Leveraging Digitally Enabled Supply Chain Practices for Business Value Creation

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ABSTRACT

Integrating the supply chain is increasingly being advocated as the basis for organizations to realize performance gains in the near future. This paper explores the relationships between IT infrastructure, digitization, resource flow integration in the supply chain, and its consequences for business value creation. Data for this study were collected by a survey of supply chain and logistics managers in manufacturing and retail organizations. The analytical approach focuses on generating insights by combining descriptive analysis with inferential statistical techniques. Results suggest that the increased agility and responsiveness required by organizations with innovative products can be shaped by IT infrastructure integration and digitization initiatives. IT infrastructure integration and digitization initiatives, in turn, provide the platform for the integration of physical, financial, and information flows across the supply chain. The requirements for integrating these resource flows are shaped by the demand attributes of an organization’s products, and the integration of different resources across the supply chain have different implications for various dimensions of firm performance.
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Introduction

In an increasingly uncertain and complex business environment organizations are looking at their supply chains to improve productivity and profitability. Many organizations today are launching initiatives to integrate their end-to-end supply chains, i.e., from lower tier suppliers to the final consumer. Managers and researchers alike are paying considerable attention to supply chain management for meeting a variety of organizational objectives; from reducing costs, to leveraging the skills of supply chain partners for competitive advantage (Ramdas and Spekman 2000). Competitive success and performance gains from such initiatives cannot exist in a vacuum, it requires joint ventures, partnerships and other collaborative structures that enable organizations to compete as supply webs with each other (Evans and Wurster 1999, Lambert, et al. 1998). The Global Supply Chain Forum defines supply chain management as “the integration of key business processes from end user through original suppliers that provides products, services, and information flow that add value to customer and other stakeholders,” (Lambert, et al. 1998). The definition emphasizes moving away from the traditional focus of logistics, which has been on managing the physical flow of goods, to a broader focus on coordinating the interdependence of physical, financial, and information flows across the supply chain.

Our objective in this study is to investigate how information technology (IT) capabilities can impact physical, financial, and information flow integration, and the business value implications of integrating these resources across the supply chain. Information technology plays a critical role in enabling the integration of physical, financial, and information flows across the supply chain (Parekh 2001). Successful organizations such as Wal-Mart, Dell, Honda, etc., are cutting their inventory holdings down by substituting information flow for inventory. These organizations use IT to coordinate inter-organizational transaction events and share data across the supply chain. A good indicator of the growing interest in the area is the market for supply chain management software which is expected to reach US$12.5 billion by 2004; a compound annual growth rate of 28 percent from 1999 (Supply Chain Advisor 2001). Today, logistics firms, such as United Parcel Service, Menlo Logistics, and Schneider, along with IT firms such as IBM, Microsoft and i2, are offering solutions to address inefficiencies across globally distributed supply chains. While there has been some discussion of the
problems with current supply chains, there is limited systematic investigation of IT capabilities, their impacts on resource flows across the supply chain, and consequent performance implications. We also examine how these relationships change across organizations whose products differ in the length of their product life cycles. The nature of an organization’s product portfolio shapes the extent of demand uncertainty that needs to be accommodated by its supply chain. Shorter product life cycles are associated with more innovative products that have higher levels of demand uncertainty, thereby raising the bar on supply chain capabilities required to efficiently and responsively match supply and demand.

The analysis blends descriptive and inferential statistics to generate insights on the effective design and implementation of supply chain management practices. Compared to conventional model testing with aggregated measures, our approach offers the advantage of detecting interesting relationships at a finer level of aggregation without sacrificing statistical rigor. We analyze key relationships by contrasting sub-samples that exhibit high and low values for a given variable. The results suggest that the level of digitization - the extent to which supply chain activities and transactions are conducted online- is fairly limited with the highest level of digitization observed in outbound activities. The platform provided by IT infrastructure integration and digitization is associated with resource flow integration across the supply chain. Integration of information flows provides the foundation for integration of physical and resource flows in the supply chain. Furthermore, organizations with more innovative products are likely to demonstrate higher levels of digitization, IT integration and resource flow integration. Resource flow integration is positively associated with performance outcomes with different types of resource flow integration affecting different dimensions of organizational performance. Overall, the results provide interesting insights into current supply chain practices as well avenues for further investigation.

The remainder of the paper is organized as follows; we first present a conceptual model of IT-enabled resource flow integration and its impact on organizational performance. The model also examines the influence of product innovativeness as measured by the length of product life cycle on other study variables. The development of the conceptual model is followed by a brief overview of data collection procedures to set the context for examination of relationships in the model. The analysis first examines the extent of digitization in supply chain activities of organizations in our sample. Subsequently, we explore the relationships between IT
infrastructure integration, digitization, supply chain integration and organizational performance. The final section of the paper collates the results of our analysis and discusses their implications.

**The Conceptual Model**

Effective management of the supply chain by applying integrative technologies to coordinate key inter-organizational processes is widely regarded as the basis for organizations to realize productivity gains over the next few years. Central to realizing such gains is the ability to sense supply and demand signals, minimize excess stock in the supply chain by matching demand with supply and minimizing stock-outs. Delays in information transfer, often attributed to the distributed location of information across different points in the supply chain, exacerbate any mismatch between the demand and supply. This is referred to as the bullwhip effect, where divergence between demand and supply is amplified as information travels upstream across the supply chain. Such amplification of demand variation creates significant market mediation costs in balancing supply with demand, which manifests in the form of stock-outs and stockpiles at different stages in the supply chain (Simchi-Levi et al. 2002). Wal-Mart is often proffered as a textbook example of an organization that optimizes physical and information flows across the retail supply chain. Scanner data from checkout counters and inventory information is transferred in near real-time to suppliers via satellite and used not only for inventory replenishment, but also to enable pricing and stocking decisions. Similarly, Cisco’s customers place a majority of their orders online, which are digitally transmitted to contract manufacturers and logistics partners. More than 60% of the orders placed by Cisco’s customers are directly shipped to them by contract manufacturers (Bovet and Martha 2000). Having the capability to integrate their physical, financial and information flows across the supply chain appears to enable organizations to balance supply and demand in an efficient and responsive manner.

Resource flow integration is conceptualized as integration of materials (Stevens 1990), information (Lee et al. 1997), and financial flows across the supply chain. We consider interleaved flows of money, goods, and information resources as indicative of resource flow integration. The joint optimization of these flows is expected to improve multiple aspects of organizational performance. The central construct in our conceptual model (Figure 1). Our conceptual model focuses on the extent to which resource flow integration is influenced by characteristics of the IT platform (IT infrastructure and Digitization) and degree of innovativeness of an
organization’s products, and the relationships of the different resource integration levels with performance outcomes. Organizational performance is assessed in a broad sense by considering strategic and operational performance, financial and non-financial performance, and current as well as long-term performance.

Insert Figure 1 about here

Information flow integration is defined as the timely sharing of information about stocks and flows of resources, events, and outcomes. An organization and its supply chain partners can share information flow about, (i) events, such as order receipt and production, (ii) stocks, such as work-in-process and finished goods inventory, (iii) flows, such as shipment and delivery, and (iv) outcomes, such as profit margins, revenues, and sales and performance. Sharing of inventory, shipment, order, and performance information, and collaboration in planning and forecasting, are used as measures of information flow integration.

Physical flow integration is defined as the joint optimization of stocks and flows of materials and finished goods between an organization and its supply chain partners. Downstream physical flows consist of raw material, subassemblies and finished goods moving to the customer, while upstream physical flows consist of returns and repairs. Inventory optimization, just in time deliveries, joint management of inventory, postponement and distribution network configuration, are identified as measures that reflect the degree to which an organization’s physical stocks and flows are coordinated with its supply chain partners.

Financial flow integration is defined as the degree to which the stock and flow of money and financial transactions across the supply chain are; (i) triggered by pre-defined events, (ii) digitally automated, and (iii) precisely measured and optimized across the supply chain. Key downstream financial flows that need to be managed include prices, invoices, and credit terms, while essential upstream financial flows that need to be coordinated are payments and accounts payables. Financial flow integration can enable better working capital and cash flow management through automation of payable and receivable processes on delivery of goods. More importantly, organizations make efforts to reduce their cash-to-cash conversion cycle, which assesses the time taken by its customers to pay relative to the time taken to make payments to its suppliers. Effectively, the cash-to-cash conversion cycle is based on three components, i.e., days of inventory, days of receivables, and days of payables. Dell, for example, has reportedly achieved negative cash-to-cash conversion cycles.
A platform for resource flow integration is provided by IT infrastructure capabilities and the extent to which supply chain processes are conducted digitally. Today, many transactions on the supply- and buy-side can be executed over the Internet. Platform independence and the open architecture of E-commerce applications reduces many of the constraints on deployment of IT applications. In addition, these applications provide the ability to communicate across the supply chain in near real-time by exchanging data that is consistently represented and reliably shared across partners. Yet, when IT capabilities are not assimilated and embedded to create process capabilities, they are unlikely to yield business value. Consider the case of Kmart; the once successful giant retailer was unable to implement digitally enabled supply chain capabilities in order to compete with Wal-Mart’s growing market share. It’s much publicized stockouts and stockpiles from such failed initiatives resulted in bloated costs and eroded margins, contributing further to the troubles of the beleaguered corporation.

Coordination of multi-lateral relationships and processes between supply chain partners based on IT connectivity can play a critical role in the performance of supply chains and their member organizations. A case in point is that of Dell, which has transformed the process of configuring customized PCs. It also challenged the use of traditional channels for distribution when most manufacturers relied on retailers who stocked prepackaged models. Working with its supply chain partners and an integrated IT platform, Dell delivers customized PCs using modern supply chain practices. Companies such as Cemex in the cement industry, Li and Fung in the apparel industry, and Cisco in the networking and routers industry are examples of companies that have created and deployed an IT platform to achieve tight resource and activity coordination with partners and architect supply chains that exhibit efficient, adaptive, and agile behavior (Bovet and Martha 2000).

The level of product innovativeness that characterizes an organization’s product portfolio can provide different imperatives for the extent of integration of different resources across the supply chain and, subsequently, their impacts on organizational performance. In a predictable product demand environment with fairly standardized and mature products, the focus of integration is likely to shift towards efficiency and cost minimization. In contrast, volatile product demand contexts, driven by new and innovative products, require that changes in demand are sensed and responded to with agility (Fisher 1997). Thus, a key element of the market uncertainty facing organizations depends on the extent to which their products are novel and new to the
market. The length of the product life cycle is indicative of the level of innovativeness where new and
innovative products are expected to have shorter product life cycles, as compared to mature and functional
products that have longer product life cycles.

Thus, product innovativeness, IT capabilities, and digitization are likely to impact the physical,
financial and information flow integration in the supply chain. This study empirically explores these
relationships to develop an understanding of the relationships between these key elements. The findings of our
empirical research can be used to inform and critically evaluate organizational supply chain initiatives.

Data Collection and Analysis Methods

A survey for collecting data was developed and administered to supply chain and logistics managers.
Since pre-existing validated measures were not available for many of the variables of interest in the study,
multi-item measures were developed for such variables by anchoring them in prior research, industry reports on
digitally enabled supply chain initiatives, and discussions with several members in the practice community
involved with the management of IT-enabled supply chain improvement initiatives. The survey was subjected
to a two-stage pilot test with IS researchers and subsequently with supply chain and logistics managers. Survey
questions included in the final survey for data collection are provided in the Appendix. The questionnaire was
first mailed to 432 manufacturing and retail organizations in the US, and then made available to the same set of
potential respondents on a web site. About 90% of respondents completed the survey on the website, even
though all potential respondents received both the paper copies of the survey and instructions on accessing the
survey web site. After taking into account returned surveys and undelivered e-mails due to incorrect or
outdated contact information, the effective mail-out for the survey was 360 organizations. A total of 110
responses were received, representing a response rate of 30.55%. The median organization size was 4000
employees and the median organization revenue was 1.5 billion dollars with close to 60% of the respondents
reporting revenues greater than 1 billion dollars. Majority of the respondents were from publicly listed
organizations (62.5%) with the rest from private (15.4%) and subsidiaries of publicly listed organizations
(22.19%). Forty-five percent of the respondents were from the logistics function, seventeen percent each from
the supply chain and distribution functions, thirteen percent had responsibility for IT pertaining to the supply
chain, six percent specified that their direct responsibility focused on e-commerce and digitization to support the
supply chain, and three percent belonged to the purchasing function. Collectively, our respondents appear to hold positions that are well aligned to the subject matter of our current investigation and are likely to be well informed of relevant initiatives within their firms. Our tests for non-response bias on key demographic variables did not suggest any systematic bias in the respondents when compared to non-respondents.

In order to standardize the scales, the response for each variable was transformed to a 5-point linear scale ranging from 0 to 1 with increments of 0.2 each. A response was considered to indicate a low state of the variable if the value is $\leq 0.40$ and to indicate a high state for values $\geq 0.60$. Since we are interested in discovering patterns of differences across low and high states for a given variable, the middle group was dropped. One-way analysis of variance across high and low states was used to detect significant differences across the groups. Mean values and significant differences of the dependent variable for high and low states of each of the independent variables are also reported.

**The State of Digitization**

Digitization, as defined in this study, refers to the extent to which supply chain activities and transactions are conducted online by using Internet technologies. While there isn’t a formal definition for what it means to be ‘online,’ we use the term in the commonly accepted sense that data pertaining to events and transactions are captured, transmitted, and shared across the supply chain through the Internet. Digitization can help organizations to overcome the drawbacks associated with fragmented and incompatible IT infrastructures across supply chain participants. With digitization, organizations can synchronize information, physical, and financial flows across the supply chain, define virtual integration mechanisms, and compress lead times. Digitization of core supply chain processes, including procurement, manufacturing, inventory management, logistics, distribution, transportation, and sales, can have a significant impact on coordinating resources across the supply chain and, consequently, organizational performance.

Given the potential benefits from conducting supply chain activities online, one of the questions we examine is, what is the extent to which organizations are digitizing their supply chain activities? We asked respondents to indicate the extent to which they conducted various supply chain activities online. Overall levels of digitization were generally at the lower end of the scale. 38% of the respondents did not realize any revenue from online sales, 50% realized less than one fifth of their revenue online, and only 12% realized more than one fifth of their revenue online.
fifth of their revenues from online sales. The adoption level of online sales channels, while showing evidence of activity, in aggregate, remains low across manufacturing and retail organizations.

The analysis suggests that organizations are digitizing a greater proportion of intra-organization and outbound supply chain activities in comparison with inbound supply chain activities. The proportion is slightly higher for outbound activities in comparison to intra-organizational activities. Approximately 62% of the organizations reported that they conduct some to all of their outbound supply chain activities online, while 52% reported the same level of digitization for intra-organizational activities. Intra-organization and outbound supply chain activities also have the highest mean values for digitization (Figure 2). The level of digitization in outbound activities can be attributed, in part, to the focus on B2C (business to consumer) transactions in the early stages of e-commerce adoption. In addition, logistics and transportation companies have invested significant resources to provide online capabilities for a range of activities such as shipping, and tracking. Since a high level of digitization in outbound activities and a low level of revenue generated from online sales are observed, it suggests the possibility that organizations are using traditional sales channels but digitally coordinating the fulfillment of customer orders.

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An interesting finding that emerged from this descriptive analysis is that although organizations have not extensively digitized their online selling activities, the level of digitization of the customer service processes is remarkably high. As many as 84% of the respondents conduct most or all of their customer service activities online. This suggests that online channels such as web pages, e-mail, bulletin boards, etc., are becoming primary channels for servicing customers. Quite likely, online methods of customer support are increasingly being used to support routine inquiries, while knowledgeable customer service personnel are handling complex, unstructured interactions. Given that a majority of customer service requests tend to be routine in nature, significant economies of scale can be achieved by online processing of these activities. It is possible that organizations may be realizing productivity gains rather than strategic advantage from these applications. This finding appears to be consistent with recent research, where online selling and customer service are associated with shifting tasks from the organization to customers (Barua et al. 2001), resulting in a reduction of staffing for sales and customer service. Moving customer service activities online can have a major impact on
organizational performance provided organizations pay attention to the quality of the customer service. Albrecht (1993) notes that poor design and deployment of online capabilities can negatively impact customer support. For example, insurance companies may end up focusing on processing claims rather than helping people deal with traumatic or tragic events in their lives. Online customer service is highly susceptible to creating perceptions of impersonal service. While most organizations focus on online FAQ’s, a few may provide online service that is a glorified version of a call center with the same employees handling both phone and web service without leveraging capabilities of the new channel (Walsh 1999). At the same time, a University of Michigan study (Anonymous 2002) indicated that online customer service scored higher than offline customer service.

Because of the interesting patterns of digitization in customer service activities, we explored its association with the extent of digitization of other supply chain activities. We found that organizations that realized a significant proportion of their revenues from online sales were also more likely to web-enable their customer service activities. Many of these organizations allow customers to modify orders and handle returns on the web. To examine the trends and impacts of online customer service, we also investigated its impact on the organization’s relationship with its customers. We did not detect a relationship between the extent of customer service activities conducted online and perceived strength and continuity of the bond with customers. Thus, even though moving customer service activities online does not appear to improve an organization’s bond with its customers, it does not appear to have a negative impact either. We did detect a significant correlation between online customer service and timeliness of after sales service (r = 0.20, p= 0.02 one tailed), as well as overall productivity (r = .174, p = .035 one tailed). A Stanford Business School study (Venkatachalam, Rajgopalan and Kotha 2001) has reported similar results and found that web sites that provide a superior online customer experience have a higher level of site traffic and revenues.

**Product Innovativeness**

The nature of a product, whether innovative such as the latest wireless technologies, or functional such as everyday use washing detergent, is likely to have a significant impact on the relationship between the integration approaches used across the supply chain, as well as the performance impacts of these approaches (Fisher 1997). Innovative products, such as wireless technologies, are characterized by unpredictable demand,
higher product variety and profit margins. Typically, these products have very short product lifecycles. By comparison, functional products are mature, characterized by predictable demand with lower product variety and profit margins. These products also have longer product lifecycles than innovative products. In this study, we use the length of the product life cycle as an indicator of product innovativeness.

Physical flow integration strategies, such as just in time production and distribution, as well as digitally enabled approaches that postpone differentiation of products closer to the point of sale have received significant attention. For example, modular products can be rapidly assembled once the customer order is received, which effectively reduces inventory costs. These dynamic approaches that focus on recalibrating supply, as and when demand information is revealed, require that organizations deploy near real-time information across the supply chain, in order to coordinate resources, events, and exceptions. In effect, when a product portfolio consists of innovative products with short product life cycles, organizations need to process more information to implement strategies that require close coordination of activities and resources with their partners (Zipkin 2001). Similarly financial flow integration strategies, such as automation of financial transactions and integration of financial flows across the supply chain, also demand a similar level of sophistication in information processing. Finally information flow integration across the supply chain increases the richness of information shared, and the velocity with which this information is shared between organizations (Mendelson and Pillai 1998).

Organization information processing theory suggests that organizations operating in complex environments with demand and supply fluctuations require sophisticated information systems to sense and respond to uncertainty (Fine 1998, Galbraith 1973, Mendelson and Pillai 1998). Correlation analysis of the data indicates that organizations with innovative products have a greater level of digitization (ranging from .12, insignificant, to .30, significant at p < .001), and IT infrastructure integration (.18 for application integration, p < .05, and .34 for data consistency, p < .01) than organizations with longer product life cycles, a characteristic of functional products (Table 1). While a significant correlation between product innovativeness and information flow integration (.14) is not detected, we did observe significant correlations between product innovativeness and both physical- (.21 at p < .01) and financial- flow integration (.18 at p < .05).

Insert Table 1 about here
Organizations operating in innovative product environments have improved information technology capabilities characterized by greater data consistency and application integration across the supply chain. The apparent lack of difference in information flow integration across organizations with product life cycle is intriguing given the complexity of information processing in innovative product environments. The level of information integration with supply chain partners may likely be directly influenced by other factors such as the IT platform supply chain relationships that are shaped by product innovativeness. Interestingly, we did not observe an association between product innovativeness and online selling. While there is low penetration of online selling in our sample, it appears that both innovative and functional products can be adapted for online selling. Quite possibly a more detailed analysis of product-related issues such as product complexity, online representation of product features, importance of experiencing the product prior to purchase, and consumer’s perceived risk of the purchase decision, may influence which types of products are effectively sold through online channels.

**IT Infrastructure Integration and Digitization of Supply Chain Activities**

The IT infrastructure of an organization serves as the platform for deployment of its IT capabilities and services. A well developed IT infrastructure can provide an organization with economies of scale and capabilities of scale (Mckay and Brockway 1989). For instance, scale economies originate from the ability to consolidate and rationalize infrastructure investments. As a corollary, infrastructure investments reduce the marginal costs of investing in new business projects. Furthermore, it is the IT infrastructure that connects and integrates systems within and across organizational boundaries, thereby enabling improvements in communication, decision-making, and innovation. It can not only reduce the time delays and improve process execution efficiency along the supply chain, but also enable the organization to source and distribute its products and services to customers and markets. The IT infrastructure also impacts an organization’s ability to design and implement new business process applications for responding to emerging business opportunities (Mckay and Brockway 1989, Weill and Broadbent 1998). The best performing companies, as far as the quality and efficiency of logistics are concerned, are those that have invested heavily in integrated IT systems across the supply chain (Neumann et al. 2000). In this study, we focus our attention on data consistency and application integration between an organization and its supply chain partners. These capabilities can promote
supply chain-wide IT based coordination of processes such as order management, fulfillment, and returns management.

We first examine the relationship between IT infrastructure integration and digitization of supply chain activities. We compared the differences in mean values of digitization with high and low levels of IT infrastructure integration using one-way analysis of variance. Table 2 presents the results of our analysis, which suggests that higher levels of IT infrastructure integration are associated with higher levels of digitization. These findings support the assertion that an integrated applications infrastructure and data consistency provides the platform for digital execution of supply chain processes.

A paired sample t test indicates that the level of data consistency is much higher than the level of application integration (p= 0.003) in the sample. We next compare the mean values of digitization across the high and low levels of data consistency and application integration. Higher levels of data consistency are associated with higher level of digitization for all measures of digitization except online selling, possibly due to the low observed penetration of online selling. It is also plausible that online selling efforts may be narrowly focused on establishing an online channel presence, without adequate integration with back office and legacy application data. This finding is consistent with observations that organizations are reporting problems in tracking combined customer, inventory, and sales data across online and offline channels for the same products and customers. In fact, in a study conducted by Jupiter Media Matrix, it was found that 76% of the retailers couldn’t track their customers across multiple channels (Barua et al. 2001). The analysis reaffirms the notion that IT infrastructure of an organization provides the platform for digital deployment of supply chain activities. It also seems to lend support to the hypothesis that activities like online selling have often been implemented without adequate integration within and across the supply chain.

**IT Infrastructure Integration and Resource Flow Integration**

Konsynski (1997) discusses how information technologies such as imaging systems, workflow and inter-organizational systems, and large databases have transformed organizational boundaries,
inter-organizational relations, and market practice. IT can enable the transformation of supply chains through process redesign of inter-organizational processes (Davenport and Short 1990, Hammer 1990). Electronic marketplaces and e-procurement applications, when linked to an integrated infrastructure, can enable seamless transactions. E-commerce applications also feed in data on customer buying behavior to specialized supply chain software for overall supply chain optimization and market segmentation. Building on the emergence of ERP (Enterprise Resource Planning) applications in the 1990’s that promote application integration and shared corporate databases, vendors are now offering web-enabled supply chain applications that can be deployed for demand, supply and capacity planning along with event management across organizational boundaries. Increasingly, there is a focus on offering applications that can be integrated with other applications so as to coordinate customer facing processes, internal organization processes, and supplier facing processes. An integrated IT infrastructure, based on data consistency and application integration, is likely to be related to the extent of resource flow integration across the supply chain.

We compared the extent of resource flow integration at different levels of data consistency and application integration (Figures 2 and 3). The level of financial flow integration is reasonably high and shows a slight positive trend with higher levels of IT infrastructure integration. These high levels suggest that IT innovations for financial transactions have been broadly adopted by manufacturing and retail organizations to enhance their cash flow management. Compared to financial flow integration, physical and information flow integration show much steeper positive trends across levels of data consistency and application integration. These findings suggest that IT infrastructure initiatives focused on application integration, standards, and data consistency can considerably help improve efficiencies in physical and information flows.

The mean values of physical, financial, and information flow integration were significantly different across high and low groups of data consistency and application integration (Table 3). All measures of information flow were significantly different for high and low groups of data consistency and application integration. All measures of financial flow integration, except automation of accounts receivables, were significantly different across high and low groups of data consistency and application integration. Finally, all measures of physical flow integration were significantly different across high and low levels of data.
consistency. Two of the four measures of physical flow integration, just in time delivery and joint management of inventory with suppliers, were not different across high and low levels of application integration.

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Interestingly, processes that require deep collaboration and information sharing, and collective risk management, have the lowest mean values. For example, collaborative forecasting and sharing data with downstream partners, joint management of inventory, and activity based costing of supply chain processes have the lowest observed values. On the other hand, higher values are seen for minimization of inventory holdings, just in time delivery, capital efficiency and automation of transactions. A similar trend of low levels of collaboration is seen in the lower mean levels for information flow integration, as compared to physical and financial flow integration. The low observed values for these practices may be due to the significant adjustments to organizational practices and prevalence of existence mindsets for what are otherwise regarded as powerful value propositions. While integrated applications and data consistency provide the necessary infrastructure to orchestrate these processes, incongruent goals and principal-agent conflicts can constrain their implementation.

One of the measures of financial flow integration, automation of accounts receivables, is not different across high and low levels of data consistency and application integration. It would appear that organizations have automated their account receivables (see Table 3) processes to a greater degree, as compared to other financial flow activities. Furthermore, the standard deviation of receivables is lower (.24), as compared to payables (.30) and activity based costing (.29). It can be argued that organizations may be guided by a natural self-interest to minimize float by delaying payments and accelerating receipts, which explains higher levels of receivables automation. Overall, the analysis lends support to the proposition that an integrated IT infrastructure is likely to be associated with higher levels of integration in resource flows across the supply chain.
Digitization and Supply Chain Integration

It has been suggested that digitization can reduce asset intensity, enhance strategic control, and develop better relationships with customers (Slywotzky et al. 2000). By conducting an increasing proportion of supply chain activities online, digitization enables near real-time information sharing and the substitution of information flows for inventory while compressing lead times. To examine the impact of digitization, we compared the mean values of resource flow integration across low and high groups of digitization of the identified supply chain processes (Table 4).

Our results indicate that the primary advantage of digitization is in enabling information flow integration and, to a lesser extent, financial flow integration. Significant direct associations between digitization and physical flow integration are not detected, except in the case of customer service digitization, which is significantly related to physical flow integration. These findings suggest that an organization’s ability to substitute information flow for inventory is critical to achieve physical flow integration (Milgrom and Roberts 1988). It is likely that the lack of direct association between digitization and physical flow integration is because digitization of processes first impacts information flow integration, which, in turn, impacts physical flow integration suggesting a mediating effect of information flow integration. To investigate the relationship between physical flow integration and information flow integration, we compare the mean values of physical flow integration for high and low groups of information flow integration (Table 5). Physical flow integration is observed to be significantly greater for the sub-sample with higher levels of information flow integration. We further investigate whether information flow integration is associated with financial flow integration. Our results support that information flow integration enables all aspects of financial flow integration considered, except automation of account receivables, which has a high mean value and low variability for both low and high levels of information flow integration.
These findings form the basis of our viewpoint that digitization of processes may not directly influence physical and financial flow integration, but enable information flow integration, which, in turn, enables physical and financial flow integration. This is consistent with the widely held notion that IT and the consequent integration of information flow is an enabler of other desirable business outcomes (Leavitt and Whistler 1958). While no significant association is detected between digitization of inbound or customer service activities and financial flow integration, digitization of intra-organizational, online selling, and outbound processes are all positively associated with financial flow integration (Table 4). These results suggest that, as far as financial flows are concerned, organizations are using digitization to accelerate financial transactions with their customers and to achieve near real-time integration of these transactions with their internal ERP systems.

**Performance Implications of Supply Chain Integration**

It has been suggested that supply chain integration results in cycle time compression, and improvements in on-time delivery performance, fill rates, and product-service customization. We examine the associations between high and low groups of supply chain integration and aspects of efficiency, revenue growth, and customer relationships, regarded as key elements of an organization’s performance (Table 6). Timeliness and productivity were impacted by all measures of supply chain integration, physical, financial, and information, suggesting that the greatest impact of resource integration is in efficiency improvements.

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Physical flow integration is strongly associated with all measures of organizational performance, except delivery cycle time. The strong association of physical flow integration with customer relationships suggests that well-tuned physical flows can contribute to building bonds with customers by improving customer service and promoting continued interaction with customers, while enabling knowledge creation about customer buying patterns (Ellinger et al. 1999, Gustin et al. 1995). Physical flow integration also enables sales of existing and new products through better coordination of stocks and flows. By providing the right product at the right time, physical flow integration can enhance customer satisfaction.
Financial flow integration does not show a direct relationship with revenue growth. Despite its low variance in our sample, it is significantly associated with important efficiency performance measures, i.e., productivity and timeliness of service, as well as building customer bonds. Information flow integration, though not directly associated with new product sales and customer bonds, is directly associated with existing product sales and knowledge about customer buying patterns. Customer bonds, it appears, are influenced by key aspects of customer service, such as availability of products and seamless financial flow transactions. These findings provide further evidence that information flows integration play a mediating role between IT infrastructure and digitization initiatives and their conversion into core process capabilities that create business value. Information flow integration is influenced by IT infrastructure and digital application capability and is associated with physical and financial flow integration across the supply chain. Collectively, the integration of the three resource flows has a substantial impact on key dimensions of organizational performance.

Conclusions

The paper explores relationships between product innovativeness, IT infrastructure, digitization, supply chain integration, and performance. The study and its conclusions are subject to limitations that need to be recognized by cautious and appropriate interpretation of results. The sample used for analysis consists of only manufacturing and retail organizations limiting its generalizability to other sectors. A self-report survey instrument based on perceptual measures was the primary method of data collection. We focused on a single organization as the unit of analysis and a single respondent in each organization to report information about the organization’s supply chain. While the use of ‘key informants’ and perceptual data is considered to be appropriate (Sethi and King 1991, Ravichandran and Rai 2000), additional points of analysis supplemented with objective data for each sample point would improve the reliability of our results.

Product Innovativeness and Information Processing Capacity Requirements

Product innovativeness, as a characteristic of an organization’s market environment, presents increased information processing complexity for organizations. They can undertake initiatives to enhance their information processing capacity and subsequently leverage this enhanced capacity to coordinate critical resources and activities with supply chain partners. Our results suggest that initiatives focused on data
consistency, application integration, and digitization of supply chain applications, are particularly useful in enhancing an organization’s information processing capacity. While these initiatives are likely to be benefit organizations operating in functional product environments, where the products have long lifecycles and stable demand patterns, they are even more critical to organizations operating in innovative product environments, where the products have compressed lifecycles and unpredictable demand patterns. The latter type of product environment represents increased information processing complexity associated with demand and supply and, consequently, requires greater investments in digitally enabled information processing initiatives.

Assessment of the Level of Digitization

Many organizations are still in the early stages of digitizing their supply chains. Only a few organizations realize a substantial portion of their sales revenues from online channels. Although the extent of sales revenue generated from online activities is limited, organizations are moving an increasing proportion of their customer service activities online. Online migration of standardized customer service activities can improve responsiveness, yield productivity gains, and improve customer satisfaction from repeated interactions with the organization. In comparison to inbound supply chain activities, a greater proportion of intra-organizational and outbound supply chain activities are being conducted online. The lack of end-to-end integration of supply chain activities suggests that business process improvements can be realized by increasing coordination across an organization’s supply chain. Given the low level of multi-channel integration, there is a huge opportunity to streamline the number of interaction points with customers and generate asset efficiencies by jointly optimizing flows and stocks across channels.

Impacts of Digitization and Resource Flow Integration

Digitization directly impacts information flow integration to a much greater extent than physical or financial flow integration. Digitization of core intra- and inter-organizational processes allows firms to share near real-time information with their supply chain partners. Information flow integration, in turn, enables physical flow integration. This is consistent with, and confirms the long-held view that IT enables (Leavitt and
Whistler 1958, Davenport and Short 1990) rather than lead to direct performance outcomes. Organizations must design digitization strategies that are aligned with the information sharing requirements of their supply chain environments. Given the range of e-market solutions that have been developed, organizations can deploy a portfolio of private exchanges, consortia exchanges, and independent third-party marketplaces to digitize inter-organizational processes and share information with trading partners.

Physical, financial, and information flow integration differentially impact organizational performance measures. Among the three types of flow integration considered here, physical flow integration has the most substantial impact on measures of organizational performance considered in the study. By tightly coordinating complex physical flows, organizations can jointly optimize transportation, production, and distribution processes, thereby reducing the associated costs of production, assembly, logistics, transportation and warehousing. In many industries, logistics costs account for a substantial portion of total operating costs. The increased use of global sources for supply and production and modular supply chains coupled with globally distributed customers is a characteristic of today’s business environment. Digitally enabled logistics is a core capability that can be used by organizations to help balance demand with supply in such globally distributed environments. Streamlined logistics that integrates physical flows across different transportation modes and logistics service providers can reduce coordination costs, order-to-delivery cycle times, and provide enhanced delivery performance to customers at reduced costs. Financial flow integration can be used to decrease process cycle times and increase productivity of working capital by accelerating receivable collection and compressing the cash-to-cash conversion cycle. The enhanced service levels achieved by physical and financial flow integration can help nurture bonds with customers. In addition, integrated physical and financial flows across the supply chain can help organizations to respond to dynamic opportunities for new product sales. Organizations can integrate information across the supply chain to create knowledge about customer buying patterns, thereby increasing revenue from product sales.

**Data Consistency and Application Integration as Key IT Enablers**

IT infrastructure integration is positively associated with the digitization of key supply chain activities, except selling online. A majority of organizations engaged in online selling may have deployed web interfaces for ordering transactions without linking their order management systems to back office, legacy systems or to brick and mortar inventory management systems. Both data consistency and application integration are linked
to improvements in physical, financial, and information flow integration. As noted earlier, physical flow integration has a substantial impact on the measures of organizational performance considered here, i.e., efficiency, customer relationships, and revenue growth. Our results suggest that the association between data consistency and physical flow integration is stronger than the association between application integration and physical flow integration. This is accompanied by higher mean values of data consistency as compared to application integration. Organizations must evaluate data consistency, in terms of the representation of data and its shared meaning across the supply chain. Such evaluation should drive the implementation of standards, processes, and systems that make it feasible for them to exchange near real-time data with a shared meaning with their trading partners. Such data exchange may be a critical prerequisite to achieve application and process integration, which enable strong coordination of resources and activities across distributed supply chains.

In summary, as the innovativeness of an organization’s products increases, the associated information processing complexity for managing demand and supply signals also increases. Organizations can respond to this increased information processing complexity by integrating their IT infrastructure and investing in supply chain management applications. The implementation of IT infrastructure capabilities should focus on sharing of transactional, operational, and strategic information across the supply chain. The overall level of adoption of collaborative physical and financial processes, as well as information flows, have considerable room for growth, as suggested by the low mean values for these variables. By building capabilities to share information and collaborate across the supply chain, organizations are more likely to increase the level of physical and financial flow integration. In deriving value from such collaboration, coordination based on information sharing alone is not enough but coordination of material and financial flows enables improvements in many measures of financial performance. This suggests that organizations need to measure and evaluate key indices of intermediate physical and financial flows in addition to tangible financial and non-financial measures of organizational performance.

**Future Research Directions**

Opportunities for further research in this area are abundant, especially in view of the current interest and an insufficient number of empirical investigations that have been reported in published literature. Process-based investigations that use a longitudinal approach to investigate the design and implementation specific
supply chain practices would complement the insights on the importance of different practices from variance-based research investigations, as done in the current study. Integrating perspectives that encompass technological and process capabilities, with the behavioral and economic motivations for collaboration, can yield a comprehensive picture on the antecedent conditions for deep information sharing. Finally, examining the impact of partnering arrangements, including contractual arrangements and other governance mechanisms, on supply chain capabilities, risk sharing consequences, and value co-creation will provide critical managerial insights on the design and implementation of supply chains.
References


APPENDIX

Survey Items in the Questionnaire

Digitization

In responding to the questions in this part, please select your organization’s primary product(s) or product line(s). Primary product(s) or product line(s) commands a significant proportion of company revenues, usually 15 to 20 percent, or greater, of revenues.

- Proportion of INBOUND supply chain activities managed online (e.g. procurement, warehousing, payments).
- Proportion of INTRA- ORGANIZATION supply chain activities managed online (e.g. manufacturing, material requirement planning, product planning).
- Proportion of OUTBOUND supply chain activities managed online (e.g. orders received, billing, distribution, and tracking).
- Products and services SOLD online.
- CUSTOMER SERVICE activities conducted online (e.g. answering questions, complaints, live chat).

Please use the following scale to indicate the extent of your agreement with each statement below.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Slightly Agree</th>
<th>Neutral</th>
<th>Disagree Slightly</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>A</td>
<td>AS</td>
<td>N</td>
<td>DS</td>
<td>D</td>
<td>SD</td>
</tr>
</tbody>
</table>

Data Consistency in IT Infrastructure

- Automatic data capture systems are used (e.g. bar code) across the supply chain.
- Definitions of key data elements (e.g. customer, order, and part number) are common across the supply chain.
- Same data (e.g. order status) stored in different databases across the supply chain is consistent.
- Same data needs to be reentered in the computer at each step in the supply chain.
Application Integration in IT Infrastructure

The following applications communicate in real-time:

• Supply chain planning applications (e.g. Demand planning, transportation planning, manufacturing planning).

• Supply chain transaction applications (Order management, procurement, manufacturing and distribution).

• Supply chain applications with internal applications of our organization (such as enterprise resource planning).

• Customer relationship applications with internal applications of our organization.

Physical Flow Integration

• Inventory holdings are minimized across the supply chain.

• Supply chain wide inventory is jointly managed with suppliers and logistics partners (e.g. UPS, FedEx).

• Suppliers and logistics partners deliver products and materials just in time.

• Distribution networks are configured to minimize total supply chain-wide inventory costs.

Financial Flow Integration

• Capital efficiency, working and fixed, is maximized across the supply chain.

• Account receivables processes are automatically triggered when we ship to our customers.

• Account payable processes are automatically triggered when we receive supplies from our suppliers.

• We use activity based costing for key supply chain processes (e.g. inventory, storage, transportation).
Information Flow Integration

- Production and delivery schedules are shared across the supply chain.  
  SA A AS N DS D SD
- Performance metrics are shared across the supply chain.  
  SA A AS N DS D SD
- Supply chain members collaborate in arriving at demand forecasts.  
  SA A AS N DS D SD
- Our downstream partners (e.g. distributors, wholesalers, retailers) share their actual sales data with us.  
  SA A AS N DS D SD
- Inventory data are visible at all steps across the supply chain.  
  SA A AS N DS D SD
- Order fulfillment and shipment status are tracked at each step across the supply chain.  
  SA A AS N DS D SD

Product Innovativeness

Products have a short life cycle (< 1 year)  
SA A AS N DS D SD

Organizational Performance

<table>
<thead>
<tr>
<th>Much better than Average</th>
<th>Better than Average</th>
<th>Same as Competitors-Average</th>
<th>Slightly Less than Average</th>
<th>Much Less than Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Efficiency

- Product delivery cycle time.  
  1 2 3 4 5
- Timeliness of after sales service.  
  1 2 3 4 5
- Productivity improvements (e.g. assets, operating costs, labor costs).  
  1 2 3 4 5

Revenue Growth

- Increasing sales of existing products.  
  1 2 3 4 5
- Access to proprietary product and process technology  
  1 2 3 4 5
- Finding new revenue streams (e.g. new products, new markets).  
  1 2 3 4 5

Customer Relationship

- Strong and continuous bond with customers.  
  1 2 3 4 5
- Precise knowledge of customer buying patterns.  
  1 2 3 4 5
Figure 1: Digitally Enabled Integration of Supply Chain Resource Flows
Figure 2: Mean Values of Digitization for Different Supply Chain Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Mean Value of Digitization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbound</td>
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<tr>
<td>Intraorganisational</td>
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</tr>
<tr>
<td>Outbound</td>
<td>0.39</td>
</tr>
<tr>
<td>Online Sales</td>
<td>0.27</td>
</tr>
<tr>
<td>Customer Service</td>
<td>0.31</td>
</tr>
</tbody>
</table>
Figure 3: Resource Flow Integration at Different Levels of Data Consistency
Figure 3: Resource Flow Integration at Different Levels of Application Integration
Figure 5: The Business Value Creation with Digital Supply Chain Capabilities
<table>
<thead>
<tr>
<th>Product Innovativeness</th>
<th>Digitization of Supply Chain Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inbound supply chain activities .18**</td>
</tr>
<tr>
<td></td>
<td>Intra-organizational supply chain activities .30***</td>
</tr>
<tr>
<td></td>
<td>Outbound supply chain activities .28***</td>
</tr>
<tr>
<td></td>
<td>Online selling activities .12</td>
</tr>
<tr>
<td></td>
<td>Customer service activities .18*</td>
</tr>
</tbody>
</table>

|                        | IT Infrastructure Integration          |
|                        | Data Consistency .34**                 |
|                        | Application Integration .18*           |

|                        | Resource Flow Integration              |
| Physical Flow Integration | .21**                             |
| Financial Flow Integration | .18*                               |
| Information Flow Integration | .14                               |

*** p < .001, ** p < .01, * p < .05 (correlation-one tailed)
Table 2: Differences in Digitization Across Levels of IT Infrastructure Integration

<table>
<thead>
<tr>
<th>Digitization Activities</th>
<th>Data Consistency</th>
<th>Application Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Group</td>
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</tr>
<tr>
<td>Inbound supply chain activities</td>
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<tr>
<td>Intra-organizational supply chain activities</td>
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<td>.42</td>
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<tr>
<td>Outbound supply chain activities</td>
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<td>.43</td>
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<tr>
<td>Online selling activities</td>
<td>.22</td>
<td>.29</td>
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<tr>
<td>Customer service activities</td>
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</table>

*** p < .001, ** p < .01, * p < .05
Table 3: Differences in Resource Flow Integration Across IT Infrastructure Integration Levels

<table>
<thead>
<tr>
<th>Flow Integration</th>
<th>Data Consistency</th>
<th>Application Integration</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Low Group</td>
<td>High Group</td>
</tr>
<tr>
<td><strong>Physical flow Integration</strong></td>
<td></td>
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<tr>
<td>Inventory holdings are minimized</td>
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</tr>
<tr>
<td>Inventory is jointly managed with partners</td>
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<td>.58</td>
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<td>Just in time delivery</td>
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<tr>
<td>Distribution network configuration minimizes inventory costs.</td>
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<td><strong>Financial flow Integration</strong></td>
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<td></td>
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<tr>
<td>Maximization of supply chain efficiency</td>
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<td>.56</td>
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<tr>
<td>Automation of account receivables</td>
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<td>.78</td>
</tr>
<tr>
<td>Automation of account payables</td>
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<td>.67</td>
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<tr>
<td>Activity based costing</td>
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<tr>
<td><strong>Information flow Integration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharing production and delivery schedules</td>
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<td>.66</td>
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<tr>
<td>Performance metrics are shared</td>
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<tr>
<td>Collaborative demand forecasting</td>
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<td>.55</td>
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<td>Downstream partners share sales data</td>
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<tr>
<td>Inventory visibility</td>
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<td>Order and shipment tracking</td>
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*** p < .001, ** p < .01, * p < .05
### Table 4: The Impact of Digitization on Supply Chain Integration

<table>
<thead>
<tr>
<th>Digitization of Processes</th>
<th>Physical flow Integration</th>
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<th>Information flow Integration</th>
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<td>.39</td>
<td>.39</td>
</tr>
<tr>
<td>High Group</td>
<td>.54</td>
<td>.44</td>
<td>.50</td>
</tr>
<tr>
<td>Sig.</td>
<td>.13</td>
<td>.30</td>
<td>.05*</td>
</tr>
<tr>
<td><strong>Intraorganization</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low Group</td>
<td>.50</td>
<td>.38</td>
<td>.42</td>
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<tr>
<td>High Group</td>
<td>.55</td>
<td>.48</td>
<td>.52</td>
</tr>
<tr>
<td>Sig.</td>
<td>.29</td>
<td>.01**</td>
<td>.04*</td>
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<tr>
<td><strong>Outbound</strong></td>
<td></td>
<td></td>
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<tr>
<td>Low Group</td>
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<td>.34</td>
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<td>High Group</td>
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<tr>
<td>Sig.</td>
<td>.10</td>
<td>.000***</td>
<td>.005**</td>
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<td><strong>Online Selling</strong></td>
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<td>Sig.</td>
<td>.24</td>
<td>.03*</td>
<td>.04*</td>
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<td><strong>Customer Service</strong></td>
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*** p < .001, ** p < .01, * p < .05
### Table 5: Physical flow and Financial flow Resource Integration Across Different Levels of Financial flow Integration

<table>
<thead>
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<td>High Group</td>
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<td>Sig.</td>
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<td>.001**</td>
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<table>
<thead>
<tr>
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<td>.04*</td>
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*** p < .001, ** p < .01, * p < .05
Table 6: The Impact of Resource Integration on Organizational Performance

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<th>Performance Measures</th>
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<td>.003**</td>
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<td>Timeliness of service</td>
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<td>.50</td>
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<td>.000***</td>
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<td>Productivity</td>
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<td>.04*</td>
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<td>.003**</td>
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<td>New product sales</td>
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<td>.70</td>
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*** p < .001, ** p < .01, * p < .05