Complexity of service value networks: Conceptualization and empirical investigation

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This paper explores how service value is created in a network context and how the structure and dynamics of the value network as well as customer expectations influence the complexity of the services ecosystem. The paper then discusses what transformative role information and communication technology (ICT) plays in coordinating and delivering value and managing this complexity. A conceptual model is developed for understanding and investigating the nature, delivery, and exchange of service value and assessing the complexity of a service value network. Three central arguments are presented. First, value in the services economy is driven and determined by the end consumer and delivered through a complex web of direct and indirect relationships between value network actors. Second, the complexity of service value networks not only depends on the number of actors but also on the conditional probabilities that these actors are involved in delivering the service to the consumer. Third, ICT plays a central role in reducing complexity for consumers by providing greater levels of value network integration, information visibility, and means to manage and anticipate change.

INTRODUCTION

The services sector is undeniably a key engine of growth in today's leading global economies. Accounting for nearly 80 percent of the U.S. gross domestic product (GDP), the sector comprises a diverse mix of economic activities, ranging from traditional services such as transportation, government, hospitality, wholesale, and retail, to business activities such as finance, consulting, logistics, information technology (IT), telecommunications, software, and health care.[1] The transition to a services-based economy is further substantiated by the newly created North American Industrial Classification System (NAICS),[2] in which 16 of 20 sectors are services related and 250 of the new 358 new industries produce services.[3]

There are many reasons for the growth of the services sector: increasing competition in a global economy, pressure to innovate, and changing

customer demands and expectations have led traditionally products-based companies and manufacturing leaders to focus on services in "defense against commoditization of goods and a strategy for productivity, growth and retention."[3] Two frequently cited examples are General Electric Company and IBM Corporation, whose services groups have represented the strongest revenue businesses over the past few years and are expected to continue so in the future.[1,3] Given this growing importance of services in the global economy, it is therefore no surprise that both the academic and practitioner communities are showing great interest in exploring and developing the science, management, and engineering of services.[1,3,4,5,6]

Despite the increasing interest in services, there does not appear to be a common understanding of what phenomena create and drive value and what impact the structure and dynamics of services ecosystems have on market complexity. It has been argued that existing models, traditionally used for describing the exchange of physical products, will not apply in the services context, in which close interactions between suppliers, service providers, and customers exist, where knowledge is created and exchanged, and experiences, capabilities, and relationships are an integral part of the transaction.[1,3,5,6,7] New models and contexts must therefore be developed.

The aim of this paper is to address this void by exploring how service value is created in a network context, how the structure and dynamics of the value network as well as customer expectations influence the complexity of the services ecosystem, and what transformative role information and communication technology (ICT) plays in coordinating and delivering value and managing this complexity.

A conceptual model is developed for understanding and investigating the nature, delivery, and exchange of service value and assessing the complexity of a service value network. In doing so, we wish to emphasize three points that we consider to be lacking in present studies of services and value networks. First, value in the services economy is driven and determined by the end consumer and delivered through a complex web of direct and indirect relationships between value network actors. Second, the complexity of service value networks not only depends on the number of actors but also on the conditional probabilities that these actors are involved in delivering the service to the consumer. We found the concepts of information theory to be particularly useful in assessing market complexity. Thirdly, ICT reduces both consumer-perceived and market complexity by providing a greater level of value-network integration, information visibility, and means to manage and anticipate change.

This paper is structured as follows. In the next section we provide the theoretical background for our paper. We then describe and introduce the notion of a service value network, describe the elements that drive and define it, and conceptualize its complexity. Next, we illustrate our conceptual model with examples from the aerospace, automotive, retail, health-care, and telecom industries. We then discuss the influence of ICT on the development of service value networks. The last section provides some concluding remarks and discusses future research opportunities.

THEORETICAL BACKGROUND

The study of networks and network phenomena is far from new. It has been a topic of interest in many scientific fields. In the sciences, biologists have examined networks of interactions between genes and proteins to study the behavior of organisms, to model diseases, or to explore food webs.[8,9,10] Neuroscientists have used the network approach to explore the workings of the brain.[11] Engineers and computer scientists have studied information and technological networks, such as the electric power grid, telecommunications networks, and the Internet.[10,12,13] Networks have also been studied in the social sciences. Sociologists have examined the connection of people to understand the functioning of human society.[14] Economists have investigated how innovations diffuse through a network of individuals and organizations.[15]

The study of networks is also the subject of increasing attention in the management and marketing literature. It has been used to explore the economic behavior and connectedness of business and industrial networks,[16,17,18] and to study the concepts of resource allocation,[19] collaborative advantage,[20] the role and importance of alliances, joint ventures, and cooperative strategies,[21] and customer-relationship management (CRM) theory.[22]

The concept that organizations exist in networks is based on the premise that firms do not merely operate in dyadic relationships, but are deeply embedded in complex economic systems consisting of numerous interorganizational relationships.[23] It replaces the traditional view of a value chain introduced by Porter, which assumes a linear value flow and where resources flow in dyadic relationships from raw material providers to manufacturers to suppliers to customers.[24] Critics found that Porter's approach did not adequately describe the multidirectional nature and complexities of the potential myriad of business-to-business (B2B), business-to-consumer (B2C), and emerging consumer-to-consumer (C2C) relationships observed in business environments today.[25,26,27] Indeed, products and services are now designed, created, delivered, and provided to customers via complex processes, exchanges, and relationships.[28] It is argued that value chains have evolved into value grids,[29] more commonly referred to as value networks,[25,30,31,32] which are characterized by a complex web of direct and indirect ties between various participants, or actors, all delivering value either to their immediate customer or the end consumer.

The value network approach assumes the organization to be part of a larger network of organizations that together create (i.e., cocreate) value.[27,30,33] Some researchers have even argued that value nets represent extended enterprises.[34] The value network approach thus views the activities of an organization in a holistic, rather than a fragmented, manner. Consequently, the network perspective shifts the focus of a resource-based view of the firm to a perspective in which examination of resource dependency, transaction costs, and actor-network relationships is critical.

Brandenburger and Nalebuff identify several types of actors in a value network that affect the ability of a firm to produce and deliver value to an intermediate or final customer or end consumer: suppliers, other customers, competitors, and complementors.[33] (Business A is a complementor of business B if customers value A's products more when used in conjunction with B's products.) In addition to these types of actors, studies have also emphasized that value networks are shaped and influenced by government agencies, research and development institutions, educational institutions, and industry associations.[23,31]

Using a value network approach, one must not only understand who the actors are, but also have an understanding of the types and extent of relationships involved. Relationships may be formed with any actors in a value network.[35]

Several characteristics and attributes have been used to describe a network. Network size refers to the number of actors in the network. Network connectedness and density are commonly used measures to denote the relative number of ties in the network that link actors.[17] It is calculated as a ratio of the number of relationships that exist in the network, compared with the total number of possible ties if each network actor were tied to every other.[36] Dense networks, therefore imply a higher level of connectedness to value network firms. Another important characteristic is the position of a firm in the network. Using arguments from resource-dependency theory, the more dependent organizations are on the focal firm, the more control the focal firm has.[36] The position in the network thus often determines the level of influence on other network actors.

SERVICE VALUE NETWORKS

There has been a long tradition in the literature to distinguish how products and services are produced and consumed.[37,38,39] Services were differentiated from products on the basis of four characteristics, namely intangibility, heterogeneity, inseparability, and perishability.[39] However, as the study of services has evolved and many of today's offerings are characterized by bundled solutions comprising products and services, the differentiation between products and services is increasingly blurring.[40] Building on Levitt's argument that "everything is a service,"[41] we further argue that the examination of services and service value should not be distinguished from that of products; instead, products themselves should be merely seen as "vehicles for service delivery."[42] Based on this line of reasoning and the aforementioned literature, we thus model services ecosystems as value networks that include both products and services.

The visualization of complex socioeconomic systems, such as service value networks, in a comprehensive and readable manner can be daunting task.[43] While several different techniques have been used,[44] a common method to visualize and describe networks is to use a node-and-arc representation.[45] In

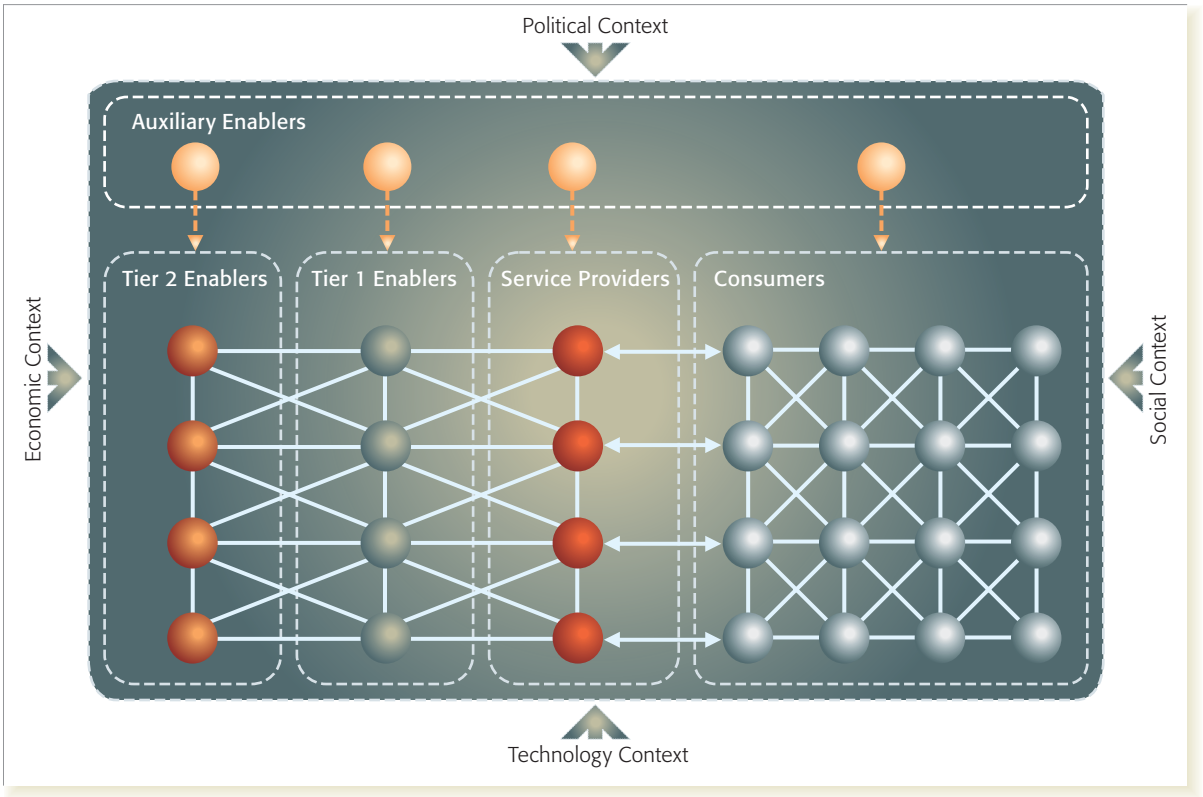

Figure 1
A conceptual model of service-value networks

this approach, nodes represent actors (e.g., people or firms), while arcs represent relationships, or ties, between actors in the network.[46] This approach has been shown to be a particularly effective means in describing the structure and dynamics of socioeconomic networks,[43,44] and we adopt it to visualize our ideas of service value networks.

Broadly speaking, a service value network contains five types of actors: consumers, service providers, tier 1 and 2 enablers, and auxiliary enablers (***Figure 1***). We further argue that value in a service value network is created through a complex set of B2B, B2C, and C2C relationships, and influenced by the social, technological, economic and political context in which it is embedded.

Consumers

Implicit to the notion of a value network is the proposition that all activities are initiated from the point where value is "realized" or "consumed."[47,48,49] As we elaborate on later, in a service value network, this point is considered the end consumer; consumers purchase consumables, use telecom services, drive automobiles, fly on airplanes, and see doctors; the other actors in the value network enable these services. Consumers thus trigger all the activities in the service value network.

In the past, manufacturers and service providers could dictate to a large extent what products and services as well as features and functionalities were brought to the market. Today, consumers play a much more central role: they demand product and service customization, speed, and high levels of quality of service, all in a seamless fashion and preferably from a single provider. In many instances, consumers will only use and continue using products and services if their value preferences and criteria are met or exceeded by the service provider.[47,49] As a result, service providers will only receive any benefit when consumers are satisfied and delighted enough. This supports Peter Drucker's fundamental idea that "the purpose of every business is to create a customer."[50]

Service providers

For end consumers to experience, use, and consume the value they desire or expect, a service (or a bundle of services) with that value must be provided by one or more actors in the value network. The primary contact point for a consumer is the service provider. Service providers supply communications services, airline services, health-care services, and banking services, for example. In our conceptualization, the service provider is also the focal actor in the service value network.

In some industries, the service provider is merely an aggregator of multiple products and services and it provides these in a bundled and integrated fashion to the consumer. In other cases, it is an enabler to other service providers. Service providers must ensure that the products and services they provide delight and satisfy their consumers. In order to do so, service providers must therefore understand and, in many cases, manage both B2B and B2C relationships, anticipate consumer needs, and address environmental changes and consumer demands.

Enablers

To provide a service to the consumer, a service provider relies on numerous enablers that help create, design, initiate, and deploy the service. In general, enablers can be differentiated as tier 1, tier 2 and auxiliary enablers, as shown in Figure 1. Tier 1 enablers provide direct goods and services to the service provider. These can be producers, manufacturers, or other service providers. Tier 2 enablers provide goods and services to tier 1 enablers. Examples include material suppliers and component manufacturers. Auxiliary enablers are those that are essential to the entire ecosystem and not specific to one industry. They tend to have an influence on some or all actors in the value network. Examples include government agencies, financial institutions (e.g., banks) and infrastructure providers (e.g., utility, facility, and transportation).

Contextual influences

Of course, all of the actors in the services ecosystem act in the context of society, culture, the economy, and politics. This argument builds on the idea of "embeddedness" presented in Granovetter's seminal article.[51] Granovetter states that economic activities can not be viewed in isolation from other institutions or from the technological, political, and social context in which organizations exist.[51]

The depression of 1929, the oil embargo of 1974, and the terrorist attacks of 2001 had enormous impacts on various segments of the economy. World War II transformed the United States into a world power. Much more subtle are people's social and cultural norms and expectations where, over time, changes enable new businesses and approaches to business. The extent and level of service expectations have undoubtedly been influenced by the immediacy of instantaneous and constant connectivity. The nature of work has changed, as 24–7 availability has become the norm in many types of jobs. All these vignettes illustrate that contextual influences can have a deep impact on economic activities and must therefore be considered when conceptualizing the structure and dynamics of service value networks.

Value in value networks

The shift toward a network approach to the services ecosystem also changes the concept of value creation.[31,32,52] While early research focused on value created at the relational level, value for consumers is now created at the network level, in which each actor contributes incremental value to the overall offering.[25] This view of value creation emphasizes the focus on core competence and competence complementarity. Instead of providing the maximum value to customers on their own and running the risk of being unprofitable in the long run, actors contribute to the value creation process by focusing on their core competence and cooperating with other network actors, such as suppliers, partners, allies, and customers, through various value constellations.[26,27] Product and service delivery is thus a complex value creation process enabled by multiple actors.

In addition, it has been shown that consumers are not only value receivers, but also coproducers, or "prosumers," of value.[32,53] We take this idea one step further and argue that consumers not only contribute to the value creation process, but in fact drive and determine all activities in the value network. Indeed, if there were no consumers, no product or service would be consumed, and the existence and necessity of actors and value network activities would likely be irrelevant. Of course, there are many instances where products and services are "pushed" to the market, but even in those cases someone must consume them. Thus, it is critical for consumers to value products and services and in

turn, value network actors must provide this value to consumers.

So what do consumers value? The literature suggests that customers do not care about products or services per se, but rather they value the benefits, such as transportation, entertainment, communication, consumables, and health care, they receive from consuming them.[47,48,54,55] This suggests that customer value is thus shaped by the consequences of using a product or service. Consumers expect these products and services to be delivered along a least common denominator; i.e., as cost-effectively and conveniently as possible and with a certain level of quality, among many other factors.[54,55]

There are several product and service features and attributes that address this least common denominator. Broadly, they can be categorized as tangible and intangible attributes.[38,42] Tangible attributes include price, quality, design functions, choices, customization, and variety. Intangible attributes include convenience, style, trust, security, efficiency, and ease of use. It should be noted that quality can be both tangible and intangible, depending on what aspect of quality is intended; e.g., defects versus aesthetics.

While there may be exceptions, value is not synonymous with owning the rights to a product or a service transaction. Value relates to the benefits of these rights.[54,56] Products and services are, for the most part, enablers rather than ends in themselves.

Consumer preferences and value perceptions for products and services are further dependent on the social context in which they are used and consumed; i.e., the social value system and social network.[51,57] Consumers, for example, may be more inclined to use a service if they hear about it through word of mouth or if a large group is already using it.[58] Consequently, C2C interaction plays a critical role in value preferences.

Actors in the value network must deliver this value. Similarly to a traditional value chain, value increases from tier 2 enablers to consumers, as perceived by the consumer. Enablers add incremental value to products and services as they transition through the value network (e.g., add components, software, functionality, and style). When the consumer finally receives and consumes the service, it reaches the highest value point (*Figure 2*).

A simple example illustrates this idea: revolutionary composite materials may enable a highly fuel-efficient airplane, but the success of the airplane investment depends on passengers' being willing to fly on the airplane. The marketplace thus determines which inventions become innovations, and which in turn provide sustainable value to consumers.[55]

Today, B2B services represent a major portion of the service economy.[1,3] In supporting the products and services of other businesses, these B2B service providers enable B2C value. Placing this into the network context, while businesses may be customers to other businesses, they essentially are one of the many nodes that ultimately deliver value to the consumer. Examples range from facility management services, to customer-service call centers, to strategy consulting for the executive team. There is a wealth of ways that B2B providers enable downstream B2C value creation, via service endeavors ranging from business process improvement to enterprise transformation.[59,60] Virtually anything and everything can be outsourced.[61] Consequently, a company's only asset may be its relationships with its customers. In this case, it owns the B2C business and employs B2B services for everything else.

The aforementioned discussion leads to the proposal of our first fundamental proposition for service value networks. We hasten to note that we are not, at this time, presenting these propositions as formal axioms.

Proposition 1: The nature and extent of B2C service value determines B2B service value, as well as the value of products and other value enablers.

Complexity of value networks

By representing value networks as formal network models, we can compare different value networks.[45] We would like to quantitatively compare networks. Certainly, we could count nodes and arcs as a basis for comparison. However, such counts do not capture the richness of many networks.[10] Further, these metrics do not provide a strong means for designing and managing value networks.

Networks can be viewed as systems whose state evolves.[10,13,62] Design and management both center

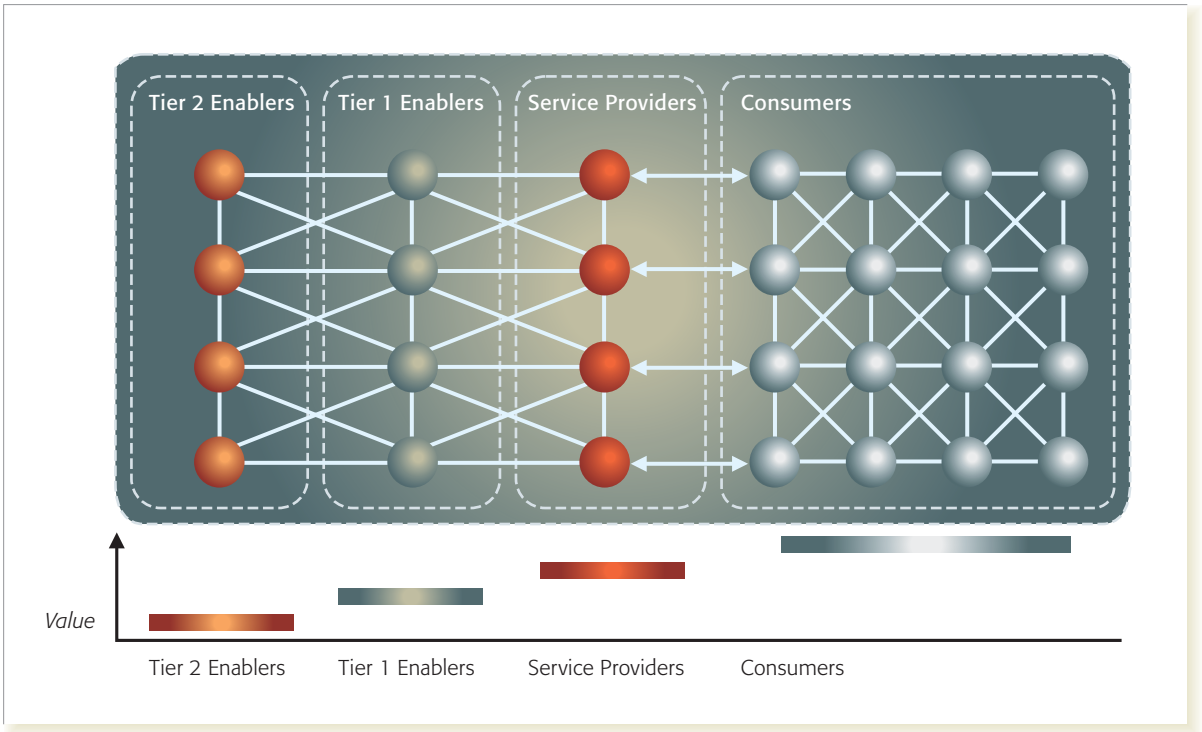

Figure 2
The nature of value

on creating and controlling the structures whereby system state evolves. This begs the question of the state of a value network. We define the state of a value network as the set of nodes that participate in any given consumer transaction. We then define the complexity C of a value network to be

$$C = \sum_{i=1}^{T} pt_i \sum_{j=1}^{N} -(pn_j|pt_i)\log(pn_j|pt_i),$$

where T is the number of types of transactions in the network, N is the number of nodes in the network, pt_i is the probability of a type i transaction, $pn_j \mid pt_i$ is the conditional probability that the j^{th} node is involved given the transaction is type i, and the logarithm is to the base 2.

This measure originated with Shannon's calculation of entropy in information theory[63] and has since been applied in domains ranging from failure diagnosis[64] to manufacturing[65,66] to sociology[67] as a measure of the observational or computational effort involved to assess the state of a system. Indeed, all measures of complexity are based on the characteristics of a representation of a system,[62] with network representations the most common.[45]

The measure of complexity resulting from the above equation is binary digits, or bits. Intuitively, it represents the number of binary questions one would have to ask and have answered to determine the state of a value network. This measure is not without subtlety. For example, if one claims, as we do later in this paper, that the complexity of the entire retail market is over 30 bits, there will undoubtedly be many skeptical responses. However, once one explains that this means that roughly one billion binary questions would be needed to determine the state of the system, people begin to understand the implications of this measure of complexity.

In applying this measure of complexity to five different markets in the following section, we distinguish between total market complexity and consumer complexity; i.e., between B2C + B2B and just B2C. As we later discuss, many market innovations are associated with reduced B2C complexity, often in parallel with increased B2B complexity. More formally, this leads to our second proposition.

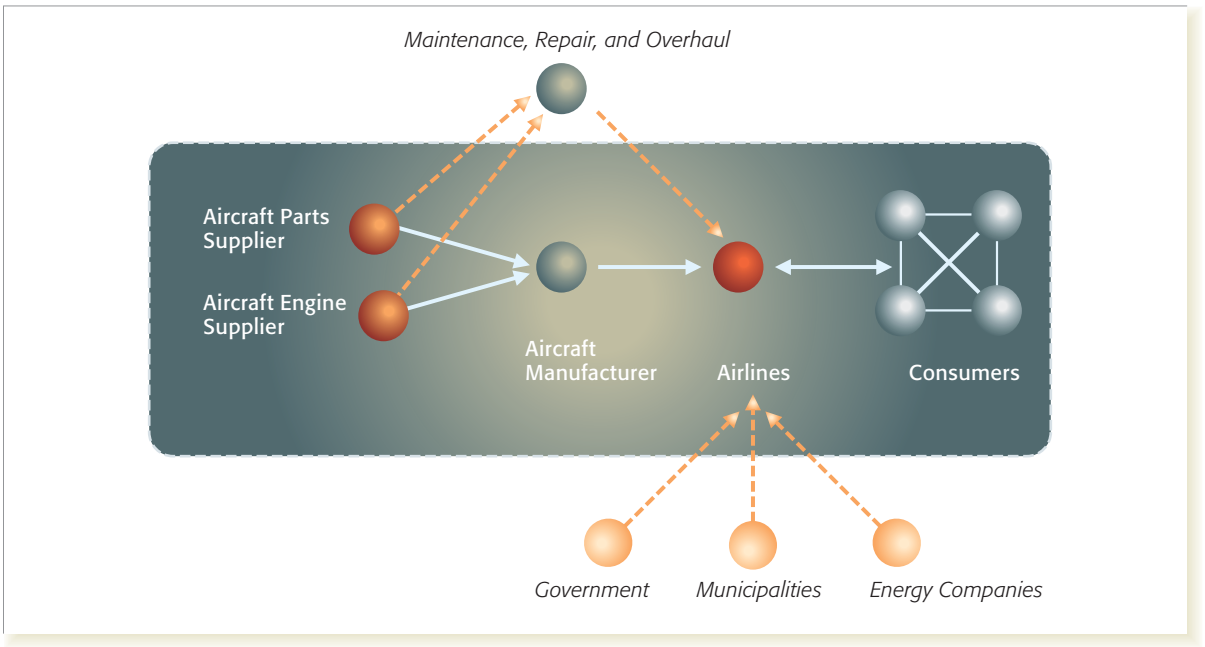

Figure 3
Value network of the aerospace market

Proposition 2: The magnitude of B2C complexity, relative to total market complexity, both expressed in terms of information theoretic binary digits (bits), reflects market maturity—this is often achieved by increasing B2B complexity, and hence total market complexity, in order to reduce B2C complexity.

In the following section, we illustrate our two central propositions for five different markets and value networks.

ILLUSTRATIVE EXAMPLES

At the outset, we should note that it would be quite difficult to prove formally that the above equation reflects the *real* complexity of value networks. For example, Golay et al.'s often-cited paper[64] relies on empirical evidence to support their mathematical arguments, including several studies that we performed in our research into the complexity of fault diagnosis.[62] We adopt a similar approach by employing empirical data to show how the proposed measure of complexity provides interesting and viable interpretations of well-known phenomena.

The empirical data of interest concerns the key players in five markets—aerospace, automotive, retail, health care, and telecom. We first organized our data collection by NAICS codes. This proved untenable. For example, this source of data indicates that there are 219 aircraft manufacturing companies in the United States. We think that there are only four relevant aircraft manufacturers for the value network described below.

For this reason, we shifted from bottom-up data collection to top-down, by focusing solely on the Fortune 1000 to identify both industry segments and numbers of companies in each segment. This approach inevitably eliminates innovative small companies from our analysis. However, we felt this limitation was acceptable for the "proof of concept" analysis reported in this paper.

Aerospace market

The aerospace value network involves the longest life cycles of our five examples (***Figure 3***). Each generation of airplanes requires many years from concept to deployment—for military aircraft, it may take two to three decades. It is not uncommon for suppliers to aircraft manufacturers and airlines to earn significantly better profit margins than the major players. The customer for airline service is, in general, most concerned about the price of flights, with secondary concerns of convenience and com-

fort. Consequently, manufacturers focus on affordability, efficiency, and reliability.

The airline industry is, without doubt, the least profitable of the five industries discussed in this paper. Government subsidies and mail delivery contracts spawned the industry. Defense investments enabled technology advances. In its century of existence, this industry has a cumulative negative net profit. Further, unlike the railroads, the government furnishes airports and air traffic control. Of course, the public consciousness regarding airline safety is a key driver.

Similarly to the automotive value network, the complexity of the aerospace network decreased substantially throughout the twentieth century. Consolidation reduced hundreds of aircraft manufacturers to just a handful.[68] Airlines are in the midst of continued consolidation worldwide. The Internet has further simplified air transportation, to the great detriment of travel agents. In the context of Proposition 2, we can see the continued reduction of complexity, with the possible exceptions of the security aspects of air travel.

Automobile market

The automotive industry, particularly in the United States, is in a significant state of flux. A wide range of factors influence how and what decisions are made in the automotive world. Consumer preferences influence current styles, reliability, and performance standards of vehicles. Government trade, safety, and environmental regulations establish incentives and requirements for modernization and change in design or production. Competitive rivalries and corporate strategies provide impetus for research, design innovations, and changes in the manufacturing process. All automakers are constantly under pressure to identify consumer preferences, national biases, and new market segments where they can sell vehicles and gain market share. Their ability to be flexible enough to quickly respond to all these pressures will largely determine the future of the industry.

This value network is somewhat more complex than that for aerospace, particularly for consumers (see *Figure 4*). This is due, in part, to the value of automobiles being very multidimensional compared to the retail offerings, e.g., laundry detergent. For many owners of automobiles, the vehicle provides more value than simply transportation. Attributes related to aesthetics and self image play a role, for instance. Other complications are the after-market for upgrades and service. Further, despite the growing use of the Internet to buy cars, most states require that the final purchase be made through dealerships who have, thus far, successfully lobbied state legislatures to prohibit direct Internet sales.

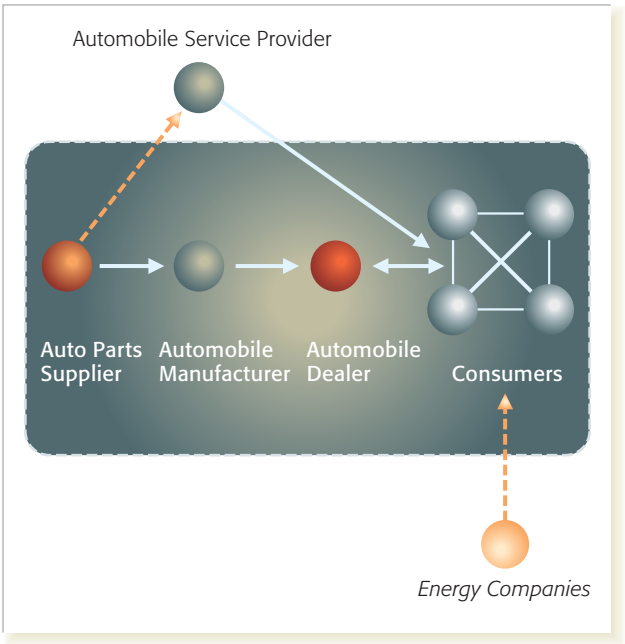

Figure 4
Value network of the automobile market

Note that the complexity of the automotive value network is much less than it was 80 to 100 years ago, when there were hundreds of automobile companies and three dominant types of propulsion: steam, electric, and, in third place, internal combustion engines. Throughout the first two-thirds of the twentieth century, dramatic consolidation reduced fragmentation, resulting in a much simpler value network.[68] Based on Proposition 2, we can see that the Internet has, of late, perhaps increased complexity (but not dramatically).

Retail market

The retail market is immense. The five markets discussed in this paper involve roughly one-half of the Fortune 1000; retailers and their suppliers involve one-half of these companies. Retail also differs in the nature of transactions. When one buys or uses an airplane or an automobile, one can

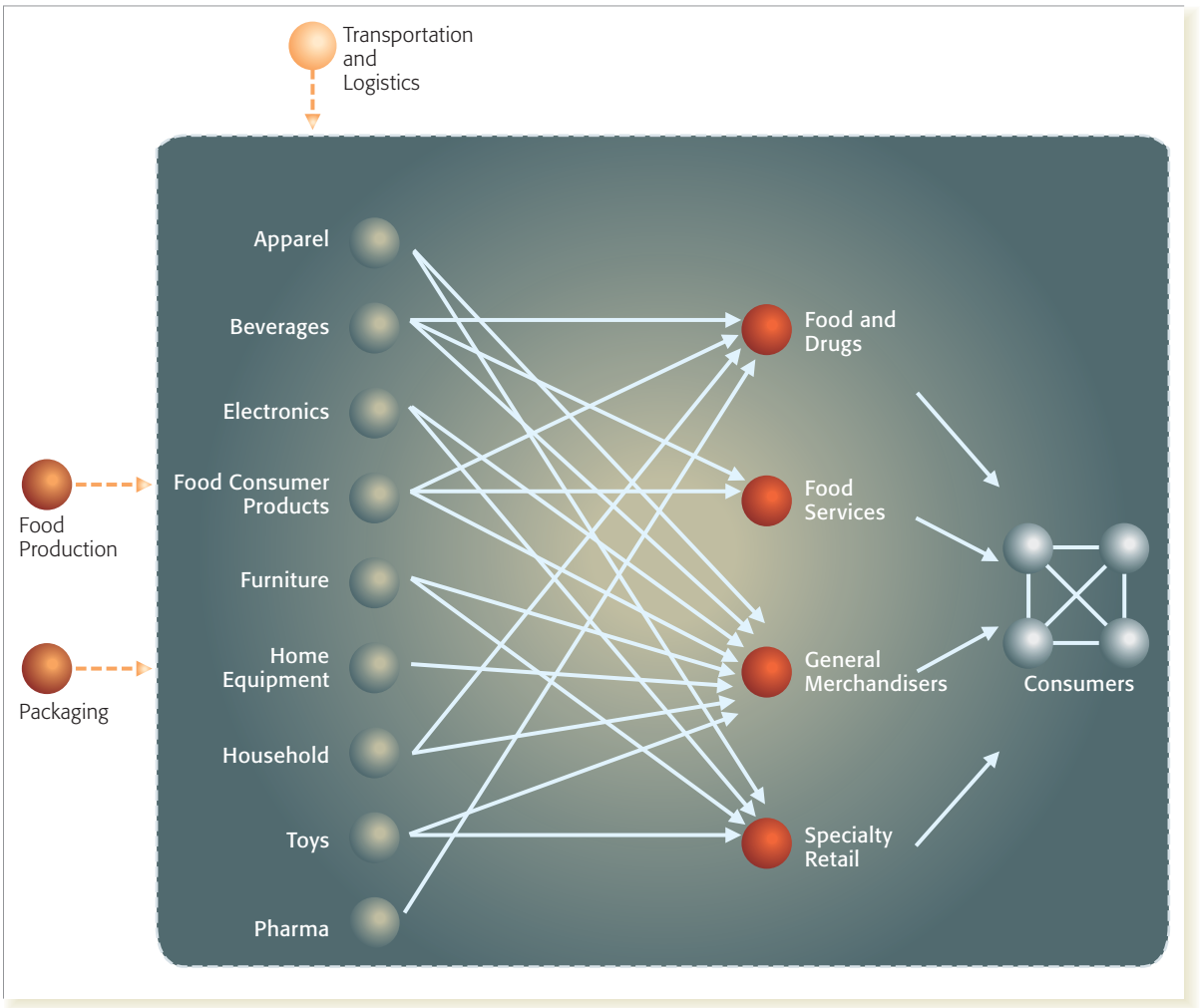

Figure 5
Value network of the retail market

reasonably expect that after the purchase one will receive all the parts of the vehicle. In contrast, it would be very unlikely to buy one of everything in a retail store. Consequently, the value network (*Figure 5*) has a more varied set of relationships between suppliers and retailers.

As later results will indicate, the retail market is very complex. However, the consumer does not have to address this complexity. A very efficient user interface has been created: stores, both brick-and-mortar and online. Increasing B2B complexity has resulted in decreasing B2C complexity. Increased convenience and decreased prices have driven consumer value (i.e., B2C value), enabled by B2B value.

Health-care market

The health-care value network is one of the most complex of the five industries discussed in this paper. This network can be described as a loose federation of independent enterprises, all trying to optimize the market from their perspective and for their benefit (*Figure 6*). Unlike aerospace, no single enterprise or type of enterprise dominates. Further, enterprises from private and public sectors, as well as academia and nonprofit organizations, are laced throughout the value network.[69,70,71] This can result in very confused customers, often receiving conflicting guidance from different players. However, this situation will inevitably change, and the Internet has enabled highly informed customers to make well-informed choices. As more information

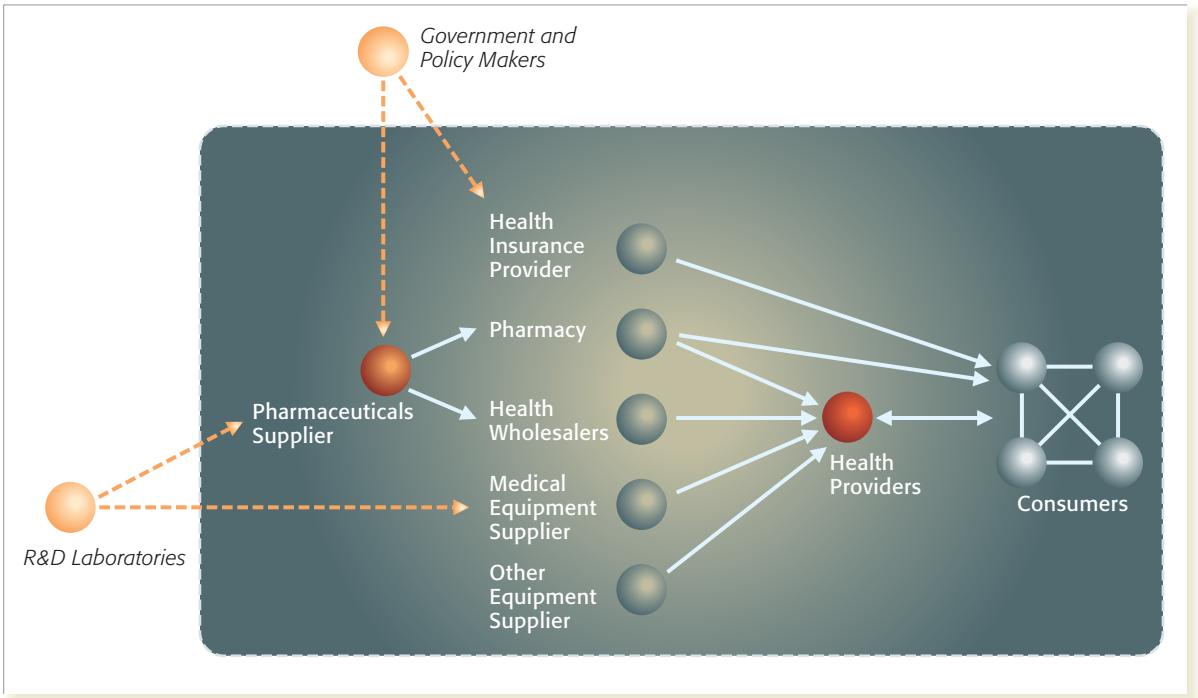

Figure 6
Value network of the health-care market

on provider performance—and availability—becomes accessible, consumers will have greatly increased leverage. It can be expected that the extreme fragmentation of the industry will not persist, if only because the projected economics of the industry as it is are not tenable.

In terms of Proposition 2, there are a large number of providers of services with many dimensions. Consequently, service is uneven, costs are high, and consumers are confused and frustrated. The providers and enablers that can fix the B2C value proposition, while also reducing B2C complexity, are likely to reap enormous benefits. At the same time, the push for "consumer directed" health care may result in increased complexity for consumers, which has not proved successful in the other four markets. Innovations that increase B2B complexity in order to reduce B2C complexity are more likely to be successful.

Telecom market

As later results show, this market is moderately complex, but the most complex for consumers (*Figure 7*). They have too many alternatives and need to know too much in order to both make purchase decisions and realize the value promised.[72,73] This is well characterized by consumer questions to service providers that result in questions regarding one's computer, operating system, wireless card, router, etc. The long-heralded convergence to "quad play"—home phone, mobile phone, television, and Internet access in one device—portends reduced B2C complexity, quite likely enabled by increased B2B complexity. Put simply, the winners in the convergence battles will be those that can enhance B2C value, not just reduce B2B costs.

Complexity assessments

Using publicly available data from the Fortune 1000, we were able to identify the number of companies in each node of Figures 3–7.[74] The probabilities associated with each company being involved in any given transaction were calculated in one of two ways. The predominant way was simply to estimate the probability as one divided by the number of supplier or manufacturers. In a few cases, we adjusted the probabilities to reflect the fact that a Fortune 1000 supplier must be supplying at least one Fortune 1000 manufacturer. The results are shown in *Figure 8*.

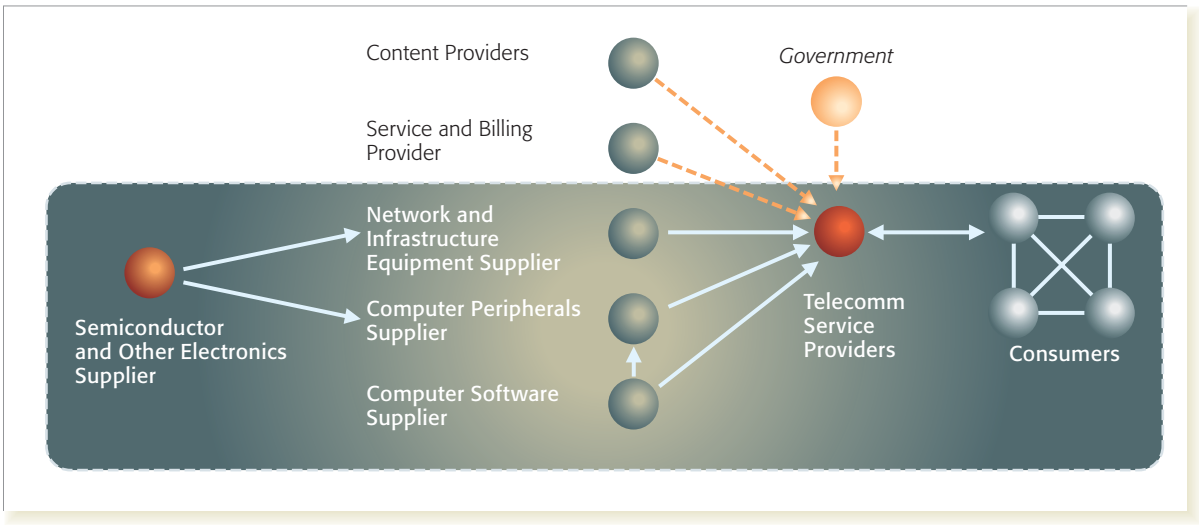

Figure 7
Value network of the telecom market

Several observations are important. First, highly fragmented markets are much more complex than highly consolidated markets. There are relatively few aerospace and automotive providers compared to retailers and consumer products companies. While manufacturers of airplanes and automobiles are likely to claim that their products are complex, consumers do not have to address this complexity and these industries benefit from this; i.e., more people fly on airlines and drive automobiles.

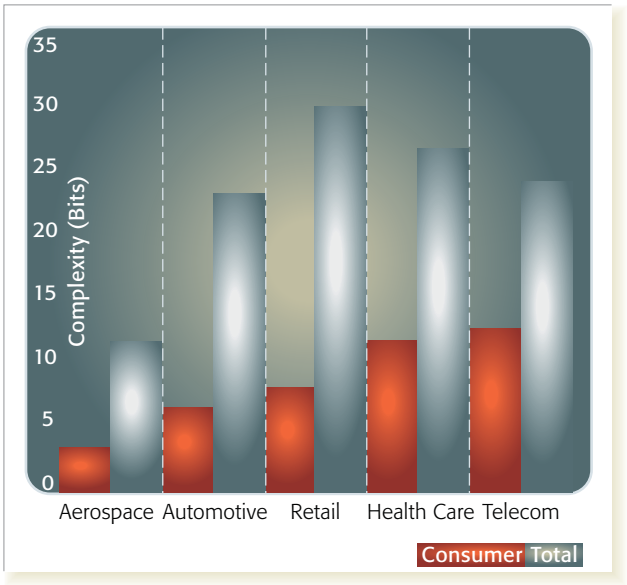

Figure 8
Total complexity and consumer complexity in five markets

Second, consumer complexity can be reduced either by market consolidation, so there are fewer choices, or by increased B2B efficiency that reduces B2C complexity. The aerospace and automotive industries are examples of the former and the retail industry is an example of the latter. Note that the telecom industry is clearly employing both mechanisms, while health care, via consumer-directed health care, is moving away from both mechanisms. This suggests that new intermediaries will emerge in health care to manage complexity for consumers.

Summary

Table 1 provides a summary of these five industries in terms of the two propositions advanced in this article. In all five cases, customer value drives the value network, e.g., if the customers hate the car, the efficiency of the supply chain cannot compensate for cars not being sold. The complexity of value networks limits abilities to optimize allocations of resources, in part because they cross enterprise boundaries, often epitomized by the inefficiencies of fragmentation. Health care is a good example of extreme fragmentation and inefficiency.

THE ROLE OF ICT IN SERVICE VALUE NETWORKS

The concept of a service value network raises a variety of issues for the development of information

Table 1 Interpretation of propositions for each market

Industry	Proposition 1 (Value)	Proposition 2 (Complexity)
Aerospace	Customers' willingness to pay for airline seats drives everything. The B2C value proposition completely determines B2B value because otherwise there is no business.	For almost all customers, the airplane is a means, not an end. Service performance dominates product performance, with service affordability being the central value issue.
Automotive	The value proposition of the automobile drives everything. If this B2C proposition does not work, B2B effectiveness and efficiency do not matter.	The value attributes of the product are more complicated in terms of transportation, style, and self-image, although the primary manufacturer determines most of this value.
Retail	Customers seek those retailers that provide what they want with the right mix of price and convenience. B2B value depends on getting B2C value right.	This value network is simple to the extent that the value concerns commodity products and services. Proprietary, niche offerings may involve more complicated networks.
Health care	Health outcomes and their costs must ultimately drive the value network. Poor outcomes and excessive costs will eventually precipitate new value propositions.	Complexity is driven by the fact that no one is "in charge." A loose confederation of independent businesses must be coordinated, perhaps by a new intermediary, to assure quality of service and acceptable prices.
Telecom	Convergence, ease of use, and price will drive the value proposition. Some B2C providers will prevail, although one or more B2B providers may transform themselves into the successful providers.	Service success depends on many players serving particular roles and sharing information on service processes and outcomes. Conflicting incentives and rewards make this overall process very complicated.

systems supporting customers and businesses and the relationships they have among each other.[3,28] ICT provides the ability to link and coordinate activities between and across service providers, customers, producers, and enablers. Broadly, there are three spheres of service value network linkages that ICT supports and enables (***Figure 9***).

Across all three spheres, ICT has had a profound impact. Studies have shown that ICT has facilitated the creation of interorganizational linkages.[75] ICT has provided means to share information more efficiently and effectively, thus improving coordination and collaboration activities.[76] Supply chain management (SCM) and enterprise resource planning (ERP) applications, for example, provide B2B actors an integrated and unified view to critical operational information. This has led to increased information visibility, and consequently greater flexibility, agility, and responsiveness for all actors.[77,78,79,80] ICT has enabled businesses to lower operating costs, increase productivity, and improve work flow.[81,82] Web services, for example, provide businesses the ability to integrate modular business processes to deliver new products and service offerings more rapidly.[83,84]

ICT has also provided significant benefits to consumers. The Internet, for example, has given consumers the ability to access, view, and process information previously not available to them, the ability to perform searches to find products and services that best meet their needs, and in essence the power to make more informed decisions. Consumer value preferences are also influenced through online forums, chat rooms, and other C2C communities. In fact, the social network effect enabled through the C2C web can significantly impact consumer preferences and purchasing behavior. Through C2C relationships, consumers become more informed and receive "no nonsense" feedback on the value, quality, and experience of services they are interested in. All of this has led to greater competition, as businesses must now provide the "best value for better-informed consumers."[85]

In order to so, businesses utilize sophisticated CRM tools to manage the business-consumer interface, identify potential consumers and new market segments through business intelligence (BI) solutions, and promote and customize their products

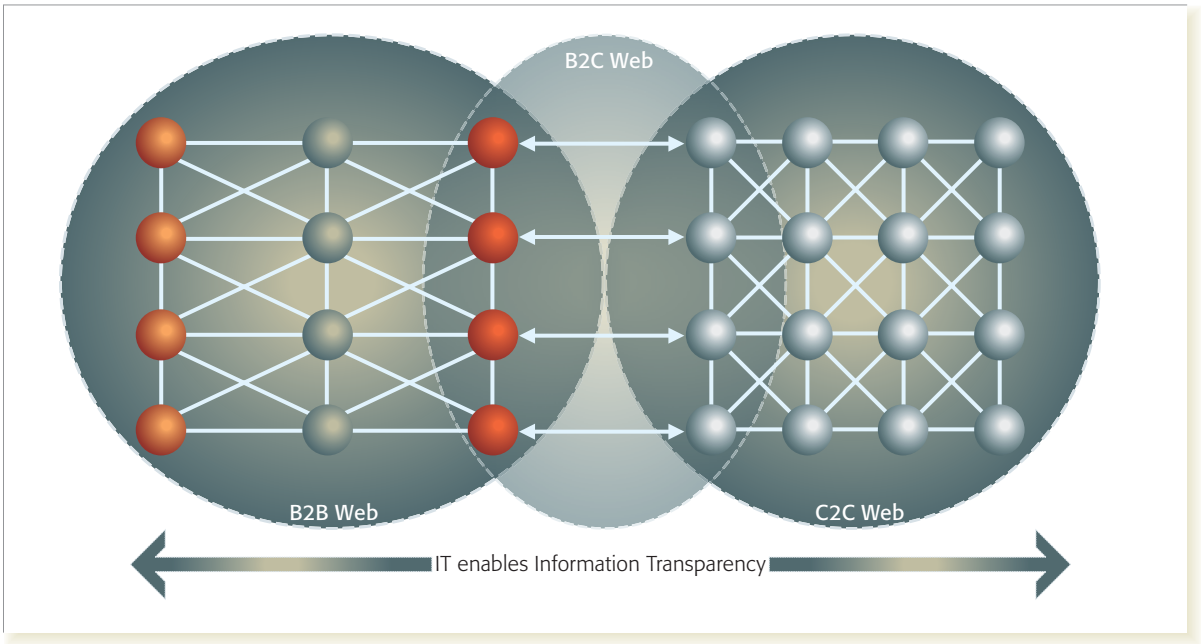

Figure 9
Spheres of ICT-enabled value-network linkages

and service offerings. Consequently, "competing on analytics" has become increasingly powerful.[86]

Given the aforementioned benefits that ICT has provided in general, it is no surprise that it has also had a deep impact on the five value networks we discussed in the previous section. We briefly highlight them here.

Aerospace

The aerospace industry has been an early adopter of high-performance computing to design airplanes and airplane parts. It also uses sophisticated information systems to coordinate its activities with designers in dispersed locations and suppliers across the world. Airlines have used ICT in all aspects of their operations, including optimization of scheduling, gate assignments, inventory control, and customer service. Sophisticated airline reservation systems initially focused on travel agencies, but more recently are accessible by consumers. Today, consumers have a wide selection of online sites, such as Travelocity** or Expedia**, and the airline industry introduced several other ICT innovations, such as e-tickets and the upcoming tracking of baggage using RFID (radio frequency identification). Finally, ICT also keeps the air traffic control flowing smoothly by coordinating takeoffs and landings and in-air flight routing. Recent examples of network and computer glitches have illustrated the dependency of the airline industry on ICT.

Automotive

Large automobile manufacturers employ complex networks to coordinate a great deal of supply and demand. To this extent, specialized systems were put into place, out of which systems such as EDI (Electronic Data Interchange) and other exchanges emerged. ICT has reduced the time and expense of product development through integrated design applications. ICT has also enabled actors in the automotive value network to collaborate more efficiently and improve organizational agility and responsiveness by seamlessly linking suppliers, partners, and dealers. The automotive industry also utilizes ICT to design and simulate its products. Today, a consumer can create and customize a desired automobile with a few clicks and then the order is sent to the manufacturer. While consumers usually must still purchase their vehicles through a dealer, which increases complexity, many dealers now have an Internet presence that allows consumers to interact directly with them. In fact, consumers can even schedule service appointments online, further enriching the customer-relationship experience.

Retail

ICT has enabled the transformation of the retail industry. Systems supporting point-of-sale, supply chain management, and CRM have enabled both great efficiencies and the availability of a wider variety of offerings, many from global sources. The Internet has, of course, enabled online shopping, but it also dovetails with traditional shopping by providing information on availability and pricing. As a result, revenues of the retail industry have doubled in the last ten years, while one-half of the publicly listed retail companies have disappeared. This is certainly not solely attributable to ICT, but these technologies have, without doubt, played a major role.

Health care

The high level of fragmentation of the health-care industry has resulted in myriad ICT offerings, as well as many homegrown IT systems. This fragmentation has impeded the development of electronic patient record systems, although recently there has been substantial progress in this area. The Internet has enabled consumers to access a wide variety of health-care information and, for a portion of the population, resulted in much better informed consumers. The emerging explosion of information due to the genomics revolution promises to enable personalized health-care delivery, but realization of this promise depends on ICT. Telemedicine has also been advancing in recent years.

Telecom

ICT has become central to telecom, at the same time that telecom has become central to the other four industries discussed in this paper. Digital networks provide the backbone for delivery of almost all services. Although there is widespread agreement that Internet, television, home phones, and mobile phones will converge into seamless offerings, at this point consumers have to juggle the pieces of the overall solution. We can reasonably expect that these pieces will come together, perhaps enabled in part by the consolidation of the industry. It is reasonable to project that the successful players will be those that decrease complexity for the consumer.

CONCLUSION

In this paper, we introduced the notion of service value networks consisting of consumers, service providers, multi-tier and auxiliary enablers. This notion assumes that the value and delivery of services is a complex set of relationships among these actors, where the consumer plays the central role. In particular, we argued that the nature and extent of B2C service value drives and determines B2B service value as well as other enablers. We also showed that the complexity of service value networks not only depends on the number of actors but also on the conditional probabilities that these actors are involved in delivering the service to the consumer. We then illustrated these ideas with examples from the aerospace, automotive, retail, health-care, and telecom industries. Finally, we showed that ICT has played a significant role in transforming the relationships among network actors and the delivery of services.

The examination of service systems as value networks presents a tremendous research opportunity to the field of service science. Through a multidisciplinary approach, we can gain further insight into how services can be managed and engineered. From an industrial engineering perspective, for example, we can advance our traditional service models to include the complexities of consumer involvement. From an information and knowledge perspective, we can examine how ICT can facilitate the exchange of information among network actors to deliver maximum value to the consumer. An economic approach to service value networks can contribute to our understanding of what incentives drive service value creation, what strategic roles networks play, and how relationships should be designed. An equally important perspective includes examination of the social, behavioral, and political forces that shape service value networks. We hope that this paper stimulates further thinking in how services are delivered through complex value networks and ultimately advances the field of service science.

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