find support that a favorable regulatory environment positively influences assimilation globally, regulatory and legal systems can differ significantly between developed and emerging countries. Developed countries such as the United States and most European Union countries have more comprehensive regulations and stronger law enforcement in privacy protection, information sharing, and contract enforcement than emerging economies such as Brazil, Russia, India and China. An important future research direction would therefore be an understanding of comparison of favorable regulatory environment characteristics and their influence on assimilation.

The brief discussion of big data management above also highlights that as tracking technologies become more assimilated in a supply chain, the need for effective and potentially novel big data strategies are needed. Each of the issues raised present exciting opportunities for future research.

7. Concluding Remarks

This study examines the global assimilation of tracking technology. Using a multi-method research approach, a theoretical model of tracking technology assimilation is developed and empirically tested. Three contexts - product, supply network, and environment - are found to significantly influence, to a differing extent, each of the three phases of assimilation. In doing so, we advance our theoretical understanding of IT innovation management, in general, and tracking technology, in particular. This study provides important managerial insights into the effective management of tracking technology in an increasingly global and complex business environment. We hope that our work will fuel further research at the intersection of IT and operations management.

References

[1] G. D. Abowd, A. K. Dey, P. J. Brown, N. Davies, M. Smith, and P. Steggles. Towards a better understanding of context and context-awareness. In *Handheld and Ubiquitous Computing*, pages 304–307. Springer, 1999.

[2] T. J. Allen, J. M. Utterback, M. A. Sirbu, N. A. Ashford, and J. H. Hollomon. Government influence on the process of innovation in Europe and Japan. *Research Policy*, 7(2):124 – 149, 1978.

[3] K.V. Andersen, N.C. Juul, H.Z. Henriksen, N. Bjorn-Andersen, and D. Bunker. *Business-to-Business e-Commerce, Enterprises Facing a Turbulent World*. DJOF Publishers, 2000.

[4] M. Attaran. RFID: An enabler of supply chain operations. *Supply Chain Management: An International Journal*, 12(4):249–257, 2007.

[5] B. Axelsson and E. Easton. *Industrial Networks: A New View of Reality.* London: Routledge, Chapman & Hall, 1992.

[6] R. P. Bagozzi and C. Fornell. *A second generation of multivariate analysis*, chapter Theoretical concepts, measurements, and meaning, pages 24–38. Praeger, New York, 1982.

[7] D. Bansal, S. Malla, K. Gudala, and P. Tiwari. Anti-counterfeit technologies: A pharmaceutical industry perspective. *Scientia Pharmaceutica*, 81(1):1, 2013.

[8] R. C. Basole and W. B. Rouse. Complexity of service value networks: Conceptualization and empirical investigation. *IBM Systems Journal*, 47(1):53–70, 2008.

[9] M. A. Bellamy and R. C. Basole. Network analysis of supply chain systems: A systematic review and future research. *Systems Engineering*, 16(2):235–249, 2013.

[10] M. Bensaou and E. Anderson. Buyer-supplier relations in industrial markets: When do buyers risk making idiosyncratic investments? *Organization Science*, 10(4):460–481, 1999.

[11] M. Bensaou and N. Venkatraman. Configurations of interorganizational relationships: A comparison between U.S. and Japanese automakers. *Management Science*, 41(9):1471–1492, 1995.

[12] K D Brouthers. Institutional, cultural and transaction cost influences on entry mode choice and performance. *Journal of International Business Studies*, 44(1):1–13, 2013.

[13] P. J. Brown, J. D. Bovey, and X. Chen. Context-aware applications: from the laboratory to the marketplace. *Personal Communications, IEEE*, 4(5):58–64, 1997.

[14] K. Butner. The smarter supply chain of the future. *Strategy & Leadership*, 38(1):22–31, 2010.

[15] G.P. Cachon and M.L. Fisher. Supply chain inventory management and the value of shared information. *Management Science*, 46(8):1032–1048, 2000.

[16] M. Cao and Q. Zhang. Supply chain collaboration: Impact on collaborative advantage and firm performance. *Journal of Operations Management*, 29(3):163–180, 2011.

[17] D. Chatterjee, R. Grewal, and V. Sambamurthy. Shaping up for E-commerce: Institutional enablers of the organizational assimilation of web technologies. *MIS Quarterly*, 26(2):65–89, 2002.

[18] P.Y.K. Chau and K.Y. Tam. Factors affecting the adoption of open systems: An exploratory study. *MIS Quarterly*, 21(1):1–25, 1997.

[19] H. Chen, R. H. L. Chiang, and V. C. Storey. Business intelligence and analytics: From big data to big impact. *MIS Quarterly*, 36(4):1165–1188, 2012.

[20] W.W. Chin. *Modern Methods for Business Research*, chapter The partial least squares approach to structural equation modeling, pages 295–336. Lawrence Erlbaum Associates, Mahwah, NJ, 1998.

[21] T. Y. Choi and Y. Hong. Unveiling the structure of supply networks: Case studies in Honda, Acura, and Daimler Chrysler. *Journal of Operations Management*, 20(5):469–493, 2002.

[22] T. Y. Choi and D. R. Krause. The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. *Journal of Operations Management*, 24(5):637 – 652, 2006.

[23] T. Y. Choi, K. J. Dooley, and M. Rungtusanatham. Supply networks and complex adaptive systems: Control versus emergence. *Journal of Operations Management*, 19(3):351–366, 2001.

[24] M. Christopher and H. Lee. Mitigating supply chain risk through improved confidence. *International Journal of Physical Distribution & Logistics Management*, 34(5):388–396, 2004.

[25] P. Chwelos, I. Benbasat, and A. S. Dexter. Research report: Empirical test of an EDI adoption model. *Information Systems Research*, 12(3):304–321, 2001.

[26] J. Dedrick, S. X. Xu, and K. Zhu. How does information technology shape supply-chain structure? Evidence on the number of suppliers. *Journal of Management Information Systems*, 25(2):41–72, 2008.

[27] D. Delen, B. C. Hardgrave, and R. Sharda. RFID for better supply chain management through enhanced information visibility. *Production and Operations Management*, 16(5):612–624, 2007.

[28] M. Delmas and I. Montiel. Greening the supply chain: When is customer pressure effective? *Journal of Economics and Management Strategy*, 18(1):171–201, 2009.

[29] A. Diamantopoulos. The error term in formative measurement models: Interpretations and modelling implications. *Journal of Modelling in Management*, 1(1):7–17, 2006.

[30] A. Diamantopoulos and J. A. Siguaw. Formative versus reflective indicators in organizational measure development: A comparison and empirical illustration. *British Journal of Management*, 17(4):263–282, 2006.

[31] A. Diamantopoulos and H. M. Winklhofer. Index construction with formative indicators: An alternative to scale development. *Journal of Marketing Research*, 38(2):269–277, 2001.

[32] P. J. DiMaggio and W. W. Powell. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48(2):147–160, 1983.

[33] Y. Dong, K. Xu, and M. Dresner. Environmental determinants of VMI adoption: An exploratory analysis. *Transportation Research Part E: Logistics and Transportation Review*, 43(4):355–369, 2007.

[34] D.H. Doty and W.H. Glick. Common methods bias: Does common methods variance really bias results? *Organizational Research Methods*, 1(4):374–406, 1998.

[35] Y. L. Doz and G. Hamel. *Alliance Advantage: the Art of Creating Value Through Partnering.* Boston: Harvard Business School Press, 1998.

[36] J. Dyer. Effective interfirm collaboration: How firms minimize transaction costs and maximize transaction value. *Strategic Management Journal*, 18(7):535–556, 1997.

[37] R. G. Fichman and C. F. Kemerer. The assimilation of software process innovations: An organizational learning perspective. *Management Science*, 43(1):1345–1363, 1997.

[38] R. G. Fichman and C. F. Kemerer. The illusory diffusion of innovation: An examination of assimilation gaps. *Information Systems Research*, 10(3):255–275, 1999.

[39] R.G. Fichman. The role of aggregation in the measurement of IT-related organizational innovation. *MIS Quarterly*, 25(4):427–455, 2001.

[40] M. Fisher. What is the right supply chain for your product? *Harvard Business Review*, March-April: 105–116, 1997.

[41] C. Fornell and D. F. Larcker. Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18(1):39–50, 1981.

[42] M. T. Frohlich and R. Westbrook. Arcs of integration: An international study of supply chain strategies. *Journal of Operations Management*, 19(2):185–200, 2001.

[43] M. J. Gallivan. Organizational adoption and assimilation of complex technological innovations: Development and application of a new framework. *ACM Sigmis Database*, 32(3):51–85, 2001.

[44] H. Gatignon and T.S. Robertson. Technology diffusion: An empirical test of competitive effects. *Journal of Marketing*, 53(1):35–49, 1989.

[45] S.R. Gavirneni, R. Kapuschinski, and S. Tayur. Value of information in capacitated supply chains. *Management Science*, 45(1):16–24, 1999.

[46] E. Golan, B. Krissoff, F. Kuchler, L. Calvin, K. Nelson, and G. Price. Traceability in the U.S. food supply: Economic theory and industry studies. Technical report, Economic Research Service, U.S. Department of Agriculture, 2004. Agricultural Economic Report No. 830.

[47] J. F. Hair, R. E. Anderson, R. L. Tatham, and W. C. Black. *Multivariate Data Analysis with Readings.* Prentice Hall, Englewood Cliffs, NJ, 5th edition, 1998.

[48] H.H. Harman. *Modern Factor Analysis.* The University of Chicago Press, Chicago, IL, 1967.

[49] P. Hart and C. Saunders. Power and trust: Critical factors in the adoption and use of electronic data interchange. *Organization Science*, 8(1):23–42, 1997.

[50] H. Z. Henriksen and J. Damsgaard. Dawn of e-government–an institutional analysis of seven initiatives and their impact. *Journal of Information Technology*, 22(1):13–23, 2007.

[51] C. W. Hill. Cooperation, opportunism, and the invisible hand: Implications for transaction cost theory. *Academy of Management Review*, 15(3):500–513, 1990.

[52] Homeland Security Act of 2002. 107th Congress, 2002. Public Law 107–296.

[53] C. Hsu, J.-N. Lee, and D. W. Straub. Institutional influences on information systems security innovations. *Information Systems Research*, 23(3-Part-2):918–939, 2012.

[54] C. L. Iacovou, I. Benbasat, and A. S. Dexter. Electronic data interchange and small organizations: Adoption and impact of technology. *MIS Quarterly*, pages 465–485, 1995.

[55] J. Jiao, T. W. Simpson, and Z. Siddique. Product family design and platform-based product development: A state-of-the-art review. *Journal of Intelligent Manufacturing*, 18(1):5–29, 2007.

[56] M. E. Johnson. *Logistics Engineering Handbook*, chapter Ubiquitous communication: Tracking technologies within the supply chain. CRC Press, Boca Raton, 2008.

[57] E. Karahanna, D. W. Straub, and N. L. Chervany. Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly*, 23(2):183–213, 1999.

[58] A. Kaufman, C. H. Wood, and G. Theyel. Collaboration and technology linkages: A strategic supplier typology. *Strategic Management Journal*, 21(6):649–663, 2000.

[59] W. Ke, H. Liu, K. K. Wei, J. Gu, and H. Chen. How do mediated and non-mediated power affect electronic supply chain management system adoption? The mediating effects of trust and institutional pressures. *Decision Support Systems*, 46(4):839–851, 2009.

[60] M. Khalifa and R.M. Davison. SME adoption of IT: The case of electronic trading systems. *IEEE Transactions on Engineering Management*, 53(2):275–284, 2006.

[61] J. L. King, V. Gurbaxani, K. L. Kraemer, F. W. McFarlan, K. S. Raman, and C.-S. Yap. Institutional factors in information technology innovation. *Information Systems Research*, 5(2):139–169, 1994.

[62] R. Klein, A. Rai, and D. W. Straub. Competitive and cooperative positioning in supply chain logistics relationships. *Decision Sciences*, 38(4):611–646, 2007.

[63] K. Lai, C. W. Y. Wong, and T. C. Cheng. Institutional isomorphism and the adoption of information technology for supply chain management. *Computers in Industry*, 57(1):93–98, 2006.

[64] P. Lavin. AEB tracks the evolution of online tracking, 2013. www.supplychaindigital.com, November 13.

[65] H. Leblebici, G. R. Salancik, A. Copay, and T. King. Institutional change and the transformation of interorganizational fields: An organizational history of the US radio broadcasting industry. *Administrative Science Quarterly*, 36(3):333–363, 1991.

[66] G. Lee and W. Xia. Organizational size and IT innovation adoption: A meta-analysis. *Information & Management*, 43(8):975–985, 2006.

[67] H. Lee and Ö. Özer. Unlocking the value of RFID. *Production and Operations Management*, 16(1): 40–67, 2007.

[68] H. Lee, A. Farhoomand, and P. Ho. Innovation through supply chain reconfiguration. *MIS Quarterly Executive*, 3(3):131–142, 2004.

[69] H. L. Lee, V. Padmanabhan, and S. Whang. Information distortion in a supply chain: The bullwhip effect. *Management Science*, 43(4):546–558, 1997.

[70] D. R. Levinson. Traceability in the food supply chain. Technical report, Department of Health & Human Services, Office of Inspector General, 2009. OEI-02-06-00210.

[71] M. W. Lewis and A. I. Grimes. Metatriangulation: Building theory from multiple paradigms. *Academy of Management Review*, 24(4):672–690, 1999.

[72] J. Li, R. Sikora, M. J. Shaw, and G. Woo Tan. A strategic analysis of inter organizational information sharing. *Decision Support Systems*, 42(1):251–266, 2006.

[73] H. Liu, W. Ke, K. K. Wei, J. Gu, and H. Chen. The role of institutional pressures and organizational culture in the firm's intention to adopt internet-enabled supply chain management systems. *Journal of Operations Management*, 28(5):372 – 384, 2010.

[74] J.-B. Lohmöller. *Latent variable path modeling with partial least squares*. Springer Science & Business Media, 2013.

[75] A. Malhotra, S. Gosain, and O. A. E. Sawy. Absorptive capacity configurations in supply chains: gearing for partner-enabled market knowledge creation. *MIS Quarterly*, 29(1):145–187, 2005.

[76] F. Mata, W. Fuerst, and J. Barney. Information technology and sustained competitive advantage: A resource-based analysis. *MIS Quarterly*, 19(4):487–505, 1995.

[77] J. W. Meyer and B. Rowan. Institutionalized organizations: Formal structure as myth and ceremony. *American Journal of Sociology*, pages 340–363, 1977.

[78] Ahmed Musa, Angappa Gunasekaran, and Yahaya Yusuf. Supply chain product visibility: Methods, systems and impacts. *Expert Systems with Applications*, 41(1):176–194, 2014.

[79] Sharon Novak and Steven D. Eppinger. Sourcing by design: Product complexity and the supply chain. *Management Science*, 47(1):189–204, 2001.

[80] J.C. Nunnally. *Psychometric Theory*. McGraw-Hill, New York, 1978.

[81] Gerardo Okhuysen and Jean-Philippe Bonardi. The challenges of building theory by combining lenses. *Academy of Management Review*, 36(1):6–11, 2011.

[82] C. Oliver. The influence of institutional and task environment relationships on organizational performance: The Canadian construction industry. *Journal of Management Studies*, 34(1):99–124, 1997.

[83] P. Papastathopoulou, G. J. Avlonitis, and N. G. Panagopoulos. Intraorganizational information and communication technology diffusion: Implications for industrial sellers and buyers. *Industrial Marketing Management*, 36(3):322–336, 2007.

[84] S. Petter, D. Straub, and A. Rai. Specifying formative constructs in information systems research. *MIS Quarterly*, 31(4):623–656, 2007.

[85] M. E. Porter. *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press, 1985.

[86] W. W. Powell and P. J. DiMaggio. *The new institutionalism in organizational analysis*. University of Chicago Press, 1991.

[87] A. Rai and R. Patnyakuni. A structural model for CASE adoption behavior. *Journal of Management Information Systems*, 13(2):205–234, 1996.

[88] A. Rai, P. Brown, and X. Tang. Organizational assimilation of electronic procurement innovations. *Journal of Management Information Systems*, 26(1):257–296, 2009.

[89] C. M. Ringle, S. Wende, and A. Will. SmartPLS 2.0 (M3) beta, 2005.

[90] P W Roberts and R Greenwood. Integrating transaction cost and institutional theories: Toward a constrained-efficiency framework for understanding organizational design adoption. *Academy of Management Review*, 22(2):346–373, 1997.

[91] E. M. Rogers. *Diffusion of Innovations*. The Free Press, New York, 6th edition, 2010.

[92] A. Rushton, J. Oxley, and P. Croucher. *The Handbook of Logistics and Distribution Management*. Kogan Page, London, 2nd edition, 2000.

[93] P. R. Schulman. General attributes of safe organisations. *Quality and Safety in Health Care*, 13(suppl 2):ii39–ii44, 2004.

[94] W R Scott. *Institutions and organizations*. Thousand Oaks, 1995.

[95] V. Sethi and W.R. King. Development of measures to assess the extent to which an information technology application provides competitive advantage. *Management Science*, 40(12):1601–1627, 1994.

[96] T. M. Simatupang and R. Sridharan. The collaboration index: A measure for supply chain collaboration. *International Journal of Physical Distribution and Logistics Management*, 35(1):44–62, 2005.

[97] J.-Y. Son and I. Benbasat. Organizational buyers' adoption and use of B2B electronic marketplaces: Efficiency-and legitimacy-oriented perspectives. *Journal of Management Information Systems*, 24(1): 55–99, 2007.

[98] C. Speier, J. M. Whipple, D. J. Closs, and M. D. Voss. Global supply chain design considerations: Mitigating product safety and security risks. *Journal of Operations Management*, 29(7):721–736, 2011.

[99] G. C. Stevens. Integrating the supply chain. *International Journal of Physical Distribution & Logistics Management*, 19(8):3–8, 1989.

[100] D. Straub. Validating instruments in MIS research. *MIS Quarterly*, 13(2):147–169, 1989.

[101] M. Subramani. How do suppliers benefit from information technology use in supply chain relationships. *MIS Quarterly*, 28(1):45–73, 2004.

[102] Seymour Sudman and Norman M Bradburn. Effects of time and memory factors on response in surveys. *Journal of the American Statistical Association*, 68(344):805–815, 1973.

[103] W. L. Tate, K J Dooley, and L M Ellram. Transaction cost and institutional drivers of supplier adoption of environmental practices. *Journal of Business Logistics*, 32(1):6–16, 2011.

[104] H. H. Teo, K. K. Wei, and I. Benbasat. Predicting intention to adopt interorganizational linkages: An institutional perspective. *MIS Quarterly*, 27(1):19–49, 2003.

[105] U.S. Food and Drug Administration. FDA clears first blood tracking device that uses radio frequency identification technology, 2013. May 28.

[106] A. Vance, C. Elie-Dit-Cosaque, and D. Straub. Examining trust in information technology artifacts: The effects of system quality and culture on trust. *Journal of Management Information Systems*, 24 (4):73–100, 2008.

[107] N. Venkatraman. Strategic orientation of business enterprises: The construct, dimensionality, and measurement. *Management Science*, 35(8):942–962, 1989.

[108] N. Venkatraman and J. H. Grant. Construct measurement in organizational strategy research: A critique and proposal. *Academy of Management Review*, 11(1):71–87, 1986.

[109] G. Walker and D. Weber. Supplier competition, uncertainty, and make-or-buy decisions. *Academy of Management Journal*, 30(3):589–596, 1987.

[110] O. E. Williamson. The economics of organization: The transaction cost approach. *American Journal of Sociology*, 87(3):548–577, 1981.

[111] O. E. Williamson. Outsourcing: Transaction cost economics and supply chain management. *Journal of Supply Chain Management*, 44(2):5–16, 2008.

[112] M. Winkenbach. Remapping the last mile of the urban supply chain. *MIT Sloan Management Review*, April 27, 2016.

[113] S. G Winter. On coase, competence, and the corporation. *Journal of Law, Economics & Organization*, 4:163–180, 1988.

[114] H. Wold. Soft modelling: The basic design and some extensions. *Systems under indirect observation, Part II*, pages 36–37, 1982.

[115] K. Zhu, K. L. Kraemer, and S. Xu. Process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business. *Management Science*, 52(10):1557–1576, 2006.

APPENDIX A: LITERATURE REVIEW

	Theoretical Perspective																**Stage**			
Reference	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	I	A	R	TT Type
Hamilton (1993)	•																	•		Satellite
Patterson et al. (2003)	•											•						•		Barcode, GPS, Cellular
Rishel et al. (2003)	•																	•		Satellite
Golob and Regan (2005)	•																•	•		Wireless
Eng (2006)	•																	•		Mobile/Wireless
Matta and Moberg (2006)	•																	•		Barcode, RFID
Vijayaraman and Osyk (2006)	•																•			RFID
Bendoly et al. (2007)					•			•									•	•		RFID
Brown and Russell (2007)	•											•					•	•		RFID
Curtin et al. (2007)	•						•										•	•	•	RFID
Huyskens and Loebbecke (2007)	•										•							•		RFID
Schmitt et al. (2007)	•																	•		RFID
Whitaker et al. (2007)										•			•					•		RFID
Chang et al. (2008)	•											•					•	•		RFID
Doolin and Al Haj Ali (2008)												•						•		Mobile/Wireless
Shih et al. (2008)	•																	•		RFID
Chao and Lin (2009)											•						•			Barcode, RFID
Leimeister et al. (2009)	•																•			RFID
Roh et al. (2009)													•					•		RFID
Wen et al. (2009)																		•		RFID
Bhattacharya et al. (2010)	•																•	•		RFID
Kim and Garrison (2010)	•																•	•	•	RFID
Strüker and Gille (2010)									•									•	•	RFID
Tsai et al. (2010)	•																•			RFID
Wang et al. (2010)												•						•		RFID
Whang (2010)		•																•		RFID
Cheng and Yeh (2011)											•						•	•		RFID
Hossain and Quaddus (2011)	•		•									•	•					•	•	RFID
Thiesse et al. (2011)	•											•						•		RFID
Wu and Subramanian (2011)	•											•						•		RFID
Quetti et al. (2012)	•						•											•		RFID
Tsai et al. (2012)																		•		RFID
Pan et al. (2013)	•					•								•			•			Mobile/Wireless
Ramanathan et al. (2013)											•							•		RFID
Tsai et al. (2013)	•					•											•			RFID
Hossain and Quaddus (2015)	•		•								•	•						•		RFID
Fosso Wamba et al. (2016)	•																	•		RFID
Reyes et al. (2016)																•	•	•		RFID
This Study	•					•									•		•	•	•	All Types

Key: [1] Diffusion of innovation theory, [2] Economic game theory, [3] Expectation confirmation theory, [4] High-reliability theory, [5] Information processing theory, [6] Institutional theory, [7] Network externality theory, [8] Organizational absorptive capacity, [9] Organizational inertia theory, [10] Resource-based view, [11] Technology acceptance & UTAUT model, [12] Technology-organization-environment model, [13] Theory of expected benefits, [14] Theory of organizational learning, [15] Transaction cost economics, [16] None, (I) Initiation, (A) Adoption, (R) Routinization

References

[1] E. Bendoly, A. Citurs, and B. Konsynski. Internal infrastructural impacts on RFID perceptions and commitment: Knowledge, operational procedures, and information-processing standards. *Decision Sciences*, 38(3):423–449, 2007.

[2] M. Bhattacharya, C.-H. Chu, J. Hayya, and T. Mullen. An exploratory study of RFID adoption in the retail sector. *Operations Management Research*, 3(1-2):80–89, 2010.

[3] I. Brown and J. Russell. Radio frequency identification technology: An exploratory study on adoption in the south african retail sector. *International Journal of Information Management*, 27(4):250–265, 2007.

[4] S.-I. Chang, S.-Y. Hung, D. C. Yen, and Y.-J. Chen. The determinants of RFID adoption in the logistics industry- A supply chain management perspective. *Communications of the Association for Information Systems*, 23(1):12, 2008.

[5] Y.-H. Cheng and Y.-J. Yeh. Exploring radio frequency identification technology's application in international distribution centers and adoption rate forecasting. *Technological Forecasting and Social Change*, 78(4):661–673, 2011.

[6] J. Curtin, R. J. Kauffman, and F. J. Riggins. Making the 'MOST' out of RFID technology: A research agenda for the study of the adoption, usage and impact of RFID. *Information Technology and Management*, 8(2):87–110, 2007.

[7] B. Doolin and E. Al Haj Ali. Adoption of mobile technology in the supply chain: An exploratory cross-case analysis. *International Journal of E-Business Research*, 4(4):1–15, 2008.

[8] T.-Y. Eng. Mobile supply chain management: Challenges for implementation. *Technovation*, 26(5): 682–686, 2006.

[9] S. Fosso Wamba, A. Gunasekaran, M. Bhattacharya, and R. Dubey. Determinants of RFID adoption intention by SMEs: An empirical investigation. *Production Planning & Control*, pages 1–12, 2016.

[10] T. F. Golob and A. C. Regan. Trucking industry preferences for traveler information for drivers using wireless internet-enabled devices. *Transportation Research Part C: Emerging Technologies*, 13(3):235–250, 2005.

[11] J. W. Hamilton. Wireless communication systems: A satellite-based communications approach for competitive advantage in logistic and transportation support services. *Computers in Industry*, 21(3): 273–278, 1993.

[12] M. A. Hossain and M. Quaddus. The adoption and continued usage intention of RFID: An integrated framework. *Information Technology & People*, 24(3):236–256, 2011.

[13] M. A. Hossain and M. Quaddus. Radio frequency identification (RFID) adoption: A cross-sectional comparison of voluntary and mandatory contexts. *Information Systems Frontiers*, 17(5):1057–1076, 2015.

[14] C. Huyskens and C. Loebbecke. *RFID Adoption*, pages 345–361. Springer, 2007.

[15] S. Kim and G. Garrison. Understanding users' behaviors regarding supply chain technology: Determinants impacting the adoption and implementation of RFID technology in south korea. *International Journal of Information Management*, 30(5):388–398, 2010.

[16] S. Leimeister, J. M. Leimeister, U. Knebel, and H. Krcmar. A cross-national comparison of perceived strategic importance of RFID for CIOs in Germany and Italy. *International Journal of Information Management*, 29(1):37–47, 2009.

[17] V. Matta and C. Moberg. The development of a research agenda for RFID adoption and effectiveness in supply chains. *Issues in Information Systems*, 7(2):246–251, 2006.

[18] Y. Pan, T. Nam, S. Ogara, and S. Lee. Adoption model of mobile-enabled systems in supply chain. *Industrial Management & Data Systems*, 113(2):171–189, 2013.

[19] K. A. Patterson, C. M. Grimm, and T. M. Corsi. Adopting new technologies for supply chain management. *Transportation Research Part E: Logistics and Transportation Review*, 39(2):95–121, 2003.

[20] C. Quetti, F. Pigni, and A. Clerici. Factors affecting RFID adoption in a vertical supply chain: The case of the silk industry in italy. *Production Planning & Control*, 23(4):315–331, 2012.

[21] R. Ramanathan, U. Ramanathan, and L. W. Ko. Adoption of RFID technologies in UK logistics: Moderating roles of size, barcode experience and government support. *Expert Systems with Applications*, 2013.

[22] P. M. Reyes, S. Li, and J. K. Visich. Determinants of RFID adoption stage and perceived benefits. *European Journal of Operational Research*, 254(3):801–812, 2016.

[23] T. D. Rishel, J. P. Scott, and A. J. Stenger. A preliminary look at using satellite communication for collaboration in the supply chain. *Transportation Journal*, pages 17–30, 2003.

[24] J. J. Roh, A. Kunnathur, and M. Tarafdar. Classification of RFID adoption: An expected benefits approach. *Information & Management*, 46(6):357–363, 2009.

[25] P. Schmitt, F. Thiesse, and F. Elgar. Adoption and diffusion of RFID technology in the automotive industry. *Communications of the ACM*, 48(8):100–106, 2007.

[26] J. Struker and D. Gille. RFID adoption and the role of organisational size. *Business Process Management Journal*, 16(6):972–990, 2010.

[27] F. Thiesse, T. Staake, P. Schmitt, and E. Fleisch. The rise of the "next-generation bar code": An international RFID adoption study. *Supply Chain Management: An International Journal*, 16(5):328–345, 2011.

[28] M.-C. Tsai, W. Lee, and H.-C. Wu. Determinants of RFID adoption intention: Evidence from Taiwanese retail chains. *Information & Management*, 47(5):255–261, 2010.

[29] M.-C. Tsai, K.-H. Lai, and W.-C. Hsu. A study of the institutional forces influencing the adoption intention of RFID by suppliers. *Information & Management*, 50(1):59–65, 2013.

[30] W.-C. Tsai and L.-L. Tang. A model of the adoption of radio frequency identification technology: The case of logistics service firms. *Journal of Engineering and Technology Management*, 29(1):131–151, 2012.

[31] B. S. Vijayaraman and B. A. Osyk. An empirical study of RFID implementation in the warehousing industry. *International Journal of Logistics Management*, 17(1):6–20, 2006.

[32] Y.-M. Wang, Y.-S. Wang, and Y.-F. Yang. Understanding the determinants of RFID adoption in the manufacturing industry. *Technological Forecasting and Social Change*, 77(5):803–815, 2010.

[33] L. Wen, S. Zailani, and Y. Fernando. Determinants of RFID adoption in supply chain among manufacturing companies in china: A discriminant analysis. *Journal of Technology Management & Innovation*, 4(1):22–32, 2009.

[34] S. Whang. Timing of RFID adoption in a supply chain. *Management Science*, 56(2):343–355, 2010.

[35] J. Whitaker, S. Mithas, and M. S. Krishnan. A field study of RFID deployment and return expectations. *Production and Operations Management*, 16(5):599–612, 2007.

[36] X. Wu and C. Subramaniam. Understanding and predicting radio frequency identification (RFID) adoption in supply chains. *Journal of Organizational Computing and Electronic Commerce*, 21(4): 348–367, 2011.

APPENDIX B: SURVEY INSTRUMENT

Tracking Technology Initiation. Please indicate how significant each of the following potential benefits of tracking technology was rated when your business unit was considering it for business activities.

	Not Significant – Very Significant				
1. To improve operational efficiency	1	2	3	4	5
2. To prevent product loss	1	2	3	4	5
3. To meet regulatory compliance	1	2	3	4	5
4. To reduce costs	1	2	3	4	5
5. To gain productivity	1	2	3	4	5
6. To improve coordination with customers and suppliers	1	2	3	4	5
7. To increase visibility into the supply network	1	2	3	4	5
8. To improve the level of customer service	1	2	3	4	5

Tracking Technology Adoption. Check box if tracking technology is used to any extent in the following value chain activities:

Inbound Logistics
- ☐ Monitoring inbound shipments
- ☐ Exchanging information with suppliers

Customer Service
- ☐ Tracking product movement in warehouse
- ☐ Positioning inventory

Sourcing and Procurement
- ☐ Making ordering decisions
- ☐ Evaluating supplier performance

Inbound Logistics
- ☐ Monitoring outbound shipments
- ☐ Exchanging information with customers

Customer Service
- ☐ Processing claims
- ☐ Supporting product returns

Fleet Management
- ☐ Monitoring fleet location and status
- ☐ Monitoring driver performance
- ☐ Planning fleet repair or replacement

Sales and Marketing
- ☐ Providing value-added services
- ☐ Forecasting demand

Tracking Technology Routinization. If your business unit has used tracking technology, please rate the extent to which...

	Not Significant – Very Significant				
1. Inbound shipments are tracked by your business unit	1	2	3	4	5
2. Outbound shipments are tracked by your business unit	1	2	3	4	5
3. TT is used by your upstream suppliers	1	2	3	4	5
4. TT is used by your downstream customers	1	2	3	4	5
5. TT is used for sourcing and procurement planning	1	2	3	4	5
6. TT is used for demand forecasting	1	2	3	4	5
7. TT is used for fleet management	1	2	3	4	5

Handling Risk. Please indicate the extent to which you agree with the following statements:

Product in your supply network	Strongly Disagree – Strongly Agree				
1. are fragile	1	2	3	4	5
2. require specialized handling	1	2	3	4	5
3. are perishable	1	2	3	4	5
4. include hazardous materials	1	2	3	4	5
5. need a climate controlled environment	1	2	3	4	5

Demand Uncertainy. Please indicate the extent to which you agree with the following statements:

Demand for products in your supply network	Strongly Disagree – Strongly Agree				
1. is difficult to predict	1	2	3	4	5
2. shows significant variability	1	2	3	4	5
3. cannot be accurately forecast	1	2	3	4	5

Supply Network Complexity.

1. The number of upstream suppliers your business unit interacts with is approximately: ______
2. The number of downstream customers your business unit interacts with is approximately: ______
3. The number of transfer points (e.g. handoffs) in your supply network is approximately: ______

Collaboration Intensity. Please rate the extent to which ...

	Not at all – To a great extent				
1. your logistics provider(s) manage your supply network	1	2	3	4	5
2. you share relevant information with your logistics provider(s).	1	2	3	4	5
3. your logistics provider(s) shares relevant information with you.	1	2	3	4	5
4. you share relevant information with your upstream suppliers and downstream customers.	1	2	3	4	5
5. your upstream suppliers and downstream customers share relevant information with you.	1	2	3	4	5
6. your decisions are synchronized with your logistics service provider(s).	1	2	3	4	5
7. your decisions are synchronized with your upstream suppliers and downstream customers.	1	2	3	4	5
8. you share relevant goals with your logistics provider(s).	1	2	3	4	5
9. you share relevant goals with your upstream suppliers and downstream customers.	1	2	3	4	5

Technology Integration. Please indicate the extent to which you agree with the following statements:

	Strongly Disagree – Strongly Agree				
1. Internal databases and information systems are electronically integrated with the Internet.	1	2	3	4	5
2. Functional business areas are electronically integrated with internal DBs and IS.	1	2	3	4	5
3. Internal databases and information systems are electronically integrated with suppliers.	1	2	3	4	5
4. Internal databases and information systems are electronically integrated with customers.	1	2	3	4	5

Competitive Pressure. Please rate the extent to which ...

	Strongly Disagree – Strongly Agree				
1. Competitors that have adopted tracking technologies (TT) benefited greatly.	1	2	3	4	5
2. Competitors that have adopted TT are perceived favorably by their suppliers and customers.	1	2	3	4	5
3. Competitors that have adopted TT are perceived favorably by others in your industry.	1	2	3	4	5
4. Competitors that have adopted TT are more successful.	1	2	3	4	5
5. It is a strategic necessity to adopt TT to compete in the marketplace	1	2	3	4	5
6. There is a constant threat of losing competitive advantage if TT are not adopted.	1	2	3	4	5

Customer Pressure. Please rate the extent to which ...

	Strongly Disagree – Strongly Agree				
1. Customers that matter to you believe that you should use tracking technologies.	1	2	3	4	5
2. Customers that matter to you encourage you to use tracking technologies.	1	2	3	4	5
3. Customers that matter to you require you to use tracking technologies.	1	2	3	4	5
4. You may not retain customers that matter to you without tracking technologies.	1	2	3	4	5
5. Customers that matter to you will switch to your competitors if you do not use tracking technologies.	1	2	3	4	5

Regulatory Environment. Please rate the extent to which ...

	Strongly Disagree – Strongly Agree				
1. The use of tracking technology is driven by incentives provided by the government.	1	2	3	4	5
2. The use of tracking technology is required by governmental legislation.	1	2	3	4	5
3. Business laws support asset and product tracking.	1	2	3	4	5
4. There is adequate legal protection for tracking technology use.	1	2	3	4	5
5. The use of tracking technologies is promoted by government policies.	1	2	3	4	5

Table 1: Sample characteristics

Category	Detail	%	Category	Detail	%	Category	Detail	%
Country	U.S.	79.3	Employee Size	<100	40.6	Industry	Transportation	36.6
	Non-U.S.	20.7		100-499	21.9		Manufacturing	9.9
				500-999	9		Food & Beverage	6.9
Supply Network Scale	Global	56.6		1000-4,999	13.6		Warehousing	6.4
	National	29		5,000-10,000	5.8		Wholesale/Distribution	5.8
	Regional	9		>10,000	9.2		Healthcare	3.9
	Local	3.9					Services	3
			Respondent Title	CEO/CIO/CTO	9.7		Computers & Electronics	2.2
Ann. Revenue ($M)	<1	8.4		President	7.7		Consulting	2.2
	1-5	14.2		Senior VP	4.3		Information Technology	2.1
	5-10	8.8		VP	12.5		Chemicals & Plastics	1.9
	10-50	16.6		Director	22.8		Pharmaceuticals	1.9
	50-100	10.7		Manager	28.4		Other	17.2
	>100	41.3		Others	14.6			

Table 2: Descriptive statistics

	Mean	Std. Dev.
Tracking Technology Initiation	3.81	0.75
Tracking Technology Adoption	5.02	4.16
Tracking Technology Routinization	3.01	0.94
Technology Integration	3.4	1.07
Collaboration Intensity	3.26	0.91
Structural Complexity	2.96	0.69
Demand Uncertainty	3.22	0.88
Handling Risk	2.89	0.93
Competitive Pressure	3.6	0.89
Customer Pressure	3.23	1.08
Regulatory Environment	2.47	0.82

Table 3: Results of the measurement model

	Construct	Cronbach's Alpha	Composite Reliability	AVE	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	Adoption	n.a.	n.a.	n.a.	1.000										
(2)	Collaboration	n.a.	n.a.	n.a.	0.09	1.000									
(3)	Competitive	0.918	0.941	0.727	0.155	0.049	1.000								
(4)	Customer	0.937	0.949	0.788	0.233	0.053	0.148	1.000							
(5)	Demand	0.772	0.828	0.622	0.014	0.000	0.002	0.003	1.000						
(6)	Handling	n.a.	n.a.	n.a.	0.028	0.011	0.025	0.012	0.000	1.000					
(7)	Initiation	n.a.	n.a.	n.a.	0.111	0.02	0.249	0.207	0.005	0.029	1.000				
(8)	Regulatory	0.838	0.884	0.604	0.022	0.003	0.026	0.054	0.003	0.022	0.035	1.000			
(9)	Routinization	n.a.	n.a.	n.a.	0.215	0.057	0.106	0.164	0.014	0.031	0.194	0.05	1.000		
(10)	Structural	n.a.	n.a.	n.a.	0.011	0.014	0.014	0.011	0.000	0.014	0.004	0.000	0.018	1.000	
(11)	Technology	0.874	0.841	0.715	0.135	0.128	0.064	0.104	0.004	0.03	0.034	0.033	0.127	0.0131	1.000

Figure 1: Value proposition of tracking technologies, improving information availability along three dimensions

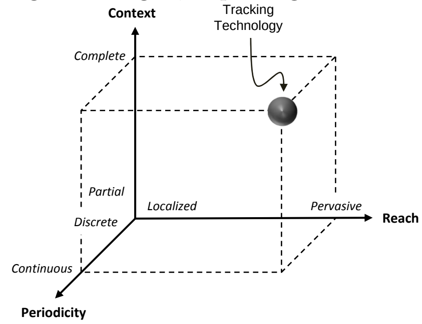

Table 4: Results of the structural model (theoretical, controls, and full)

	Theoretical (Model 1)			Controls (Model 2)			Full (Model 3)		
	Init.	Adop.	Rout.	Init.	Adop.	Rout.	Init.	Adop.	Rout.
Tech. Integration	0.0053	0.1183***	0.0968**	—	—	—	0.005	0.0868***	0.0964**
	-0.619	-2.739	-2.542				0.2	-2.649	-2.363
Collab. Intensity	0.0037	0.172***	0.1444**	—	—	—	0.003	0.1644****	0.1269***
	-1.496	-2.723	-2.629				0.933	-2.707	-2.686
Struct. Complexity	0.0721*	0.1335**	0.0421	—	—	—	0.0853*	0.1286**	0.0347
	-1.835	-2.509	-0.571				1.748	-2.199	-0.319
Dmd. Uncertainty	-0.0542**	-0.084**	-0.0446	—	—	—	-0.0415**	-0.0797**	0.0409
	-2.272	-2.134	-1.154				2.455	-2.037	-1.09
Hdlg. Risk	0.0834**	0.0654*	0.0597	—	—	—	0.0640**	0.0481*	0.0497
	-2.493	-1.927	-0.749				-2.41	-1.854	-0.484
Comp. Pressure	0.337****	0.0456	0.031	—	—	—	0.2885***	0.0413	0.0267
	-3.177	-0.917	-1.497				2.661	-0.613	-0.139
Cust. Pressure	0.1951****	0.3057*****	0.1587**	—	—	—	0.1578****	0.2949*****	0.1405***
	-2.993	-7.012	-2.449				3.008	-7.896	-2.3
Reg. Envmt.	0.0731*	0.0016	0.0992	—	—	—	0.0645**	0.0015	0.0948
	-1.891	-1.175	-0.155				1.669	-0.535	-0.115
Empl. Size	—	—	—	0.1339***	0.0829**	0.0411	0.1264**	0.0743*	0.0338
				-2.701	-2.109	-1.49	2.366	-1.65	-1.321
Geog. Location	—	—	—	0.0226	0.057	0.0354	0.0211	0.0493	0.0349
				-0.725	-0.374	-1.156	0.043	-0.165	-1.011
Rev.	—	—	—	0.0718**	0.0119	0.0422	0.0662*	0.0105	0.0362
				-2.143	-0.94	-0.998	1.828	-0.719	-0.268
SN Scope	—	—	—	0.1628**	0.1373*	0.1176	0.1271**	0.08**	0.0399
				-2.727	-2.204	-1.714	-2.377	-1.667	-1.346
Prod. Ownership	—	—	—	0.0241	0.051	0.0456	0.0215	0.0464	0.0329
				-0.744	-0.379	-1.121	-0.043	-0.169	-0.99
R^2	0.34	0.31	0.33	0.17	0.12	0.13	0.39	0.32	0.38
F	31.6****	35.0****	32.5**	19.2***	18.3**	23.3****	94.2****	91.8***	95.7***

***** p<0.001, **** p<0.005, *** p<0.01, ** p<0.05, * p<0.1; t-statistics are shown in parentheses.

Figure 2: Supply chain as a system

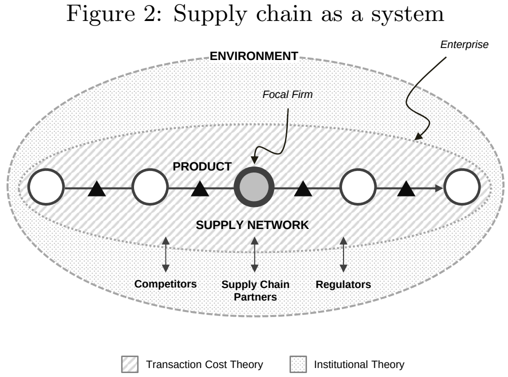

Figure 3: Research model