The Complementarity of Information Technology Infrastructure and E-Commerce Capability: A Resource-Based Assessment of Their Business Value

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ABSTRACT: This study seeks to assess the business value of e-commerce capability and information technology (IT) infrastructure in the context of electronic business at the firm level. Grounded in the IT business-value literature and enhanced by the resource-based theory of the firm, we developed a research framework in which both the main effects and the interaction effects of e-commerce and IT on firm performance were tested. Within this theoretical framework, we formulated several hypotheses. We then developed a multidimensional e-commerce capability construct, and after establishing its validity and reliability, tested the hypotheses with empirical data from 114 companies in the retail industry. Controlling for variations of firm size and subindustry effects, our empirical analysis found a strong positive interaction effect between IT infrastructure and e-commerce capability. This suggests that their complementarity positively contributes to firm performance in terms of sales per employee, inventory turnover, and cost reduction. The results are consistent with the resource-based theory, and provide empirical evidence to the complementary synergy between front-end e-commerce capability and back-end IT infrastructure. Combined together, they become more effective in producing business value. Yet the value of this synergy has not been recognized in the IT payoff literature. The “productivity paradox” observed in various studies has been attributed to variation in methods and measures, yet we offer an additional explanation: ignoring complementarities in business value measurement implies that the impact of IT was seriously underestimated. Our results emphasized the integration of resources as a feasible path to e-commerce value—companies need to enhance the integration between front-end e-commerce capability and back-end IT infrastructure in order to reap the benefits of e-commerce investments.

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0742–1222 / 2004 $9.50 + 0.00.
ELECTRONIC COMMERCE, DEFINED HERE AS business activities conducted over the Internet, continues to penetrate the enterprise value chains. Many large companies develop Internet-enabled initiatives to strengthen online connections with customers, disseminate product information, facilitate transactions, improve customer services, and manage inventory via electronic links with suppliers. Integrating the front-end Web presence and back-end information systems (IS) is a top priority among IS managers [23]. Developing direct access to customers via interactive Web technologies is the dominant e-commerce strategy among retailers [16]. While sizable investments in e-commerce are being made, researchers are struggling to determine whether these expenditures deliver any value proposition reflected upon firms’ performance, or even how to measure the Internet-based e-commerce initiatives in the first place [5, 64].

Although showing recent signs of advance, much of the existing e-commerce literature still relies heavily on case studies, anecdotes, and conceptual frameworks, with few empirical data to characterize the Internet-based initiatives or gauge the scale of their impact on firm performance—especially in large, traditional companies [10, 63], partly because of the difficulty of developing measures and collecting data. Case studies on companies such as Wal-Mart and Office Depot provided insights into business uses of e-commerce, but are the findings of these case studies specific to a few “leading-edge” firms, or are the lessons more widely applicable? At the same time, there are cases where many firms, concerned about falling behind on the technology curve, engage in e-commerce initiatives without deriving any benefits [35]. Thus, we still know relatively little about the business value of e-commerce for most firms. To answer this question, we need evidence from large-sample statistical analysis. Such studies cannot be undertaken until we have developed a set of constructs that will reveal relevant relationships [62].

This study attempts to reduce the gap in the literature by examining the linkages among e-commerce capability, information technology (IT) infrastructure, and firm performance. Key research questions that motivate our work are: What constitutes an e-commerce capability at the firm level? How might such a capability be measured? How are these e-commerce measures related to firm performance in terms of revenue generation, cost reduction, and operational efficiency? What kind of relationship might exist between Internet systems and pre-Internet IT infrastructure—that is, are they substitutes or complements?

To answer these questions, we first developed a theoretical framework grounded on the resource-based view of the firm. Based on this framework, a series of hypotheses were developed to test whether e-commerce capabilities, in conjunction with a firm’s IT infrastructure, are associated with firm performance measures. E-commerce capability is modeled as a new type of technological resource that, combined with a
firm’s existing IT infrastructure, may have certain relationships to firm performance. We tested the model and hypotheses with empirical data from 114 companies in the retail industry.

Theoretical Development

E-COMMERCE IS AN UNFOLDING PHENOMENON. Most large firms are still in the early stage of positioning themselves to exploit the business opportunities enabled by the Internet. Hence, it is difficult to know how best to measure e-commerce capability. This points to the need for a theoretical framework that may offer guidance. In this section, we first present the conceptual framework and then explain how this was distilled from relevant theoretical perspectives in conjunction with existing literature.

Conceptual Framework

Based on our review of the literature, a conceptual framework has been developed as shown in Figure 1. In this framework, two sets of variables—e-commerce capability and IT infrastructure—are associated, jointly and individually, with firm performance. E-commerce capability represents a firm’s ability to interact with its customers and business partners and conduct businesses over the Internet [62].

This conceptual framework suggests that appropriate measures of e-commerce capability, IT infrastructure, and firm performance have to be developed. These measures should capture the characteristics of Internet functionalities and integration that can help build customer and supplier relationships across the value chain. As will be elaborated in the third section, e-commerce functionalities represent the level of integration with customers and suppliers, upstream and downstream of the value chain [62]. Specifically, e-commerce capabilities mirror a company’s strategic intent to use the Internet to share information, facilitate transactions, improve customer service, and strengthen back-end integration. To a certain extent, these e-commerce capabilities should be reflected in the functionalities of the company’s Web site, as the Internet is a new channel to reach customers and the Web serves as a gateway for dealing with customers and suppliers in the Internet age [26]. E-commerce functionalities may range from static information to online order tracking, and from digital product catalogs to personalized features tailored to the customer’s needs. These functionalities exhibit various levels of sophistication that can be measured.¹

While the measures will be elaborated in the third section, here we provide brief definitions of key constructs to facilitate the development of the theory and hypotheses. First, e-commerce capability is defined as a high-level, multidimensional construct generated from a set of specific variables measuring e-commerce functionalities. Second, IT infrastructure is represented by a composite construct termed IT intensity, which is based on several levels of an organization’s data processing architecture and networks. Third, interaction effect is the product of the two constructs—e-commerce capability and IT intensity. There is a distinction between e-commerce capability and IT intensity—the former indicates front-end capabilities that leverage the Internet for
information, transaction, and customer service, whereas the latter represents a firm’s installed base of data processing infrastructure in the back office. Hence, e-commerce capability and IT intensity represent two related, yet distinct constructs, measuring two different types of resources. The following section explores these notions further.

Resource-Based Theory on E-Commerce Capability

Current State of Knowledge About E-Commerce Business Value

We reviewed the academic literature on business value of e-commerce and IT published in major IS journals (i.e., *Information Systems Research*, *Journal of Management Information Systems*, *Management Science*, and *MIS Quarterly*) during the past ten years. Table 1 summarizes the papers relevant to this study, which are divided into two categories: those focusing on dot-coms and those focusing on traditional companies. The theory, methods, and key findings of each study are summarized in the table. Most of them employed case studies or surveys and used multiple theoretical perspectives such as transaction-cost economics, agency theory, value chain analysis, and market efficiency hypothesis. As found by Amit and Zott, “each theoretical framework has limitations when applied in the context of highly interconnected electronic markets” [1, p. 500]. No single theory can fully explain the business value of e-commerce. Rather, a theoretical integration of the received perspectives on value creation is needed. Moreover, the literature on e-commerce business value for traditional companies is still sparse. Our literature review found very few papers in this area. “The literature to date has neither articulated the central issues related to this new phenomenon, nor has it developed theory that captures the unique features of virtual markets” [1, p. 494].

The traditional IT business value literature has several studies on electronic data interchange (EDI). For example, Mukhopadhyay et al. [39] assessed the business value of EDI and found that EDI enabled effective use of information to coordinate
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| Amit and Zott [1]     | Multiple economic theories: value chain, Schumpeterian innovation, RBV, strategic network theory, and transaction-cost economics. | Inductive case studies of 59 American and European dot-com e-businesses. | No single theory can fully explain the value creation potential of e-business. Rather, a theoretical integration of the received perspectives on value creation is needed. Based on such an integration, the paper identified four sources of value creation in e-business:  
  - efficiency;  
  - complementarities;  
  - novelty;  
  - lock-in. |
| Bakos [3]             | Functions of market.                                                                             | Conceptual analysis and case studies. | This paper focuses on the impacts of e-commerce on the whole market. As a market component, firms can achieve business value from e-commerce via:  
  - increased personalization and customization of product offerings;  
  - the aggregation and disaggregation of information-based products; and  
  - lower search costs. |

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<td>Malone and Laubacher [34]</td>
<td>Transaction-cost economics.</td>
<td>Conceptual analysis and case studies.</td>
<td>E-commerce business value stems from reduction of information asymmetry and transaction costs, because it provides the capability to transact at a distance, match requirements more efficiently, negotiate through electronic means, design contract via software, and monitor compliance with technology.</td>
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<td>Lee and Clark [32]</td>
<td>Transaction-cost economics.</td>
<td>Case study.</td>
<td>E-commerce may have significant influence on transaction components, such as search, price discovery, and trade settlement.</td>
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<td>Chircu and Kauffman [13]</td>
<td>The limits-to-value model as the theoretical basis.</td>
<td>Case study; Online travel reservation systems.</td>
<td>Focusing on the process of value realization, this paper identifies barriers limiting the extent of transfer of the potential value realized value, including barriers specific to the valuation process (industry and organization barriers), and barriers specific to the conversion process (resource, knowledge, and usage barriers).</td>
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Torkzadeh and Dhillon [57] Keeney’s model based on a value-focused thinking approach. Two-phase survey. This study focused on customer value, instead of business value. Customer value, instrumented by fundamental objectives, can be enhanced via Internet operations, instrumented by means objectives. The accomplishment of this paper is the development of two instruments for fundamental objectives and means objectives.

Lederer et al. [31] A model of managerial objectives for IT investment: • transactional IT, • informational IT, • strategic IT. Survey study of 212 managers of electronic retailers. SEM was used for data analysis. Data analysis supports three hypotheses: • Organizations use the Web to improve customer relations so that they can achieve competitive advantage. • Organizations use the Web to improve information access and flexibility so that they can improve customer relations. • Organizations use the Web to improve business efficiency (back-office functions) so that they can improve customer relations.

Subramani and Walden [54] Financial theory, market efficiency hypothesis. Event study based on 251 e-commerce announcements. The impact of e-commerce announcements on a firm’s stock market value was found to be significant during the period of the study. E-commerce business capabilities are viewed as intangible resources and help firms to achieve long-term benefits, though this may vary across different sectors.

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<td>Zhu and Kraemer [62]</td>
<td>Resource-based theory; dynamic capability</td>
<td>Survey and financial data; Web site content analysis.</td>
<td>Developed a set of e-commerce metrics. Found a positive relationship between e-commerce capability and inventory turnover. E-commerce was found to reduce costs in high-tech companies but to increase costs in traditional manufacturing companies.</td>
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<td>Mukhopadhyay et al. [39]</td>
<td>IT business value.</td>
<td>Survey data; regression analysis.</td>
<td>This study found significant cost savings by using EDI—about $60 per vehicle. EDI improved information exchanges, which leads to savings in inventory holding cost, obsolete inventory cost, transportation cost, and premium freight.</td>
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<td>Steinfield et al. [50]</td>
<td>Value creation; transaction-cost economics.</td>
<td>Case study.</td>
<td>E-commerce business value may be achieved from the click-and-mortar synergies. Synergy benefits include potential costs savings, differentiation through value-added services, improved trust, and market extension.</td>
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<tr>
<td>Zhu et al. [64]</td>
<td>Technology-organization-environment (TOE) framework.</td>
<td>Survey data; structural equation modeling</td>
<td>E-commerce value is significantly influenced by technological, organizational, and environmental factors (e.g., technology readiness, firm size and scope, competition, and government regulation).</td>
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<td>Teo and Too [56]</td>
<td>A strategic grid linking the role of IT and business use of e-commerce.</td>
<td>This paper confirms the positive relationship between the strategic view of IT and business usage of e-commerce to achieve competitiveness. Achieving market responsiveness was the most significant differentiating variable in the extent of Internet usage among organizations in which IS plays different roles.</td>
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<tr>
<td>Vadapalli and Ramamurthy [60]</td>
<td>Technology–organization–environment framework.</td>
<td>This study identifies adoption stimulators for e-commerce: Innovation-specific characteristics (the social and technological context) and organization-specific characteristics (organization boundaries, transaction-cost economics, and organizational cognition).</td>
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In addition, Zwass [65] presents a systematic view of the organization of the complex enterprise of e-commerce within a hierarchical framework: infrastructures–services–products–structures. Kauffman and Walden [28] review the e-commerce literature and discuss the economic perspectives for studying e-commerce.

*Notes:* RBV = resource-based view; SEM = structural equation models; EDI = electronic data interchange. ¹ The early e-commerce empirical literature included several studies that compared prices between online and offline retailers (for a review, see Smith et al. [49]). Because price comparison is quite different from firm performance, we did not include those papers in this table. ² The IT productivity literature has been reviewed elsewhere [12, 21].
material movements between the manufacturer and its suppliers, which resulted in significant cost savings and inventory reduction. EDI has some features in common with Internet-based e-commerce, but it also exhibits significant differences, as EDI is typically a more expensive, proprietary technology over a private network controlled by one large manufacturer or supplier. In contrast, the Internet is based on open standard and may induce large-scale transformations within an organization as well as in its relationships with customers and suppliers [61]. Thus, although there is some evidence of economic impacts from IT such as EDI, it is not clear whether this can be directly extended to the Internet-based electronic business.

Because our study seeks to extend the IT value literature to the Internet-enabled e-business environment, it is natural to ask whether Internet initiatives are different from pre-Internet systems (e.g., mainframe, minicomputers, and other legacy systems). In fact, the economic characteristics of the Internet are significantly different from those of pre-Internet computer technologies [3, 61]. The Internet is characterized by global connectivity, broad interactivity, and open-standard network integration [10, 48]. These characteristics have very different impacts on customer reach and richness of information [26, 28]. Consequently, the Internet is more than a new technology: it serves as a catalyst and enables a transformation, rapid or gradual, from organizational systems that were heavily dependent on physical processes to those that rely on information for fundamental business processes [10, 28]. This transformation relies on the capabilities of both front-end customer connectivity and back-end communication infrastructure to reduce the constraints of time and distance on businesses [49, 62]. Prior to the Internet, firms often used stand-alone, proprietary systems (e.g., EDI) to communicate limited data [39]. It was difficult or costly for a firm to connect to its customers, suppliers, and business partners. In contrast, the Internet enables a two-way real-time information exchange between a firm, its customers, and suppliers [61]. This reflects a key strength of the Internet technologies—the ability to provide informational, transactional, and interactive capabilities to customers across time and space [7].

Resource-Based View and E-Commerce Capability

With the focus moving away from pre-Internet legacy systems toward Internet and e-business capabilities, we need a theoretical framework to guide our investigation. A potential theoretical framework for studying e-commerce value is the resource-based view (RBV) of the firm, which links firm performance to organizational resources and capabilities [4, 40, 59]. In the IS literature, the RBV has been used to resolve the “productivity paradox” and to explain how firms create value from IT assets and organization’s skills to leverage IT assets [14, 25]. IT payoffs depend on “fitting the pieces together”—that is, on exploiting relationships among complementary resources [8, 43].

Viewed from a resource-based perspective, it is how firms leverage their investments in IT and e-commerce to create unique Internet-enabled capabilities that determines a firm’s overall e-commerce effectiveness. One might argue that some
e-commerce technologies are readily available in the software and hardware markets; investments in e-commerce may not generate performance advantage. On the other hand, a counterargument might be, regardless of how commodity-like the technology components may be, the architecture that removes the barriers of system incompatibilities and makes it possible to build a corporate platform for launching e-business applications is clearly not a commodity [29, 42].

Moreover, e-commerce capabilities are often tightly connected to the resource base and embedded in the business processes of the firm. The degree to which e-commerce is embedded in, or fitted with, a firm varies because firms themselves are unique with respect to their resource endowments [34, 49]. Straub and Klein [53] argue that e-commerce conveys to the firm a resource that cannot be substituted for or easily imitated (such as customer proprietary data and shared information). In addition, highly networked e-businesses can enable customers themselves to create value through information sharing and online communities [3, 26]. The exploitation of these resources will lead to performance advantages for net-enhanced organizations [31]. In this environment, resources can be combined and integrated into unique functionalities that enable distinctive capabilities within a firm [55]. Hence, firms benefit from the Internet when they embed e-commerce capability into their organizational fabric in a way that produces resource complementarity.

Complementarity of Resources

Complementarity represents an enhancement of resource value and arises when a resource produces greater returns in the presence of another resource than by itself. When resources have complementarities, their potential to create value is particularly enhanced [38]. Individual resources can be duplicated across firms, yet what is far more difficult to duplicate is the resource configurations of technologies, infrastructure, business processes, and the related synergies among them [6, 15]. For example, the integration of e-commerce capability and IT infrastructure may improve connectivity and responsiveness of firm IS (e.g., via connecting various legacy databases by common Internet protocols and open standards), which leads to greater efficiency and lower costs. A mainframe-based legacy IT system that only marginally improves performance under ordinary conditions may produce substantial advantages when combined with the Internet—its greater connectivity may allow more direct interaction with customers and tighter data sharing with suppliers [62].

The complementarity between online offerings and offline assets is the essence of “clicks-and-mortar” companies. Customers who buy products over the Internet value the possibility of getting support and service offered through bricks-and-mortar retail outlets, including the convenience of in-store pickup and return [62]. All of these suggest that traditional companies might be able to leverage their offline operations and unlock the potential value provided by complementarities among strategic assets [50].

Hence, the resource-based theory highlights the role of complementarity as a source (though not the only source) of business value of e-commerce. This view is integrated in the framework shown in Figure 1. Under this theoretical framework, a
complementary interaction typically enhances the business value for both resources. A Web-based network may enable a firm to improve its interaction with customers in the front end, while the IT infrastructure enhances data processing capabilities in the back office [62]. Integrated together, they produce an embedded, mutually reinforcing and performance-enhancing resource bundle. For these reasons, it is important to focus on resource complementarity as a feasible path to e-commerce value.  

Hypotheses

Based on our theoretical review, several hypotheses were derived. The theoretical discussions above lead us to believe that e-commerce capabilities combine with IT infrastructure and create resource complementarities that explain performance variance across firms. Existing IT infrastructure is critical to enabling e-commerce capabilities. Hence, our overall hypothesis is that e-commerce capability and IT intensity exhibit a strong reinforcing interaction effect in addition to their main effects, as illustrated in the conceptual framework in Figure 1. We will test both the main effects and the interaction effects in our empirical model.

In addition, we have several specific hypotheses exploring the relationships of e-commerce to four dimensions of firm performance (i.e., sales generation, cost reduction, asset return, and inventory turnover). As discussed in the literature, the use of e-commerce may improve information flow and reduce transaction costs, hence it will make a firm’s operations more efficient and employees more productive [26, 28, 48]. The global reach of the Internet may enable the firm to widen sales areas, reach out to new markets, create new distribution channels, attract new customers, and serve new geographic market segments outside its traditional market [1, 13]. All of these should help generate more revenues for the firm (as measured by sales per employee). This leads to our first hypothesis:

\[ H1: \text{Greater e-commerce capability, in conjunction with higher levels of IT intensity, is associated with higher revenue generation.} \]

Efficiency enhancements can be realized by removing barriers to information flow via connecting previously unconnected parties, and reducing information asymmetry through the availability of more accurate and timely information [34]. Improved information can reduce coordination costs and transaction costs [32]. By leveraging the extensive interconnectivity of the Internet, e-commerce further enhances transnational efficiency by enabling faster and more informed decision-making and reducing the likelihood of mistakes [26]. Taken together, this should help reduce the cost of operations.

\[ H2: \text{Greater e-commerce capability, in conjunction with higher levels of IT intensity, is associated with lower costs of operations.} \]

Similarly, the use of e-commerce may help improve the efficiency of asset utilization. The same asset base can generate greater returns due to the synergy and integration afforded by the Internet [8, 50]. Firms’ e-commerce initiatives may result in
varying degrees of e-commerce capability, and we might assume that the more developed this capability, the greater is the positive relationship to the firm’s return on asset. This leads to the following hypothesis:

\[ H3: \text{Greater e-commerce capability, in conjunction with higher levels of IT intensity, is associated with higher return on assets.} \]

Inventory management is another area that should benefit from the use of e-commerce. As documented in the supply chain literature, the poor quality of information exchange among suppliers and retailers led to inventory buffer buildup along the supply chain—a phenomenon termed as the “bullwhip effect” [33]. The use of Internet-based e-commerce, in conjunction with a firm’s installed IT infrastructure, should improve the coordination among partners along the supply chain and increase the visibility of information flow [61]. Better information visibility along the supply chain will reduce the need for inventory and make material flow more efficient [33]. This is the notion of replacing inventory with information [37]. Hence, by improving the speed and quality of information exchange through establishing electronic information linkages, the average inventory turnover rate should increase as the inventory stock decreases along the supply chain. This leads to our final hypothesis:

\[ H4: \text{Greater e-commerce capability, in conjunction with higher levels of IT intensity, is associated with higher inventory turnover.} \]

Methodology

Having discussed our theoretical framework and hypotheses, we move from the theoretical domain to the operational domain. We start with the operationalization of the variables and constructs, then proceed to test the hypotheses with empirical data from 114 retail companies.

Constructs and Measurement

As discussed earlier in the theoretical section, the measures used for this study fall into three categories: IT infrastructure, e-commerce capability, and performance measures. Their relationships are illustrated in the conceptual framework shown in Figure 1, where each set of variables is represented in a box. We describe these variables in turn below.

Performance Measures

To assess the value of e-commerce capability, we employ multiple financial measures of firm performance, as we believe that the business value of e-commerce is best measured by gains in financial performance [41]. Specifically, for each company, we measured performance along four dimensions: sales generation, cost reduction, asset return, and inventory efficiency. Four major variables were used to operationalize
these dimensions; they also served as dependent variables in the regression analysis later. As defined in Table A1, the performance measures were as follows: (1) Sales/Emp was calculated by dividing Sales by the total number of employees (Emp) in each firm. It is a common measure of profitability per employee in retail firms [16, 23]. (2) Cost of goods sold (COGS) was a generally accepted accounting measure that indicated the cost side of a firm’s operations [39]. To account for size differences among firms, a ratio of COGS/Emp was adopted. (3) Return on assets (ROA) was used to measure a firm’s efficiency of asset utilization, which was equal to operating income divided by total assets. This variable has been found to be an important firm performance metric [8, 44]. (4) Inventory turnover (INVX) was used to measure a firm’s operational efficiency, a key metric widely cited in supply chain management literature [33, 37].

All of these performance measures are objective measures in the sense that they are reflected on firms’ financial statements and SEC filings. Moreover, all four of these variables were ratios, rather than raw numbers, so as to minimize size effects.4

IT Infrastructure Measures

IT infrastructure represents a firm’s technology platform and information foundation from which enterprise applications emanate, and it is normally conceived to include hardware, software, networks, and data processing architecture [58]. The IT infrastructure of firms tends to be highly firm specific and evolves over long periods of time, during which gradual enhancements are made to reflect changing business needs [46]. While individual components of the firm’s overall IT infrastructure can be purchased in factor markets, an integrated infrastructure that is tuned to the specific needs of the firm cannot be acquired easily—nor can firms easily throw out old technologies and replace them with new ones. In reality, new technologies are often wrapped around the old and carefully stitched together in a complex ensemble of interlocking systems. Hence, the IT infrastructure mirrors an organization’s historic progress with the use of IT and tends to be highly path dependent in its accumulation [29].

In our study, IT infrastructure is measured in three levels of computing architecture (mainframes, mini-systems, and end-user computing) and networking. They are operationalized by multiple measures: MAIN, LAN, NODE, PC, HPW, and TERM, as defined in Table A2. These are objective, quantitative measures. While MAIN and PC have been used in the IT productivity literature [21, 39, 51], we introduced LAN and NODE to measure the connectivity of local area networks that have become an important part of the corporate IT infrastructure in recent years. HPW and TERM are added to enrich the measures of end-user computing, as PC alone may not be enough capture the diversity of end-user computing in many organizations.

Rather than using these measures individually, we conceptualize that an underlying structure exists among these various IT components and links them to an integrative construct. This construct, termed IT intensity, represents a firm’s overall IT infrastructure. Its operationalization will be discussed later.
E-Commerce Capability

Our earlier discussions lead us to believe that e-commerce capability is composed of multiple dimensions, including abilities to provide information, facilitate transactions, offer customized services, and integrate the back end and fulfillment. We reviewed academic literature and discussed with an expert panel that consisted of academics and practitioners. According to the concept of order life cycle [26], a typical order cycle takes place in several consecutive steps, as shown in Figure 2, which can be characterized into four phases: information-gathering activities, transaction activities, fulfillment activities, and customer service activities. E-commerce capability can be viewed as a firm’s ability to deploy and leverage e-commerce resources to support these order cycle activities. Corresponding to the four phases of order life cycle, e-commerce capability is conceptualized to consist of four dimensions: information, transaction, customization, and back-end integration.

**Information.** The first and most common dimension of e-commerce capability is information—that is, to provide useful information about the company and its products and services. For example, in order for the customer to make a direct purchase online, a product catalog is a minimum requirement. Information-related capabilities include product information, search, navigation, product review, and store locations.

**Transaction.** Information should lead to purchases or transactions; hence, the second dimension of e-commerce capability is to facilitate online transactions. This includes taking orders on the Web site, tracking the status of the order, and other capabilities that facilitate the synergy between the online and physical channels (e.g., in-store pickup, virtual communities).

**Customization.** The third dimension of e-commerce capability is to improve customer interaction. The interactive nature of the Internet allows companies to interact with customers more closely and offer personalized information and customized products/services. This includes configuration, content personalization, account management, real-time support, and return.

**Back-end Integration.** E-commerce enables companies to forge tight electronic integration to facilitate coordination, fulfillment, and inventory management in back offices and with external partners. As discussed in the theoretical section, integration is important for fitting the pieces together and linking disparate systems and fragmented resources so as to enable firms to get greater return from their existing investment. This includes integrating the Web-based front system with corporate databases and back-end IS, facilitating fulfillment and logistics management with suppliers and distributors via the Internet, forming EDI links to transfer invoice data, and sharing inventory data with suppliers. By measuring the degree of information-based integration
with suppliers, this dimension of e-commerce capability represents the networked connections that extend the firm to the outer world along the supply chain.

We recognized that there might be some variations among companies in terms of the features of products and the needs of customers, which adds extra challenges for the design of measures. After going through several cycles of consultation with industry experts and e-commerce managers (some of whom were sponsors of this project), we generated a list of e-commerce items and pretested them on ten companies. We then consulted with our expert panel to ensure that all variables were selected on solid theoretical grounds. Based on the feedback from these academic and industry experts, we revised the variables, refined the definitions, interviewed users, and pilot-tested an additional 21 companies. This process resulted in the 23 items that were used to characterize a firm’s e-commerce capability, as defined in Table A3. They are believed to fairly closely represent a typical set of e-commerce capabilities associated with business activities conducted over the Internet by an average retail company.

Some of these measures are designed to capture complementarities between the front-end e-commerce functionalities and back-end abilities (e.g., online transactions, integration to back-end databases, compatibility, common data standard, and inventory data sharing), and synergies between online offerings and offline resources (e.g., store locator, after-sale support, in-store pickup and return).

E-Commerce Capability: A Second-Order Construct

As conceptualized above, overall e-commerce capability manifests in four related, yet distinct, facets. These facets encompass informational, transactional, and relational capabilities and, taken together, underlie a firm’s overall ability to conduct businesses over the Internet. Based on the theoretical discussions, our expectation is that each of the developed scales in Table A3 uniquely measures its associated factor and that this system of factors taken together measures an overarching, second-order construct of e-commerce capability. The individual dimensions of e-commerce capability should not be considered in isolation from each other, but should be treated in a collective and mutually reinforcing manner. Hence, the e-commerce capability is conceptualized as a multidimensional construct, representing an integrative measure of the level of capability along the four dimensions: information, transaction, customization, and back-end integration.

Sample Selection: Why Retail Industry?

To test our hypotheses, we sought an industry that had undergone significant change as a result of IT and e-commerce. Retail is one of the largest industries in the United States, measured by both sales (roughly $500 billion annually) and employment (over 4 million employees). This industry has undergone significant transformations in the past 20 years with the introduction of increasingly sophisticated information technologies such as point-of-sale scanner, computer-based systems for inventory man-
agement, and EDI links with suppliers and distribution centers. More recently, the retail industry has experienced competition from Internet-based e-tailers, such as Amazon.com, Buy.com, and eToys. While the dot-com phenomenon was short lived, the online competition has pressed the large traditional retailers to aggressively deploy e-commerce initiatives and rapidly build their consumer-direct, cross-channel capabilities [23]. Retailers are using the Internet—once considered a threat—to increase sales, reduce costs, share inventory data, and make e-commerce integral to their existing bricks-and-mortar businesses. By integrating the front-end, Web-based systems with the back-end databases and legacy enterprise systems, many retailers are transforming themselves into net-enhanced “clicks-and-mortar” organizations [50].5

Yet retail companies exhibit significant differences in their IT infrastructure and e-commerce capabilities. Some retailers have been able to adapt to the Internet environment, while others have struggled to simply get a Web site operational, let alone devise a coherent e-commerce strategy [16]. It remains a managerial challenge how to become net enhanced by exploiting existing asset bases, the unique resources of the Internet, and the synergies between the physical and digital channels. These factors make the retail industry an appropriate testing field of our research.

Concentrating on a single industry allows us to control for extraneous industry factors that could confound the analysis. As we believe that the key potential of e-commerce lies in efficiency gains and cost reduction for large traditional companies, rather than pure-play dot-coms, our sample did not include any pure-play e-retailers. A list of 300 retailers was assembled based on four-digit SIC codes from Fortune 1000 and Ward’s Business Directory. After eliminating those companies for which we were unable to obtain data on back-end integration, we generated a database of 114 retailers (all of which are “clicks-and-mortar” companies) with SIC codes ranging from 5211 to 5990, including department stores, electronics retailers, computer and software stores, general merchandise, building materials, and miscellaneous retailers.6 Table 2 shows the sample characteristics of the data set.

Data Collection

Data used in this study were obtained from both primary data collection and secondary databases. First, data on e-commerce capabilities were collected through content analysis of each company’s Web site. These capabilities data were then matched with IT-infrastructure variables from the Harte-Hanks database of computer equipment (formerly the Computer Intelligence database), and financial-performance variables from Standard & Poor’s Compustat database.7

Through a series of intensive sessions, three groups of coders were trained to code the e-commerce functionalities according to our coding procedure. They performed detailed content analysis and examined each Web site of the companies on our list, filling out a standard data form on a five-point Likert scale. A random sample of 31 Web sites was used for reliability testing. Two groups of the coders analyzed the full Web sites. The third group reviewed the items on which disagreement occurred, and a majority rule was used to determine the coding. Intercoder reliability was then
Overall intercoder reliability of 0.91 was achieved. In addition to the pretesting and pilot study, we conducted two rounds of data collection, conducted in 2001 and 2002, respectively. The first round was mainly to test the coding procedure.

While this method worked well for customer-oriented e-commerce functionalities, we encountered difficulty in collecting data on back-end integration, which might not be directly observable from the Web site. To collect data on back-end integration, we designed a survey of IT executives and e-business managers, asking a short list of specific questions related to back-end integration (shown at the bottom of Table A3). Each of these items was reviewed for its content, scope, and purpose (content validity). To increase the response rate, the survey was kept brief and specific. The execution of the survey was managed by a professional survey firm, which had been conducting retail IT surveys for over ten years and had accumulated considerable experience and a well-connected network and database of CIOs in the retail industry. After we received the data, we checked for consistency and validity. Nonresponse bias was assessed, and no statistically significant differences were found. The responses were then incorporated into the coding of e-commerce capabilities.

### Empirical Assessment of the Constructs

The theoretically proposed structure of e-commerce capability was empirically assessed through a series of confirmatory factor analyses (CFA) using AMOS 4.0. We followed a multistage approach for assessing the measurement properties to minimize potential confounding issues. First, we examined the validity of the first-order constructs representing the four dimensions of e-commerce capability. Second, we tested the validity of the second-order e-commerce capability construct. Third, we examined the IT intensity construct. Finally, we put the e-commerce and IT constructs together and tested the overall model.
E-Commerce Capability: First-Order Factors

Following our conceptual model, a factor was created from individual e-commerce functionality indicators for each of the four dimensions of e-commerce capabilities. The factor analysis confirmed that the e-commerce indicators loaded well to the four corresponding factors—information, transaction, customization, and back-end integration, respectively. Most loadings were significant, except for a few items (ec4, ec9, ec15–16, and ec23). After eliminating these insignificant items, all factor loadings were above the typical cutoff value of 0.4 (most were above 0.5), as shown in Table 3, indicating evidence of good convergent validity [20].

Validity

Validity consists of content and construct validity. Content validity is the degree to which items in an instrument reflect the content universe to which the instrument will be generalized [52]. Content validity was verified by checking the various indicators’ managerial meanings and by a careful literature review. The items used in this study were designed based on solid theoretical grounds and were distilled from extensive literature review and field interviews. We felt that our carefully designed instruments, followed by checks, pretests, and balances imposed during and after the data collection, added to the confidence we can place in the content validity of our measures. Meanwhile, construct validity is the extent to which an operationalization measures
the concepts that it purports to measure [52]. *Convergent validity* was done by checking the critical ratios (t-statistics) of each factor. They were found to be significant, as reported in Table 3. By comparing construct variance extracted with correlations among constructs, *discriminant validity* was found to be acceptable as well [20].

Reliability

Reliability is an indication of measurement accuracy—that is, the extent to which an instrument produces consistent or error-free results. Cronbach’s α reliabilities in the test ranged from 0.72 to 0.91, hence *internal consistency* appeared to be acceptable, as shown in Table 3. Further, composite reliability was evaluated and found to be similar, based on which we may conclude that the reliability for these constructs is adequate [52].

E-Commerce Capability: Second-Order Construct

As theorized earlier, e-commerce capability is a higher-order construct across multiple dimensions. As shown in Table 4, correlations among these first-order factors are statistically significant and of high magnitude, suggesting the existence of such a higher-order factor structure. The lack of negative correlations among these dimensions implies that a high value on one dimension does not preclude a high value on another dimension. On the other hand, correlations among the first-order constructs are below the suggested cutoff value of 0.90 [2], demonstrating that the factors are distinct from each other (discriminant validity). Hence, each of these dimensions is distinct, yet the e-commerce capabilities reinforce or complement each other. A second-order factor modeling approach can capture these correlations and explain them using a higher-order construct that is an integrative latent representation of e-commerce capability, as illustrated in Figure 3. Previous research notes that this operational perspective represents a theoretically strong basis for capturing complex measures [47].

As shown in Table 5, all the structural coefficients are of high magnitude (above 0.80) and exhibit significant critical ratios, providing evidence of good model fit and

<table>
<thead>
<tr>
<th>Construct</th>
<th>Information</th>
<th>Transaction</th>
<th>Customization</th>
<th>Back-end integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>1</td>
<td>0.671***</td>
<td>0.625**</td>
<td>1</td>
</tr>
<tr>
<td>Transaction</td>
<td>0.761***</td>
<td>1</td>
<td>0.724***</td>
<td>1</td>
</tr>
<tr>
<td>Customization</td>
<td>0.615***</td>
<td>0.815***</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Back-end integration</td>
<td>0.585***</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: *** p ≤ 0.01; ** p < 0.05.
convergent validity. The composite reliability was estimated from path loadings to be 0.92, indicating high reliability for the second-order construct. Therefore, on both theoretical and empirical grounds, the conceptualization of e-commerce capability as a higher-order, multidimensional construct seems justified.

**IT Intensity Construct**

The validity and reliability of the IT construct were also examined. As shown in Table 6, all factor loadings are significant and of high magnitude, suggesting adequate convergent validity. Composite reliability is 0.91, hence reliability for the IT construct appears to be high.
Overall Model Fit

Finally, we put the e-commerce and IT constructs together and tested the overall model. By comparing the constructs' average variance extracted (AVE) with the squared correlations ($\rho^2$) among constructs, discriminant validity was computed and found to be acceptable (i.e., AVE $> \rho^2$), as shown in Table 7. This provides empirical evidence that e-commerce and IT are two distinct constructs, as conceptualized earlier in the theoretical section.

Table 8 lists several goodness-of-fit statistics to assess how the above-specified model can explain the observed data from three aspects: absolute fit, incremental fit, and model parsimony. The insignificant $p$-value for the chi-square statistics implies a good overall fit. Five incremental fit indices are all above 0.9, the conventional cutoff point [20], suggesting an excellent model fit compared to a baseline model. As to the parsimonious fit, the normed chi-square is below 2.0, the upper threshold suggested by Carmines and McIver [11]. Root mean square error of approximation (RMSEA) is below the typical cutoff value, 0.08. Hence, the overall model satisfied these recommended criteria.

In conclusion, the overall fit statistics, validity, and reliability measures collectively lend substantial support for confirmation of the proposed model. This also reflects the fact that the items have been pretested and refined over several rounds of data collection.

Hypotheses Testing: Links to Firm Performance

HAVING DISCUSSED THE CONSTRUCTS and established their validity, we advance to the next phase of the research, focusing on empirical evaluation of the links to firm performance and testing the hypotheses proposed earlier via regression analysis.9

The Econometric Model

The model specifies the relationship between firm performance and a set of variables on e-commerce capability and IT intensity, while controlling for firm size and subindustry effects. The basic econometric relationship may be specified as follows:
where $EC$ stands for e-commerce capability; $IT$ denotes IT intensity; and $EC\times IT$ represents the interaction effect. $DV$ denotes the dependent variable that will be replaced in turn by each of the performance measures defined earlier. More specifically, the regression equation is

$$DV = \alpha + \beta_1 EC + \beta_2 IT + \beta_3 EC\times IT + (FirmSize + IndustryDummy + DV_{t-1}) + \varepsilon,$$  

(2)

where $\alpha$ is the intercept; the $\beta$’s are coefficients; $DV_{t-1}$ is the lagged value of the dependent variable; and $\varepsilon$ is the residual term that captures the net effect of all unspecified factors. The model includes both main and interaction effects, and suggests that a correlational relationship exists between the $DV$ and the independent variables ($IV$s).

Since our measurement has verified the reliability and validity, we can use this measurement model to form factor scores for e-commerce capability and IT intensity, which are then used as the independent variables in subsequent regressions.\(^{10}\)

### Control Variables

Some of the cross-sectional variations in performance can be explained only if controls are appropriately applied. To control for firm size and subindustry effects, we employed three control variables. (1) We chose to use a firm’s total assets, Log(Asset), as a control for firm size, which we found to be highly correlated to other size indicators.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Composite reliability</th>
<th>AVE</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-commerce</td>
<td>0.918</td>
<td>0.791</td>
<td>0.203</td>
</tr>
<tr>
<td>IT</td>
<td>0.911</td>
<td>0.605</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Goodness-of-fit Measures</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute fit</td>
<td></td>
</tr>
<tr>
<td>Normed chi-square</td>
<td>1.729</td>
</tr>
<tr>
<td>p-value</td>
<td>0.120</td>
</tr>
<tr>
<td>Incremental fit</td>
<td></td>
</tr>
<tr>
<td>Normed fit index (NFI)</td>
<td>0.949</td>
</tr>
<tr>
<td>Relative fit index (RFI)</td>
<td>0.920</td>
</tr>
<tr>
<td>Incremental fit index (IFI)</td>
<td>0.978</td>
</tr>
<tr>
<td>Tucker-Lewis index (TLI)</td>
<td>0.965</td>
</tr>
<tr>
<td>Comparative fit index (CFI)</td>
<td>0.977</td>
</tr>
<tr>
<td>RMSEA</td>
<td>0.072</td>
</tr>
</tbody>
</table>
such as total sales or number of employees. (2) Although all companies in our sample were from a single industry (retail), variations might still remain in subcategories. Hence we controlled for subindustry effects, because firms in different industry subcategories may deal with different types of products and customers. We employed sector dummies representing each firm’s primary two-digit SIC code as a control of the subindustry effects specific to that subcategory. (3) We also employed a third control variable, prior firm performance, $DV_{t+1}$, to test whether prior firm performance would dilute the significance of the proposed relationships. It also helps reduce the adverse impact of serial correlation in the regressions. In addition, it is straightforward to reformulate the above model to the error-correction form, which presents the change in the DV as results of the IV plus part of the deviation from the long-run equilibrium. This is useful to rule out possible spurious relations [19]. Having cleared these statistical issues, next we discuss the major empirical results, corresponding to the hypotheses defined in the “Hypotheses” subsection.

**Interaction Effects of IT and E-Commerce**

Regression results are summarized in Table 9. The overall models are statistically significant across all four regressions, as suggested by the adjusted $R^2$ and the $p$-values. Interaction effects are found to be significant and positive for Sales/Emp, ROA, and INVX, but negative for COGS/Emp. This is actually consistent with the theoretical predictions made earlier. IT and e-commerce jointly improve Sales/Emp, ROA, and INVX, but reduce cost of operations (hence, the negative coefficient).

Mathematically, the interaction effect can be expressed by taking the first derivative of Equation (2):

$$\frac{\partial DV}{\partial EC} = a + bIT.$$  

(3)

High IT-intensity firms exhibit a stronger relationship between e-commerce capability and firm performance than low IT-intensity firms. Hence, e-commerce and IT exhibit a mutually reinforcing complementarity. To further test the significance of the interaction effects, we compared the incremental $R^2$ between the full model (with interaction terms) and the partial model (without the interaction terms). The result is reported in the lower rows of Table 9. The incremental $R^2$ ranges from 0.03 to 0.12, meaning that additional 3~12 percent of explained variance has resulted from the inclusion of the interaction effects. To compare the partial model against the full model, a Wald test was performed, and the differences were found to be statistically significant. Based on this, we rejected the partial model in favor of the full model [19, p. 153].

**Revenue Generation**

To test H1, we regressed sales per employee against the set of independent variables specified in Equation (2). The adjusted $R^2 = 0.379$ and $p$-value < 0.001 (see column 2
Table 9. Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Sales/Emp</th>
<th>COGS/Emp</th>
<th>ROA</th>
<th>INVX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.379***</td>
<td>0.348***</td>
<td>0.361***</td>
<td>0.312***</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>IVs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-commerce capability</td>
<td>0.251**</td>
<td>–0.201*</td>
<td>0.104</td>
<td>0.129*</td>
</tr>
<tr>
<td>IT intensity</td>
<td>0.257**</td>
<td>–0.198*</td>
<td>–0.150*</td>
<td>0.355***</td>
</tr>
<tr>
<td>Interaction $EC \times IT$</td>
<td>0.309**</td>
<td>–0.306**</td>
<td>0.163*</td>
<td>0.207**</td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$DV_{t–1}$</td>
<td>0.013*</td>
<td>0.007</td>
<td>0.686**</td>
<td>—</td>
</tr>
<tr>
<td>Firm size: log (asset)</td>
<td>0.044</td>
<td>0.030</td>
<td>0.011*</td>
<td>–0.013*</td>
</tr>
<tr>
<td>Subindustry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIC2 = 52</td>
<td>0.686</td>
<td>0.507**</td>
<td>0.049*</td>
<td>–0.341</td>
</tr>
<tr>
<td>SIC2 = 53</td>
<td>0.090</td>
<td>0.083</td>
<td>0.158</td>
<td>0.402</td>
</tr>
<tr>
<td>SIC2 = 54</td>
<td>0.211</td>
<td>0.135</td>
<td>0.069</td>
<td>–0.259</td>
</tr>
<tr>
<td>SIC2 = 55</td>
<td>1.532***</td>
<td>1.514**</td>
<td>0.273</td>
<td>–0.146</td>
</tr>
<tr>
<td>SIC2 = 56</td>
<td>0.100</td>
<td>0.047</td>
<td>0.429</td>
<td>–0.440</td>
</tr>
<tr>
<td>SIC2 = 57</td>
<td>0.503</td>
<td>0.364</td>
<td>0.621*</td>
<td>–0.448</td>
</tr>
<tr>
<td>SIC2 = 58</td>
<td>–0.010</td>
<td>0.003</td>
<td>0.160</td>
<td>1.463***</td>
</tr>
<tr>
<td>SIC2 = 59</td>
<td>0.135</td>
<td>0.082</td>
<td>–0.092</td>
<td>–0.378</td>
</tr>
<tr>
<td>Model test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incremental adj. $R^2$</td>
<td>0.029</td>
<td>0.055</td>
<td>0.026</td>
<td>0.117</td>
</tr>
<tr>
<td>Wald test</td>
<td>2.396**</td>
<td>3.095**</td>
<td>4.126**</td>
<td>5.639***</td>
</tr>
</tbody>
</table>

Notes: Significance: *** $p \leq 0.01$; ** $0.01 < p \leq 0.05$; * $0.05 < p \leq 0.10$. If $p$-value is listed as 0.000, it means $p < 0.001$. Each column represents a regression with the dependent variable listed on the top row. Entries reported above are standardized regression coefficients. The White heteroskedasticity-consistent variance estimator was used for all cases when the White heteroskedasticity statistic was significant at the 5 percent level. —: Previous year’s INVX was not included, as the serial correlation was so strong that the regression was overwhelmed by INVX$_{t–1}$, and all other IVs became insignificant.
in Table 9), hence we can reject the null hypothesis. Both e-commerce capability and IT intensity were significant and positive. Their interaction effect was positive and statistically significant. Thus H1 is supported.

Cost Measures

To test H2, COGS/Emp was regressed in the model of Equation (2). The adjusted $R^2 = 0.348$ ($p < 0.001$) indicates a reasonably good overall model (column 3 of Table 9). E-commerce capability was marginally significant with a negative coefficient. A similar result was found for IT intensity. The interaction effect was found to be statistically more significant. Its negative coefficient implies that the interaction effect tends to be associated with decreased cost, meaning that IT and e-commerce combined can help reduce costs of operations, although each of them alone may not be as effective as their combination. This result is consistent with the theoretical notions of complementarity.

Return on Assets

To test H3, ROA was used as the DV in the model specified in Equation (2). As shown in column 4 of Table 9, the adjusted $R^2 = 0.361$ ($p < 0.001$) indicates a reasonably good fit of the overall model. The interaction effect was positive and significant, indicating that the integration of IT and e-commerce is associated with increased return on asset. The main effect of e-commerce capability was in the right direction but statistically insignificant, while the IT intensity was marginally significant but negative, which was not expected. The negative relationship between IT and ROA suggests that an emphasis on IT alone cannot ensure a high return on assets. In fact, IT investments were often recorded as assets in many companies. More IT assets may not necessarily generate higher operating income; this would lead to a lower ROA.

Inventory Turnover

Using INVX as the dependent variable as proposed in H4, the regression model of Equation (2) was found to be statistically significant, as shown in the last column of Table 9. E-commerce capability was found to be marginally significant, indicating a positive association of e-commerce capability to INVX. Similarly, the coefficient of IT intensity was positively significant with a higher magnitude, suggesting that a more IT-intensive infrastructure helps to make inventory management more efficient. The interaction effect was significant as well. This result provides empirical evidence of the positive association of e-commerce capability and IT intensity with supply chain efficiency, consistent with the theoretical predictions made in the second section. The result also seems to support the theoretical argument that better information flow along the supply chain can substitute for physical inventory [37].
Discussions and Implications
Interpretation of Key Findings
The findings reported above show that e-commerce capability and IT infrastructure exhibit positive relationships to firm performance measures, suggesting that they have contributed to business value at the firm level. The significant interaction effects indicate that the integration of e-commerce capability and IT infrastructure reinforced the main effects. This reveals that e-commerce capability and IT infrastructure are not simply additive; mutually enhancing synergies exist between legacy IT systems and Internet-based e-commerce capabilities. Integrated together, they produce an embedded, performance-enhancing resource bundle. It is possible that the integration of e-commerce capability and IT intensity improves connectivity and responsiveness of firms’ IS, which leads to lower costs and greater efficiency. Taken together, the overall results are consistent with the resource-based theory, especially our complementarity arguments made earlier in the theoretical section.

In the IT business value literature, many earlier studies did not find performance effects because they dealt with IT components such as personal computer and IT capital but did not take into account the issues of resource synergies [5, 12]. The “productivity paradox” observed in various studies has been attributed to variation in methods and measures used in the analyses [21], yet we offer an additional explanation: Ignoring complementarities in business value measurement implies that the impact of IT could be seriously underestimated. Our results emphasized the significance of integration of resources. This itself offers a theoretical extension to the IT business value research stream.

On the methodology side, this study introduces a higher-order construct to measure e-commerce capabilities. The results suggest that e-commerce capability can be more parsimoniously represented as a higher-order factor structure than as a set of correlated first-order factors. As empirically validated, this approach is taken to be more rigorous than simply adding the items up [47]. Although showing recent signs of advance, there has been a gap in the IS literature with regard to this kind of theoretical development and empirical examination [44].

Limitations
Our methodology required tradeoffs that may limit the use of the data and interpretation of the results. We focus on key limitations here. First, although we have invested considerable effort in data collection, our data set is limited to the retail industry. We do not know how the results will carry through in other industries, although the systematic nature of our investigation adds to our belief that the framework can be extended to other industries. Second, because our data set is cross-sectional in nature, we can only show associations, not causality, and we cannot demonstrate the long-term sustainability of the relationships. Third, our data set focused on variables related to e-commerce and IT resources only. They did not capture managerial skills
and other intangible resources related to the organizational use of e-commerce (though these other resources might be correlated to IT and e-commerce resources). It might be fruitful to explore other resources more broadly, especially organizational, managerial, and human resources [9], and the synergy between online and offline assets as complementarity may exist among these resources as well [62]. Finally, our sample size of 114 firms is relatively small. Because of the small size, we did not use SEM. Hence, our regression results should be viewed with caution, because regression analysis, although valid as a research methodology, may not give a global picture of the whole situation.

Implications for Research

These limitations suggest avenues for further research. For instance, replicating this study across a broader sampling frame will help validate the results. Also, collecting more extensive data on the integration of front-end e-commerce and back-end IT will be valuable for a more in-depth test of the theoretical notion of complementarity, which will also help tighten up the link between the theory and the empirical model. More importantly, e-commerce is a dynamic capability [17, 55] that requires firms to build and then dynamically reconfigure in order to align with changing technology and business environments. To investigate the dynamic nature of e-commerce capability and how the relationships with firm performance might change over time, we plan to enhance the database over time to pave the way for a longitudinal study. As we can see, this current study provides a base upon which future research can build. There is clearly much more work to be done.

We hope this study offers implications for other researchers who are interested in the business value of IT in e-commerce environments. We have developed several e-commerce constructs, extended the complementarity theoretic perspective to the e-business domain, and provided some initial evidence to show that this seems a promising framework for studying the value of e-commerce. As discussed earlier, the IT-value literature has traditionally dealt with individual IT components, paying insufficient attention to the issues of complementarities among various resources. Future studies should emphasize these relationships. In addition, our research methodology can be extended to other industry sectors, such as manufacturing and services, and can be applied to developing and other developed economies.

Although our data did not capture enough details about organizational and managerial skills regarding the use of e-commerce, field interviews and case studies [30, 36] have shown that managers in high-IT-intensity firms tend to develop substantial skills and build appropriate business processes and organizational structures over time for effectively managing the synergies between the front end and the back office. These managerial skills and organizational structures tend to be correlated with the level of IT investment and e-commerce sophistication. By providing a framework and a set of instruments, this study provides a base for more rigorous test when more extensive data become available.
Implications for Management

Our research results have managerial implications as well. By modeling e-commerce capability as a holistic construct, it becomes clear that organizations must simultaneously develop each of the first-order capabilities to achieve high levels of e-commerce and IT capability. After several years’ investments, most firms are now competent in terms of information and transactions, yet the other two dimensions of e-commerce capability—customization and back-end integration—are still the weak links and deserve more efforts. Organizations should strive to achieve a strategic fit in which e-commerce and IT become integrated and embedded in the firm’s business processes. For managers, positioning e-commerce to leverage other complementary resources such as IT infrastructure and connectivity with suppliers should be a priority. As shown by empirical evidence, isolated investments may actually increase costs and reduce return on assets; a state of alignment and integration is important. This points to resource complementarity as a feasible path to e-commerce value—companies need to enhance the integration between front-end e-commerce capability and back-end IT infrastructure in order to reap the benefits of e-commerce investments. Getting more returns from existing investments might be more productive than making new investments in hardware and software systems. This is especially timely in an economic climate where managers face heightened pressure to justify e-commerce investments, and IT budget is getting increasingly scrutinized.

Conclusions

The IS literature has numerous studies about the “productivity paradox.” Yet the recent rise and fall of the e-commerce phenomenon has renewed or increased the urgency for understanding the relationship among e-commerce capability, IT investment, and firm performance. With the poor performance of IT firms and the burst of the dot-com bubble, there has been a trend toward downplaying the effect of IT and e-commerce, as evidenced by opinions stating that IT investments have no beneficial effect on economic productivity [35]. This may have far-reaching implications for firms’ investment decisions in new generations of IT and e-business. Underinvestment is a significant risk, as it may undercut the future growth of an organization.

Using the resource-based theory to investigate the business value of e-commerce, this study extends the IT business value literature to electronic business environment. The complementarity argument provides a theoretical perspective for studying the contexts and conditions under which e-commerce produces business value at the firm level. Particularly, it points toward a balanced perspective, one that acknowledges the commodity view of IT components while allowing that superior performance may arise from combining e-commerce capabilities with IT infrastructure and other complementary resources.

We have found that the complementarity of IT infrastructure and e-commerce capability indeed delivers a value proposition reflected upon firms’ performance, which
exceeds that of any of these effects individually, hence providing empirical evidence of the complementary synergy between IT infrastructure and e-commerce capability.

To sum up, this paper contributes theory-based synthesis and empirical evidence to an e-commerce literature that is still fragmented. Our results provide a theoretical framework for understanding how e-commerce capability and IT infrastructure may be viewed as complementary resources. We see this research as but a first step toward understanding the complex relationships among electronic business, organizational capabilities, and firm performance. We hope that these initial results will stimulate others to engage in more research to refine the theory and measurement of e-commerce capability and organizational performance.

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Notes

1. Throughout this paper, we use three related terms: e-commerce initiatives, e-commerce capabilities, and e-commerce functionalities. E-commerce initiatives taken by firms result in e-commerce capabilities, which are measured by e-commerce functionality indicators.

2. With this work, we are not attempting a complete model of the various organizational resources related to IT and e-commerce investment. We are instead making a more modest point that the Internet brings e-commerce resources that should be included in any such model but are new to the literature.

3. The bullwhip effect is defined as the artificial amplification of volatility in supply chains due to information distortion and demand uncertainties [33].

4. These variables indicate different aspects of a firm’s business performance; they do not necessarily move in the same direction. Hence, we have no theoretical basis to form an overarching performance construct. This was later empirically tested. If we were to form one construct based on these four performance measures, the Cronbach’s $\alpha$ was 0.293. Such a low $\alpha$ indicates that the four measures do not vary in the same direction.

5. For example, Home Depot wired 1,000 stores with broadband Internet access and built Web sites so shoppers can buy online either in stores or at homes. “The Web helps us to increase the bandwidth of the business and leverage our physical-store capabilities,” according to Ron Griffin, CIO of Home Depot [22].

6. The sample includes such companies as Best Buy, CompUSA, Circuit City, US Office Products, Value America, PC Connection, Office Depot, OfficeMax, Wal-Mart, Costco, Home Depot, Homebase, Lowe’s, Kohl’s, Staples, JC Penney, Target, Lands’ End, Toys “R” Us, Borders, Walgreens, Gap, Ross, and Sears.

7. The methodology of matching data from different sources to enhance the scope of data set was recommended by several recent studies in the IS literature. For example, studies [8, 44] matched subjective ratings on IT leaders with objective data on firm performance from Compustat.
8. We also performed an exploratory factor analysis (EFA) without constraining the number of factors and found that the items loaded well to their corresponding factors and that the CFA factor structure held well.

9. In principle, another equally valid approach is to use structural equation models (e.g., LISREL) to assess the paths to firm performance. We chose to use regression analysis for the considerations of sample size. Hair et al. [20] suggested that the appropriate ratio of sample size to the number of parameters estimated be maintained at 10:1 or higher for structural equation models [20, p. 604]. Our sample size is too small to meet this requirement, especially in light of the large number of interaction terms to be estimated. This also makes it difficult to interpret the results of interaction effects [24, 45].

10. AMOS estimates factor score weight when fitting the proposed measurement model. The factor score weight table gives regression weights for predicting the unobserved latent variables from the observed variables. Thus, we can multiply each indicator by its estimated weight, add up all weighted indicators, and use the weighted sum to form a factor score, which can then be used as an independent variable in regression analysis. This approach is more rigorous than simply adding up the factors, because it takes into account the appropriate weight of each factor.

11. Considerable evidence in the finance literature indicates that current financial performance is often strongly related to prior financial performance [18]. Analyses conducted without controlling for this effect may overstate the significance of IT or e-commerce variables.

12. Some SIC controls were significant, indicating that certain industry-related effects exist in the retail industry. Size was found significant only for ROA and INVX.

REFERENCES


### Appendix. Variables and Measures

#### Table A1. Performance Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales/Emp</td>
<td>Revenue per employee</td>
<td>It is calculated by dividing Sales by the total number of employees (Emp) in each firm. It measures the productivity per employee in retail firms.</td>
</tr>
<tr>
<td>COGS/Emp</td>
<td>COGS per employee</td>
<td>It is calculated by dividing cost of goods sold (COGS) by Emp. COGS represents all costs directly allocated by the company to production, such as direct materials and supplies, direct labor, and overhead.</td>
</tr>
<tr>
<td>ROA</td>
<td>Return on asset</td>
<td>It is a ratio of operating income to total asset. This ratio is slightly different from the typical accounting definition of ROA, where net income is often used. Instead, operating income is used in this study to minimize the confounding effect of tax, interest, and so on.</td>
</tr>
<tr>
<td>INVX</td>
<td>Inventory turnover</td>
<td>INVX is calculated from COGS divided by the average inventory level. It represents the number of times the average inventory of a firm is sold over a given time period (typically a year). It is an indicator of a firm's operational efficiency along its supply chain.</td>
</tr>
</tbody>
</table>

#### Table A2. IT Infrastructure Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>Number of PCs</td>
<td>Total number of personal computers (including laptops) in the company.</td>
</tr>
<tr>
<td>LAN</td>
<td>Total number of local area networks</td>
<td>Total number of installed local area networks (LANs) in an organization, which represents the extent of the connectivity of the organization's IT infrastructure. In general, LANs are measured by “bridges.”</td>
</tr>
<tr>
<td>NODE</td>
<td>Number of nodes</td>
<td>Total number of installed LAN nodes.</td>
</tr>
<tr>
<td>MAIN</td>
<td>Number of mainframes</td>
<td>Total number of installed A370 IBM computers and other general-purpose (non-A370) mainframe computers.</td>
</tr>
<tr>
<td>HPW</td>
<td>Number of workstations</td>
<td>Total number of high-performance workstations.</td>
</tr>
<tr>
<td>TERM</td>
<td>Number of terminals</td>
<td>Total number of installed terminals in the organization.</td>
</tr>
<tr>
<td>IT intensity</td>
<td>Factor score of the IT construct</td>
<td>The factor score of the IT construct using the above seven IT infrastructure variables (PC, LAN, NODE, MAIN, MINI, HPW, and TERM) as indicators in CFA.</td>
</tr>
</tbody>
</table>
Table A3. Structure of E-Commerce Capabilities

<table>
<thead>
<tr>
<th>E-commerce capability</th>
<th>Indicators</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>ec1  Product information</td>
<td>This signifies whether a product catalog or other product availability information is available online. In order for the customer to make a direct purchase online, a product catalog is a minimum requirement.</td>
</tr>
<tr>
<td></td>
<td>ec2  Search capability</td>
<td>This indicates whether the Web site offers attribute-based search capability. It assists customers in finding a specifically needed product quickly.</td>
</tr>
<tr>
<td></td>
<td>ec3  Product review</td>
<td>Information provided to potential customers about third-party reviews or customer ratings of the product quality and usability.</td>
</tr>
<tr>
<td></td>
<td>ec4  Virtual experience</td>
<td>This refers to the ability to allow customers to try or experience the product through virtual reality, 3D graphics, animation, and so on.</td>
</tr>
<tr>
<td></td>
<td>ec5  Store locator</td>
<td>The Web site helps the customer to find out if a retail store is located in a particular region (usually based on zip code or address).</td>
</tr>
<tr>
<td>Transaction</td>
<td>ec6  Buy capability</td>
<td>This enables the customer to place the order online via the Web site.</td>
</tr>
<tr>
<td></td>
<td>ec7  Online order tracking</td>
<td>The functionality that allows customers to track the status of the order on the Web site.</td>
</tr>
<tr>
<td></td>
<td>ec8  In-store pickup</td>
<td>Customers can order online and pick up in local stores.</td>
</tr>
<tr>
<td></td>
<td>ec9  Virtual communities</td>
<td>Whether the Web site offers an online community for consumers to share information, experience, concerns, and so on.</td>
</tr>
<tr>
<td></td>
<td>ec10 Security indicator</td>
<td>Indications about the security of transactions and customers’ sensitive data, such as posting of a third-party security company’s evaluation of the firm’s Web site.</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>E-commerce capability</th>
<th>Indicators</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customization</td>
<td>ec11 Configurator</td>
<td>This enables the customer to configure product features via the Web site.</td>
</tr>
<tr>
<td></td>
<td>ec12 Content personalization</td>
<td>This functionality allows online visitors to customize the content viewed on the Web site.</td>
</tr>
<tr>
<td></td>
<td>ec13 Account management</td>
<td>The customer can register online and set up a personalized account to gain access to private messages, product update, and express checkout.</td>
</tr>
<tr>
<td></td>
<td>ec14 Real-time support</td>
<td>Online technical support handled by live representatives through Web-enabled voice communication, instant messaging, or a 1-800 number.</td>
</tr>
<tr>
<td></td>
<td>ec15 After-sale support</td>
<td>The Web site posts product updates, e-mail based support, warranty registration, maintenance, and repair FAQs, or other after-sale service.</td>
</tr>
<tr>
<td></td>
<td>ec16 Return</td>
<td>Information, procedure, and mechanism to facilitate the return or exchange of products (e.g., return the item to a nearby store).</td>
</tr>
<tr>
<td>Back-end integration</td>
<td>ec17 Integration to back-end systems</td>
<td>Integrate the Web-based front system with corporate databases and back-end information systems.</td>
</tr>
<tr>
<td></td>
<td>ec18 Common data standard</td>
<td>Do the back-office systems share common standards of data and communication?</td>
</tr>
<tr>
<td></td>
<td>ec19 Compatibility</td>
<td>The extent to which the back-end systems are compatible with each other and with the Internet protocol.</td>
</tr>
<tr>
<td></td>
<td>ec20 EDI links</td>
<td>Whether the firm uses EDI or extranet to transfer invoice data with its suppliers and business partners.</td>
</tr>
<tr>
<td></td>
<td>ec21 Inventory data sharing</td>
<td>Allows suppliers to check inventory in stores and warehouses through electronic links, and facilitates auto replenishment.</td>
</tr>
<tr>
<td></td>
<td>ec22 Fulfillment</td>
<td>A functionality to facilitate shipment and logistics management with suppliers and distributors via the Internet.</td>
</tr>
<tr>
<td></td>
<td>ec23 Delivery logistics</td>
<td>Whether customers can log on to the Web site to view the status of the order processing and shipment.</td>
</tr>
</tbody>
</table>