
Choice of Transaction Channels: The Effects of Product Characteristics on Market Evolution

SULIN BA, JAN STALLAERT, ANDREW B. WHINSTON, AND
HAN ZHANG

SULIN BA is an Associate Professor of Information Systems at the School of Business at the University of Connecticut. She holds a Ph.D. from the University of Texas at Austin. Her research interests focus on the design of trust building intermediaries that facilitate electronic market transactions. She has published in *Management Science*, *Information Systems Research*, *MIS Quarterly*, *Decision Support Systems*, and other academic journals. She is also a recipient of the Year 2000 *MIS Quarterly* Best Paper Award. She currently serves on the editorial board of *Decision Support Systems* and *International Journal of Electronic Commerce*.

JAN STALLAERT is an Associate Professor in Information Systems at the School of Business at the University of Connecticut. His current research topics range from market mechanisms in eCommerce to Collective Decision Making methods. Dr. Stallaert received an Engineering degree and a B.A. in Philosophy from the Catholic University of Leuven (Belgium), and a Ph.D. from the University of California, Los Angeles. He has published in *Management Science*, *Information Systems Research*, *Discrete Applied Mathematics*, *Communications of the ACM*, and other academic journals. He has also consulted and implemented decision support systems for various Fortune 500 companies.

ANDREW B. WHINSTON is Hugh Roy Cullen Centennial Chair Professor of Business Administration, Information Systems, Economics and Computer Science, and Director of the Center for Research in Electronic Commerce at the University of Texas at Austin.

HAN ZHANG is an Assistant Professor of Information Technology Management at the College of Management, Georgia Institute of Technology. He received his Ph.D. in Information Systems from the University of Texas at Austin in August 2000. His research focuses on online trust and reputation related issues, trusted third parties or intermediaries, and the evolution of electronic markets. He has published in *Information Systems Research*, *Decision Support Systems*, and other academic journals. He currently serves on the editorial review board of *Journal of Database Management*.

ABSTRACT: The capabilities of network technologies have facilitated the growth of electronic commerce. Major issues—notably, security and product quality uncertainty—still pose serious challenges to the further adoption of electronic commerce. Traditional market transactions have a long history and well-understood protections for buyers and sellers. In the electronic markets, formal and informal mechanisms

such as trusted third parties (TTP) have emerged trying to ensure safe transactions. In this paper, we investigate under what conditions people will stick to the traditional market and face-to-face transactions, and under what conditions electronic transactions will be the convention of the future. Of particular interest is the role of TTPs in facilitating online transactions. Using evolutionary game theory, we present an analytical model of buyer and seller choices and examine which patterns of transactions can be sustained. We further study how the traders' adaptive behavior may influence the outcome of the market evolution. Through this analysis, we demonstrate that the market will show divergence: for commodity products, electronic transactions through TTPs will get established as the convention for market transactions when traders use historical information about other traders' past strategies. For "look and feel" products, the market evolution depends on the initial distribution of the transaction strategies in the population.

KEY WORDS AND PHRASES: electronic commerce, electronic markets, evolutionarily stable equilibrium, evolutionary game theory, market evolution, product characteristics, stochastically stable equilibrium, transaction channel, trusted third party.

OVER THE PAST FEW YEARS, INTERNET FRAUD continues to rise, causing consumers to become wary of online transactions. According to the FBI's Internet Fraud Complaint Center, the center referred three times as many complaints to law enforcement agencies in 2002 as it did in 2001, and victims of Internet fraud lost \$54 million in 2002, up from \$17 million in 2001. For the third straight year, Internet auction fraud topped the list of reported offenses, accounting for 46 percent of referred complaints, followed by nondelivery and nonpayment of merchandise (31 percent of complaints) [38]. Obviously, with the growth of electronic transactions, online fraud is rising at an alarming speed, significantly affecting consumer trust toward electronic commerce and posing serious threats to the increased participation in electronic markets.

Recognizing the potentially damaging effects of online fraud on electronic commerce and responding to the need of promoting trust and creating a safe online transaction environment [8, 27, 29], many researchers have begun to look into the role of various formal or informal mechanisms to encourage trustworthiness and reduce risks in the electronic market [5, 6, 11, 19, 29, 30]. Trusted third parties (TTP) such as escrow.com and VeriSign have also emerged. Are they able to facilitate the growth of electronic markets? What are the theoretical justifications to the existence of these services?

In this paper, we study the evolution of transaction conventions, whereby a convention is defined as a pure strategy Nash equilibrium where everybody continues to play the same strategy, barring errors or experiments [46]. Using both simulation and analytical modeling, we study how transaction models evolve, depending on product characteristics and the information available to market participants, and attempt to show, through the dynamics of the market evolution process, which transaction model (equilibrium) will be established, among several models, as the convention in the

future. In addition, we will show that an important determinant in the evolutionary process is the manner in which people adapt their behavior. As a result, we investigate whether different models of behavioral change give rise to different outcomes of the market evolution. Through this analysis, we hope to provide insights to how e-commerce companies should position and manage their transaction models for competitive advantage.

Trusted Third Parties in the Electronic Market

THE PRESENCE OF ASYMMETRIC INFORMATION contributes to the fundamental lack of faith between most businesses and consumers on the Web today [24]. Buyers inevitably face many difficulties in selecting reliable sellers and quality products, which in turn, produces the lemons problem [1], whereby bad products drive out good products due to asymmetric information such as product quality uncertainty. Sellers may face the problem of nonpayment for merchandise, the usage of stolen credit cards, or illegitimate returns of swapped merchandise by the buyers. Thus, there is the need for institutional setups that can encourage trustworthiness among trading partners, minimize misrepresentation of product offerings, and encourage consumer confidence in online markets.

Many researchers are exploring the role of intermediaries or TTPs in electronic markets. Sarkar et al. [40] propose that widely available information infrastructures will not only reinforce the position of traditional intermediaries but also promote the growth of a new generation of "cybermediaries." Regarding the problem of asymmetric information, some research has proposed empowering customers engaged in electronic commerce by providing access to more advanced and powerful technological tools to conduct business transactions (e.g., [13, 35, 41]). Lee and Yoo [30] focus on the problem of quality discovery in the trade of physical goods in electronic markets. They argue that a third-party mechanism can provide quality inspection, therefore, solving the lemons problem. In other words, a TTP mechanism can help an auctioneer successfully implement an electronic auction market for goods with complex attributes. Ba et al. [6] spell out an analytical design of a TTP from an economic incentive perspective to deal with the issue of information asymmetry and to encourage and maintain trustworthiness, vital to the growth of electronic commerce. Hu et al. [26] study a special type of TTP, online escrow service providers, and provide guidelines for online escrow service providers to establish an optimal pricing strategy. Ba and Pavlou [4] use customer feedback data from eBay to illustrate that feedback systems may serve as a TTP that enhances a seller's trust evaluation among buyers, thus generating price premiums for the seller. Resnick et al. [37] also note that eBay attributes its high rate of successful transactions to its Feedback Forum.

In practice, systems designed to facilitate online transactions have also emerged. Currently, there are several intermediaries that serve as TTPs to disseminate online product quality information or to ensure safe transactions. For example, escrow.com acts as a TTP for online auction buyers and sellers by managing the payment process during a transaction. Bizrate (www.bizrate.com) uses information from consumers to

keep track of merchants' reputations. iExchange (www.iExchange.com) monitors reputations of stock market analysts according to the performance of their picks. Although these intermediaries conduct their services in certain business settings, they all utilize the idea of externalizing private knowledge to reduce asymmetric information in the electronic market, thus reducing online transaction risks and promoting the welfare of their users.

Given the various transaction models available, how will the market evolve? Will the TTP model thrive in the electronic market? Although TTP services may increase the payoffs of their users [4, 30, 37], online users currently do not use those services as often as expected [15, 26]. Similarly, the commonly accepted assumption that operating an electronic channel is more cost-effective for commodity products than maintaining a physical presence does not necessarily imply that electronic transactions will be the new convention. Even though everyone would be better off with an electronic channel in this instance, it might be hard to change from a former convention to a new convention. One only has to bring to mind the "standards wars" in technology (e.g., DOS-Windows versus Mac operating systems): the better standard is not always the one to eventually win out; many times it is the convention that gets established first that remains in effect. For example, Bikhchandani et al. [9] discuss how quickly such conventions may get established in the presence of noisy signals.

Using evolutionary game theory [45, 46], we examine different transaction models, including different strategies, of both buyers and sellers in traditional markets and electronic markets, and illustrate which transaction equilibrium is stable and can be established as the prevailing convention in the long run. In the next section, we describe two main factors that affect the market evolution process: the characteristics of the products involved in market transactions and the market participants' learning behavior.

Major Determinants of Market Evolution: Product Characteristics and Learning Paradigms

AS E-COMMERCE DEVELOPS, many companies have come to realize that on the Web, not all products are equal. Products possess both different characteristics and qualitative differences of the same characteristics. Therefore, understanding the role of product characteristics and how these characteristics might affect consumers' shopping behavior is important for understanding transaction strategies.

Since the inception of commercial activities on the Internet, information asymmetry has been perceived by some to be a significant barrier to the extensive acceptance of the electronic market [6, 12]. Among the many aspects of information asymmetry, *product quality uncertainty* is closely related to online fraud: trading parties often do not have the same information about the product quality. For example, when bidders view a product listing at an online auction site, they may not have easy access to information regarding the true quality of the product. Recognizing the difficulty of guaranteeing product quality, eBay excuses itself from the responsibility in its User

Agreement, saying the company "has no control over the quality, safety or legality of the items advertised, the truth or accuracy of the listings."¹ Without a doubt, information asymmetry exposes electronic market participants to more risks and fraudulent transactions.

Understanding product characteristics is essential to consumers' ability to appraise product quality online, which, consequently, affects their shopping behaviors. Hotelling's spatial-competition model [25] has long demonstrated that in addition to price, product characteristics such as quality, color, and shopping place also determine from which seller a buyer will purchase a certain product. For example, the quality of commodity products, such as stock shares and paper clips, can be clearly and contractually articulated and conveyed. Touching and feeling such products are unnecessary. The convenience of being able to browse the Internet in one's own living room has added value. On the other hand, sales of products such as artwork, which has a strong "look and feel" nature, will be highly affected by information asymmetry. De Figueiredo [14] develops an e-commerce product continuum in which he characterizes products into commodity products (e.g., oil, paper clips), quasi-commodity products (e.g., books, CDs, videos), "look and feel" products (e.g., suits, homes), and "look and feel" products with variable quality (e.g., art). *Ceteris paribus*, quality is easiest to judge on the Web for commodity products, but most difficult to judge for "look and feel" products with variable quality. For the latter, direct experience adds to the customer's total utility. Buyers need to actually touch, feel, try on, or see these products in person before they buy. A simple description would not be enough for a discerning shopper.

In this paper, we are primarily concerned with products that are commonly traded in a consumer-to-consumer (C2C) or business-to-consumer (B2C) environment, but are not widely available; for example, collector's items such as rare coins or stamps, specialty products such as very specific photographic lenses, or works of art that are hard to find. Such products may be commodity products or "look and feel" products. For instance, the characteristics of lenses are well defined and well described as quasi-commodity products, but the vast assortment means that not many choices are kept in stock. These items may be offered for sale through online auctions (by individual sellers or small retailers), or may be available from (small) retailers' Web sites. In the physical world, such items are sold by a small number of (specialty) stores or individuals (e.g., through classified ads). In these situations, the matching of buyers and sellers is difficult. Our model does not apply to transactions involving large e-tailers (such as Amazon.com). Such transactions are better modeled as Stackelberg games, where the large e-tailer is a long-term player who would be committed to its Stackelberg strategy.

In addition to product characteristics, traders' adaptive behavior may also affect their choice of transaction models, and thus the evolution of the market. In this paper, we investigate how information used by the transacting parties influences their behavior and, in turn, determines the evolutionary path of the market system.

The dynamics of a system are determined by how players adapt their strategies, or what learning paradigms they use. There are different ways of adaptive play that are

mostly influenced by the players' cognitive abilities and the information or memory the players possess [45]. Therefore, we model the market dynamics in two different ways, each with its own interpretation in an e-commerce environment.

The first method of learning we study is one of *Natural Selection*, a term coined by biologists to indicate that species with superior strategies would create more offspring than others and hence be "naturally selected" [44]. In our setting, players in this framework have the least amount of information available: they mimic the behavior of more successful players, or, equivalently, experiment with different strategies themselves, thus being pulled toward the strategy that for them yields the higher average payoffs. This model is appropriate when players either have no (historical) information about the players they are matched against, or are unwilling to use past information about other players' strategies as a predictor of future behavior. For example, in a C2C environment (or in a B2C environment where the online merchants do not have an established reputation), when there is no information available about sellers (e.g., in the absence of feedback mechanisms), buyers may not be aware of what strategies sellers may have played in the past, or may be unwilling to use this information as a future indicator if they are afraid that a seller may suddenly start milking his or her good reputation and shift strategy.

The second learning paradigm we use to investigate the market dynamics is the Best Reply model, an adaptive mechanism that has been studied by game theorists (see, e.g., [20]). Here players optimize their expected payoff, given what they expect others to do. The expectation of others' behavior is derived from a sample of the histories of other players' past actions. In this model, information about other players' past actions is a necessity, and every player must be willing to use that information as an indicator of future behavior. Therefore, a mechanism such as eBay's Feedback Forum, which disseminates information about the players' past behavior, becomes critical. In addition, we allow every player to "deviate" from the optimal strategy with a very small probability. That is, a player sometimes may want to experiment with a strategy that is not necessarily optimal based upon his historical information: the player may make a mistake, or is bound by limited information-processing capability, or just plain wants to do something different and comes up with a strategy that does not yield the highest expected payoff.

Although seemingly related, the two learning paradigms model two different processes: Natural Selection models the *diffusion of behavior* throughout the population (where the behavior of the individual decision-maker is abstracted out), whereas the Best Reply paradigm models the evolution of the actions of an *individual (rational)* decision-maker. The first model requires the least cognitive abilities: the players do not need a memory of past plays, nor do they need to compute an optimal strategy. The Best Reply model assumes that players have access to a history of plays, that they are willing to use that information to guide future actions, and that they can compute the optimal strategy given the available information.

The two different learning models do not yield the same outcomes. The natural selection model gives rise to *evolutionarily stable strategies* (ESS) that form evolutionarily stable equilibria in which no small group with a "mutant" strategy (i.e., one

that deviates from the ESS) can successfully invade the population (i.e., get a higher payoff). An evolutionarily stable equilibrium is not necessarily unique and depends strongly on the initial conditions of the system. Different starting conditions may yield different final equilibria.

The equilibrium of the best reply model, by contrast, is always unique (save for ties in the payoffs of the conventions). The resulting equilibrium is a *stochastically stable equilibrium* (SSE), which is independent of the initial conditions of the system. An SSE is a convention that, among several Nash equilibria, is asymptotically observed with positive probability.

Either an evolutionarily stable equilibrium or an SSE is a convention that gets established as the most prevailing convention over time. An ESS is a convention that survives all other conventions, because the ESS strategy gives the players the highest payoff and choice of another strategy by a small number of players gives a lower payoff. On the other hand, the SSE is the convention that is played most frequently over time. In other words, a convention other than the SSE may be played for a short amount of time, but the process will quickly revert back to the SSE. In the fourth section, we identify the corresponding prevailing convention based on the learning paradigm the players choose. For further comparisons between an evolutionary stable equilibrium and an SSE, we refer the reader to the abundant literature on evolutionary game theory, such as Young [46].

The Evolution of Market Transactions

Modeling Assumptions

MODELING BUYER-SELLER BEHAVIOR is a difficult task. Consumer behavior literature [2, 33] distinguishes types of buying processes broadly as "planned" (e.g., a completely rational buying decision) and "unplanned" buying (e.g., impulse buying). Within these categories, different phases have been identified. For planned buying, these phases consist of need identification, evaluation of alternatives, and, finally, choice of outlet. In each phase, the consumer acquires information and, hence, incurs some search cost. The buying process may be abandoned during any of these phases. Different unplanned buying transactions, on the other hand, have varying phases and may not even succeed in the same manner.

In order to abstract away from the different buying processes and search costs, we model vendors and buyers as playing a game with asymmetric strategies where they are randomly matched with each other. Although implicit, we assume that the seller has decided on a transaction channel(s) first, but the buyer is not aware of the seller's choice. When the buyer decides to purchase a product, he or she chooses a channel and tries to identify a seller who has a product that satisfies his or her need. In principle, we assume trade is possible, but only if the consumer and the vendor choose a compatible transaction channel. If not, the possibility of trade is forgone *for now* and the buyer/vendor may match in the future when compatible modes are chosen (or the buyer may abandon the buying process). By not allowing a trade, we implicitly model

search cost: the gains from trade will only be realized later, incurring an "opportunity cost," which accounts for the search cost as well. The choice of a compatible transaction channel plays an important role in the different stages of planned buying: acquiring information and final purchase are only possible when buyers and sellers communicate through the same channel. Unplanned buying (especially impulse buying), on the other hand, is to a large extent conditioned on which transaction channel is chosen. In essence, buyers and sellers face a coordination problem [36]: potential buyers and sellers may not know of each other's existence and both parties have to make a choice on where to look for the other party.

We model an asymmetric game played by a seller with seven strategies and a buyer with four strategies (Table 1). Overall, both the seller and the buyer may adopt the traditional transaction channel (transaction in a physical store) or the electronic transaction channel (transaction online). Specifically, both the seller and the buyer may have the following four common strategies: traditional transaction (TT), cheating on electronic transaction (ET_c) (e.g., the fly-by-night strategy), playing honest on electronic transaction (ET_h), and electronic transaction through a TTP ($ETTP$) (e.g., using an online escrow service, authentication service, or other TTP). Moreover, the seller may offer both traditional transaction and electronic transaction simultaneously, therefore having three additional strategies: traditional transaction or playing honest on electronic transaction (ET_h/TT), traditional transaction or electronic transaction through TTP ($ETTP/TT$), and traditional transaction or playing honest on electronic transaction or electronic transaction through a TTP ($ET_h/ETTP/TT$). We assume sellers will not cheat if they have physical stores, since we are only concerned with incremental cheating behavior specifically enabled by the electronic channels. In addition, since buyers always purchase products through a pure transaction channel, we do not model buyers with strategies combining multiple channels, as this would mean that the buyer's search costs are increased and we will not be able to model search costs implicitly as the opportunity cost of trade lost. This framework can apply to the B2C market (e.g., small online retailers of electronics such as the ones rated on www.resellerratings.com) or the C2C market (e.g., online auction markets). According to a recent FBI report [38], such markets have the highest cases of online fraud, and the number of fraud cases is rising at an increasing rate every year.

If both the buyer and the seller adopt ET_h , then their payoffs will be x_b, x_s , respectively. If they both adopt ET_c , then the payoff will be $-t_b$ for the buyer, $-t_s$ for the seller ($-t_b, -t_s \leq 0$) because each suffers some loss (e.g., time lost) by playing the cheating strategy. If both play $ETTP$, then the payoff will be a_b for the buyer and a_s for the seller, where $a_b = x_b - c_b^{ETTP}$, $a_s = x_s - c_s^{ETTP}$. In other words, if both trading parties want to use a TTP (e.g., escrow service), then they will have to pay c_b^{ETTP} and c_s^{ETTP} for the cost of the service. When both players play TT , the buyer gets b_b , and the seller gets b_s . Because the electronic market is expected to be more efficient than the traditional market due to lower transaction costs [31, 32, 42], it is reasonable to assume for the seller that $b_s = x_s - c_s^{TT}$ and $c_s^{ETTP} < c_s^{TT}$ (or equivalently, $b_s < a_s$). With respect to commodity and quasi-commodity products, we further assume that for the buyer $b_b = x_b - c_b^{TT}$ and $c_b^{ETTP} < c_b^{TT}$ (or equivalently, $b_b < a_b$) because of lower search costs for

Table 1. The Payoff Structure of the Stage Game in Market Evolution

		Seller					
Buyer		ET_c	ET_h	$ETIP$	π	ET_h/π	$ETIP/\pi$
		$ET_c/ETIP$	$ET_h/ETIP$	$\pi/ETIP$	ET_h/π	$ETIP/\pi$	$ET_h/ETIP/\pi$
Buyer	ET_c	$-t_b - t_s$	$x_b + g_b$ $x_s - l_s$	0, 0	0, 0	$x_b + g_b$ $x_s - (l_s + c)$	$x_b + g_b$ $x_s - (l_s + c)$
	ET_h	$x_b - l_b$ $x_s + g_s$	$x_b x_s$	0, 0	0, 0	$x_b x_s - c$	$x_b x_s - c$
Buyer	$ETIP$	0, 0	0, 0	$a_b a_s$	0, 0	0, 0	$a_b a_s - c$
	π	0, 0	0, 0	0, 0	$b_b b_s$	$b_b b_s - c$	$b_b b_s - c$

buyers in the electronic market [7, 16, 34]. On the other hand, for “look and feel” products, because of the added utility from touching and seeing the product before purchase, we assume that, on average, $a_b < x_b < b_b$.

If one of the trading parties plays ET_h but the other plays ET_c , the cheating party will get a payoff of $x + g$, where g is the extra gain from cheating, and the cheated will get a payoff of $x - l < 0$, where l is the loss from being cheated. When incompatible shopping channels are chosen—say, (ET_h, TT) or $(ETTP, TT)$ —the transaction cannot happen, thus the payoff is $(0, 0)$. That is, a transaction could not take place because either the parties insisted on transacting in different channels or they were not aware of the possibility of trade since they were using different channels in the present time period.

When a seller offers multiple channels such as ET_h/TT , $ETTP/TT$, or $ET_h/ETTP/TT$, then the transaction can happen when the buyer's channel matches one of the channels offered by the seller. For example, if a buyer adopts $ETTP$, and a seller adopts $ET_h/ETTP/TT$, then, basically, the transaction will be played out by $(ETTP, ETTP)$. However, since the seller offers multiple channels simultaneously, he or she will incur an additional cost c to maintain both the traditional channel and the electronic channel. Therefore, the buyer still gets payoff a_b , but the seller gets payoff $a_s - c$. Similarly, if a buyer and a seller play $(ET_c, ET_h/TT)$, then their payoffs will be $(x_b + g_b, x_s - (l_s + c))$.

In the next two subsections, we will demonstrate that the two learning paradigms discussed in the third section yield different outcomes for market evolution, and that only the best reply model yields a unique equilibrium. We will discuss learning by natural selection and the best reply model in subsections.

Learning by Natural Selection or Imitation

We first study the dynamics of the market when buyers and sellers of commodity and quasi-commodity products use the least information and adapt their strategy based on the results of their past behavior or of peers' results (e.g., buyers communicating to other buyers the average payoffs of their strategy). Less successful traders adjust their strategies and switch to a new strategy that they perceive as more successful—that is, having higher average payoffs. We start with an initial distribution of buyers and sellers playing strategies i and j , respectively. After a certain number of trades, players with the lowest total payoff in the population consider changing their strategy. We repeat this process long enough until the system becomes stable—that is, until an ESS is reached. It is known that for an asymmetric game, the evolutionarily stable equilibrium corresponds to a pure strategy Nash equilibrium [39]. We introduce an agent-based simulation to get insight into the evolutionary path and the robustness of the equilibrium as a function of the initial conditions and other parameters of the system. A similar evolutionary game theory approach based on simulation has been applied to a wide variety of economic problems, from analyzing the evolution of bargaining [10] to the evolution of the medium of exchange in an economy [23].

Our agent-based simulation has a population of N buyers and N sellers. N stays constant over time. There are N_i^0 buyers of type i and N_j^0 sellers of type j originally. A

buyer of type i always plays strategy i and a seller of type j always plays strategy j . In each time period t , every buyer is randomly matched with a seller, and the payoffs as a result of this pairing are as given in Table 1. Each buyer and seller trades exactly once during each time period, and this is repeated T times. A period consisting of T time periods is called an *epoch*, and is indexed by η . At the end of each epoch, the total wealth is computed from the payoffs in these T transactions. The θ buyers and sellers with the lowest wealth accumulated after each epoch will die off and be replaced by θ new buyers and sellers. That is, the economic agents who are less successful will leave the game or adapt to other strategies that are likely to be more successful. The new buyers and sellers are generated in proportion to the *surviving* individuals after each epoch—that is, the probability that a new buyer of type i is generated after epoch η is

$$(1 - \varepsilon) \frac{\bar{N}_i^\eta}{\sum_k \bar{N}_k^\eta} + \frac{\varepsilon}{m} = (1 - \varepsilon) \frac{\bar{N}_i^\eta}{N - \theta} + \frac{\varepsilon}{m},$$

where $\bar{N}_i^\eta$ are the survivors of type i at the end of epoch η , ε is the probability that the player chooses a “mutant” strategy—that is, a random strategy with equal likelihood—and m is the number of strategies available. Hence, the strategies of the types who accumulated less wealth (and were thus likely to have disappeared at the end of epoch η) are less likely to be imitated than the strategies of the individuals who were better off.

Note that our regeneration of strategies is more conservative than the standard replicator dynamics (the replicator dynamics is $(\partial p_i' / \partial t) = p_i'(\pi_i' - \bar{\pi}')$, where $p_i' = (N_i' / N)$, and π_i' and $\bar{\pi}'$ are the average payoffs for type i and the overall average payoff, respectively, in time t) used in evolutionary dynamics (see, e.g., [18]). The latter has a growth rate proportional to the average payoffs of the types, whereas our growth rate is proportional to the players who decide not to change their strategy, and in general, is slower than the replicator dynamics. The intuition behind our growth rate is that we assume in our setting that players who want to switch their strategy may have an idea about which strategy is performing better (because more players are using it or other players are sticking to their strategy), but they do not observe other players' average payoffs (as it would be hard to get information about others' exact payoffs).

After running many simulations, a typical outcome for the evolution of the buyers' strategy in a market with commodity goods is displayed in Figures 1 and 2. In both cases, the distribution of buyers' (as well as sellers') strategies was uniform; Figure 1 starts out with buyers evenly distributed over the four strategies, whereas Figure 2 has twice as many buyers playing TT than the other three strategies. In Figure 1, the evolutionarily stable equilibrium becomes $(ETTP, ETTP)$, whereas in the second situation it is (TT, TT) . The outcomes seem to be robust for different values of the payoffs and different values of θ , T , and ε (ε determines the convergence rate; the *lower* ε is, the *faster* the equilibrium is reached). The graphs for sellers' strategies look similar.

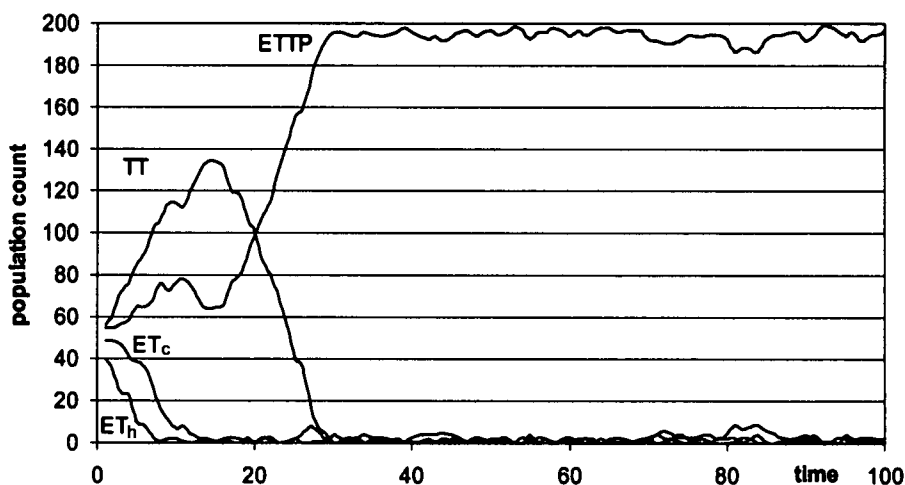


Figure 1. Uniform Distribution of Initial Buyer Strategies ($N = 200$, $\theta = 25$, $\varepsilon = 0.20$)

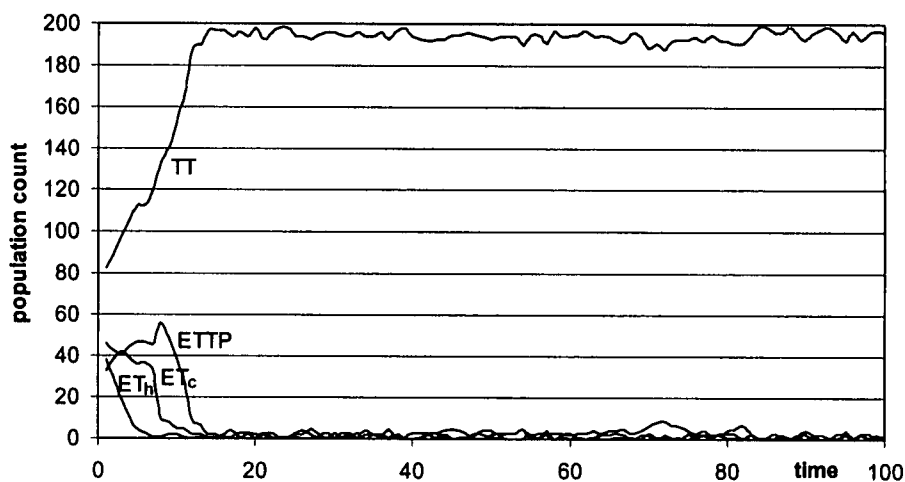


Figure 2. Initial Buyer Population with TT Doubled ($N = 200$, $\theta = 25$, $\varepsilon = 0.20$)

Figure 3 displays the same situation, with the difference that the number of honest buyers/sellers (ET_h/ET_h) is high and there are *no* people playing ET_c in the beginning (the only ET_c strategy is a mutant strategy). We would like to see which equilibrium would appear in this case, and find out whether (ET_h, ET_h) will become the equilibrium. It turns out that despite the abundance of ET_h players (both buyers and sellers), (ET_h, ET_h) is not an evolutionarily stable equilibrium as could be expected. Again, Figure 3 only displays the evolution of buyer strategies, but the evolution of seller strategies looks similar. It is interesting to follow the behavior of the system: at first honest players are being forced out by dishonest players, but since there are only dishonest players left, it becomes favorable to play a strategy that is robust against

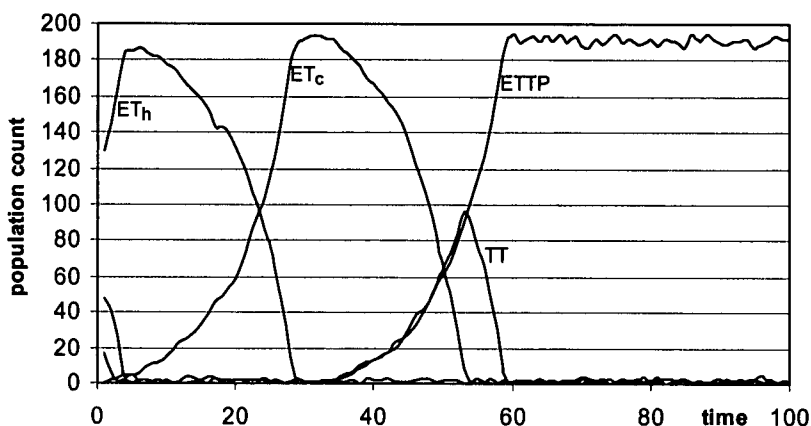


Figure 3. Initial Distribution of Buyer Strategies (ET_c , ET_h , $ETTP$, TT) is (0 percent, 70 percent, 5 percent, 25 percent) (with $N = 200$, $\theta = 25$, $\varepsilon = 0.20$)

cheating: $ETTP$ or TT . When dishonest players have been weeded out, the $ETTP$ strategy takes over as the dominant strategy because of the higher payoffs and becomes the eventual ESS.

In conclusion, if the transacting parties adapt their behavior by imitating more successful behavior, $ETTP$ becomes the ESS in most of the cases. That is, $ETTP$ becomes the new convention for market transaction. Only when there is a dominant proportion of traders who insist on transacting over the physical channel does TT become the ESS. However, as will be seen in the next section, when traders use historical information about strategies played by the other party, the stochastically stable equilibrium for commodity and quasi-commodity products is always $ETTP$.

For "look and feel" products, similar phenomena were observed. That is, the final ESS was dependent upon the initial distribution of the strategies in the population. But the dependence is more pronounced. In addition, the ESS was also a function of the relative payoffs of $ETTP$ and TT for the buyers and sellers. That is, for "look and feel" products, the payoff for buyers (on average) is higher using TT than using $ETTP$, whereas for the seller, the opposite holds (operating an electronic channel is always considered less expensive than maintaining a physical outlet, regardless of product characteristics). Hence, if the relative gain of using $ETTP$ for the seller outweighed the relative decrease in payoff for the buyer, ($ETTP$, $ETTP$) was more likely to become the ESS when the initial distribution of TT players was not too high. Otherwise the (TT , TT) became the new ESS. These results are consistent with the analytical results in the best reply model presented analytically in Corollary 2. Again, we have never observed (ET_h , ET_h), (ET_c , ET_c), or any other strategy pair to become an ESS.

In conclusion, we can say that the simulations show that unless the initial distribution of the population is predominantly playing one pure strategy (such as TT), the final ESS becomes the socially desired one—that is, the Nash equilibrium with the highest social welfare. Thus, switching channels to the most socially preferred channel (in

terms of welfare) is most likely to take place, when the initial population is not already locked into another (inferior) convention.

The Best Reply Model

In the best reply model it is assumed that players use historical information about the other player's actions as indicative of future actions. Rather than looking at how certain behavior in the population is diffused, as in the previous subsection, here we model the *individual actions* of a decision-maker who, based on historical information about his opponent, computes a *best reply strategy*. The best reply is computed as follows. This model underlines the importance of feedback profiles on the Web, where trading parties can gauge past actions and determine a best reply based on them. We assume that the history of the past m plays is available, and, because m may be large, and that a player samples k out of the m plays to compute his best reply strategy as follows. Let $p_i^j(x_i)$ be the proportion of the time strategy x_i was played by player i in the sample of k plays. A *best reply strategy* $x_j^*(p_i^j)$ for player $j \neq i$ is the strategy that maximizes j 's expected payoff, assuming i chooses his strategy according to the distribution $p_i^j(x_i)$.

We first need some preliminary results. In the following, define $L(s)$ to be the length of a shortest directed path in the best reply graph from a strategy-tuple s to a strict Nash equilibrium.

Lemma: The game from Table 1 is a weakly acyclic game² and $L_T \stackrel{\text{def}}{=} \max_s \{L(s)\} = 3$.

Proof: See the Appendix.

The consequences of the lemma are that the conventions of a weakly acyclic game are always pure strategy Nash equilibria and that if $k \leq m/(L_T + 2)$, then the best reply behavior converges almost surely to a convention. The fact that the sample size k should be less than or equal to 20 percent of the available history m is not a severe restriction: typically, there exists an abundance of feedback reviews about past transactions such that a player computing a best reply strategy will only sample a small subset of this available information. Therefore, in the game described in Table 1, with incomplete sampling, which introduces stochastic variation into the players' responses, a possibility exists that the players will coordinate by chance, and if they do so frequently enough, the process eventually converges to a pure strategy Nash equilibrium.

In the model stated in Table 1, there are only two pure strategy Nash equilibria: $(ETTP, ETTP)$ and (TT, TT) for both commodity/quasi-commodity products and "look and feel" products. Note that there is a unique Pareto optimum (ET_h, ET_h) , but it is not a Nash equilibrium. This follows from the well-known fact that the subgame consisting of the strategies ET_c and ET_h is a "prisoner's dilemma" game [21]. Hence, this Pareto optimum is not attainable without imposing further rules, if we assume that both players are free agents. Even when the prisoner's dilemma game is played re-

peatedly, we know that it does not necessarily give us a Pareto optimal outcome. Therefore, the question now is: which strategy will be the prevailing convention with the existence of the electronic market?

Presently, traditional transactions have been a widely accepted practice for many years, whereas electronic commerce is only a recent phenomenon enabled by network technologies. As we mentioned before, the traditional market is a social-economic Nash equilibrium that has been functioning properly. People are comfortable with the mechanisms embedded in the current equilibrium: there are mechanisms in the traditional market to facilitate transactions, such as payment settlement methods and trust-building mechanisms (e.g., credit systems, rating agencies). Therefore, there is no incentive for business parties to deviate from it. The new electronic market, although offering many advantages, inevitably involves risks, some of them being the security concerns and product quality uncertainties. Although these risks can be mitigated through TTPs, moving into a new equilibrium takes time and learning. Given the existence of multiple Nash equilibria and the current institutional infrastructure that is functional for TT, will the market eventually learn to use TTPs? We use the stochastically stable equilibrium theory [45] to study the process. Simply speaking, stochastically stable equilibria are calculated by finding the paths of least resistance among equilibria, and then discovering the equilibrium among them that has the lowest overall resistance. This represents a special case of a general theorem on perturbed Markov processes [17] that characterizes their stochastically stable states graph-theoretically.

Let Γ be a two-person asymmetric game. Let S_i be the finite set of strategies available to player i ($i = 1, 2$). Let N be a finite population of traders that could be classified into two nonempty classes C_1, C_2 . Each member of C_i is a candidate to play role i in the game. For instance, C_1 is the class of buyers, and C_2 is the class of sellers.

Let $t = 1, 2, \dots$, represent sequential time periods. The game is played once each period. One individual is randomly drawn from each of the two classes and is assigned to play role i in the game in period t . We denote the two players as Player 1 (e.g., buyer) and Player 2 (e.g., seller). Player 1 and Player 2, respectively, pick pure strategies $s_1(t)$ and $s_2(t)$ from their strategy space, according to the rule defined below. The strategy-tuple $s(t) = (s_1(t), s_2(t))$ is recorded as the play at time t . Up to time t , the history of plays is the sequence $h(t) = (s(1), s(2), \dots, s(t))$. The histories are assumed to be anonymous: it is not important who exactly played a given strategy in a given period. What is important is the information that a given strategy was played by someone.

The following is the rule for players to choose their strategies. Fix integers k and m such that $1 \leq k \leq m$. In time period $t+1$ ($t \geq m$) each player examines k plays that are drawn without replacement from the most recent m periods $t, t-1, t-2, \dots, t-m+1$. The draws made by each player are independent.³ We assume that every subset of k has a positive probability of being Player 1's or Player 2's information.⁴ For the sake of generality, we can assume that the first m plays are randomly selected. Therefore, in period $t = m+1$, the sampling process starts from some arbitrary initial sequence of m plays $h(m) = (s(1), s(2), \dots, s(m))$.

Theorem 1: (ETTP, ETTP) is a unique stochastically stable equilibrium for commodity and quasi-commodity products (that is, when $a_b = x_b - c_b^{ETTP}$, $b_b = x_b - c_b^{TT}$, $c_b^{ETTP} < c_b^{TT}$).

Proof: See the Appendix.

For "look and feel" products, we assume that $a_b < b_b$, since the buyer's payoff is higher when the product can be experienced in a traditional store, but a seller's cost of operating a physical store is assumed to be higher than operating an electronic channel, even with the costs of using a TTP added in—that is, $b_s < a_s$.

Corollary 2: For "look and feel" products (i.e., when $a_b < b_b$), the unique stochastically stable equilibrium is

- a. (TT, TT) if and only if $(b_b/a_b) > (a_s/b_s)$; and*
- b. (ETTP, ETTP) if and only if $(b_b/a_b) < (a_s/b_s)$.*

Proof: See the Appendix.

Corollary 2 is interpreted as follows: when the buyer's relative gain in payoff (i.e., b_b/a_b) from using a traditional channel is higher than the cost savings the seller would realize from using the ETTP strategy (i.e., a_s/b_s), (TT, TT) becomes the stochastically stable equilibrium; otherwise, the electronic channel (with TTP) becomes the prevailing convention.

Market Transformation and Conclusion

THE ABOVE ANALYSES INDICATE that due to the nature of the product, the market will have some divergence. Some products are more suitable for the electronic market, whereas others are more suitable for the traditional physical market, and one expects both types of markets to coexist. The market divergence results from market participants' adaptive behavior and the product characteristics.

We recognize that many online transactions may not need TTP services. For example, when a consumer buys a book from Amazon.com, which is perceived as an honest seller, the consumer most likely feels confident that Amazon will not suddenly switch to an opportunistic strategy. There is a significant segment of online transactions, however, that takes place among individual consumers or involves small retailers who do not have brand-name recognition and may act opportunistically. Then concerns about privacy, security, or online product and service quality may influence a player's willingness to transact online. For example, many customers turn to the World Wide Web (e.g., virtual malls and virtual bookstores) primarily to browse, not to buy, and many businesses have been hesitant to incorporate electronic commerce into their operations. However, the tremendous advantages offered by electronic commerce, such as lower transaction costs, greater choice, and a potentially worldwide customer and vendor base, will undoubtedly fuel the growth of the digital economy. Under the right circumstances, the payoff structure $a_b > b_b$, $a_s > b_s$ would prevail and

market participants would gradually learn that transacting in the electronic market using a TTP yields higher payoffs. While we agree that the transformation could be a very long process, and we do not expect that the above payoff structure would hold for every transaction, the electronic market with TTPs will surely emerge as the dominant environment for conducting commerce in the future for certain products. The equilibrium level of use depends upon the extent of its economic advantages over the traditional market it competes with.

One question critical to the transformation from the traditional market to the electronic market is how well consumers are able to evaluate characteristics of goods in the digital environment. At the moment, the most frequently purchased products online are books, music CDs, software CDs, video games, hardware, and electronics [43]. That is, consumers are buying digital products, such as digital CDs, software, entertainment products, as well as other information-based products that can be digitized and delivered via the network efficiently. They are also buying products that are physical goods but whose characteristics are well known or easy to perceive on the network (e.g., commodity or quasi-commodity products such as paper clips and books). For most "look and feel" goods, however, consumers still resort to the traditional market due to the difficulties of evaluating the characteristics of goods online, and our analysis suggests that this will remain so. For example, many consumers prefer to buy fruits in a traditional grocery store rather than ordering online, because they can better choose the color and ripeness of the fruit. For companies planning to compete in the electronic market, they need to carefully devise their strategy based on their product offering and provide information that is designed to help consumers understand their products. In addition, strategic alliances with well-established businesses or TTPs may be needed to enhance their reputation and trustworthiness with potential customers.

During this transformation process from the traditional market to the electronic market, the invention of new technology and acceptance of new technology will be a fundamental force. New technology utilized by vendors' storefronts will provide more possibilities for consumers to evaluate product characteristics. For example, with virtual reality, "(W)hen you're shopping for clothing, it will be displayed in your size" [22, p. 166]. Products that require direct personal experience may one day relax the requirement. Moreover, various TTPs will come out and add value for buyers and sellers in the electronic market. In that case, the electronic market with TTPs still dominates as the convention, no matter what market participants' learning behaviors are. Obviously, the development of electronic commerce exerts immense pressure on the current technology applied in the electronic market. We believe that the emergence of new technologies in electronic markets will eventually make most of the conversion a reality.

Another force fueling the transformation from traditional markets to electronic markets is that brought about by network externalities [3, 28], which means that the value of electronic markets increases as more people use them. As more and more consumers jump onto the Internet bandwagon, the electronic market will become a marketplace that merchants cannot ignore. As a result, merchants can provide more product choices, thus attracting more customers. Therefore, network externalities

encourage the use of electronic transactions—the more online transactions, the lower the setup and transaction costs. Positive network externalities are implicit in our model because the more people use a certain strategy, the easier it is to transact with them using that same strategy.

A limitation of this research is that our current model only applies to online C2C markets and B2C markets where online merchants do not have an established reputation. Relaxing some of the assumptions in the evolutionary game-theoretic model might provide a more general framework that can be used to analyze the overall market transformation, including the business-to-business (B2B) markets. In addition, empirical research examining transaction patterns and their evolution over time in markets such as eBay will complement and hopefully confirm our analytical results. This will be the next step in this line of research.

In conclusion, using an evolutionary game theory approach, we analyzed conventional and electronic markets, and demonstrated that there are two different conventions under two different payoff structures resulting from the different natures of products. Therefore, traditional markets and electronic markets will coexist under the current technological and social environment. With the development of new technologies, however, “virtual reality” may become a possibility. The implementation of virtual reality to convey product characteristics too complex to be conveyed by current technologies could lead to increased electronic transactions facilitated by TTP.

Acknowledgments: The authors thank the Editor-in-Chief and the three anonymous reviewers for their thorough and thoughtful review of the paper. Their comments and suggestions helped strengthen the analysis and greatly improved the quality of the research. The authors also thank Maxwell Stinchcombe for his insightful comments on earlier versions of the paper.

NOTES

1. Directly quoted from eBay's User Agreement (pages.ebay.com/help/policies/user-agreement.html, accessed November 20, 2003).

2. A game is weakly acyclic if, and only if, from every strategy-tuple there exists a finite sequence of best replies by one agent at a time that ends in a strict, pure strategy Nash equilibrium [45].

3. The sampling procedure can be explained in the following two ways: First, each player asks around (or reads feedback messages) to learn how the game was played in recent time periods. He stops reviewing the previous plays when he has inspected k different plays within the last m periods. For example, this is the player's maximum capability to obtain information. Second, each player just passively hears about certain previous plays, and k is the number of previous plays that come to the player's attention. Therefore, the fraction k/m assesses the completeness of the players' information relative to the surviving previous plays.

4. It is not necessary to assume that every subset of k previous plays out of the last m would be selected with equal probability as a player's information set. This is reasonable, considering that people tend to refer to recent history when making decisions.

5. Note that an absorbing state can never be a mixed-strategy equilibrium.

REFERENCES

1. Akerlof, G.A. The market for lemons: Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, 84, 3 (August 1970), 488–500.

2. Arnould, E.J.; Price, L.; and Zinkhan, G. *Consumers*. New York: McGraw-Hill/Irwin, 2004.
3. Au, Y.A., and Kauffman, R.J. Should we wait? Network externalities, compatibility, and electronic billing adoption. *Journal of Management Information Systems*, 18, 2 (Fall 2001), 47–64.
4. Ba, S., and Pavlou, P. Evidence of the effect of trust building technology in electronic markets: Price premiums and buyer behavior. *MIS Quarterly*, 26, 3 (September 2002), 243–268.
5. Ba, S.; Whinston, A.B.; and Zhang, H. The design of a trusted third party for electronic commerce transactions. In E.D. Hoadley and I. Benbasat (eds.), *Proceedings of the Fourth Americas Conference on Information Systems*. Atlanta: Association for Information Systems, 1998, 269–271.
6. Ba, S.; Whinston, A.B.; and Zhang, H. Building trust in online auction markets through an economic incentive mechanism. *Decision Support Systems*, 35, 3 (June 2003), 273–286.
7. Bakos, Y. The emerging role of electronic marketplaces on the Internet. *Communications of the ACM*, 41, 8 (August 1998), 35–42.
8. Bhattacharjee, A. Individual trust in online firms: Scale development and initial test. *Journal of Management Information Systems*, 19, 1 (Summer 2002), 211–242.
9. Bikhchandani, S.; Hirshleifer, D.; and Welch, I. A theory of fads, fashion, custom, and cultural change as informational cascades. *Journal of Political Economy*, 100, 5 (October 1992), 992–1026.
10. Carpenter, J.P. Evolutionary models of bargaining: Comparing agent-based computational and analytical approaches to understanding convention evolution. *Computational Economics*, 19, 1 (February 2002), 25–49.
11. Chircu, A.; Davis, G.; and Kauffman, R. The role of trust and expertise in the adoption of electronic commerce intermediaries. Management Information Systems Research Center Working Paper, University of Minnesota, Minneapolis, March 2000.
12. Choi, S.-Y.; Stahl, D.O.; and Whinston, A.B. *The Economics of Electronic Commerce*. Indianapolis: Macmillan Technical Publishing, 1997.
13. Conway, D.G., and Koehler, G.J. Interface agents: Caveat mercator in electronic commerce. *Decision Support Systems*, 27, 4 (January 2000), 355–366.
14. De Figueiredo, J. Finding sustainable profitability in electronic commerce. *Sloan Management Review*, 41, 4 (Summer 2000), 41–52.
15. Eldridge, L. Internet commerce and the meltdown of certification authorities: Is the Washington State solution a good model? *UCLA Law Review*, 45, 6 (August 1998), 1805–1842.
16. Elofson, G., and Robinson, W. Creating a custom mass-production channel on the Internet. *Communications of the ACM*, 41, 3 (March 1998), 56–62.
17. Freidlin, M., and Wentzell, A. *Random Perturbations of Dynamical Systems*. New York: Springer-Verlag, 1984.
18. Friedman, D. Evolutionary games in economics. *Econometrica*, 59, 3 (May 1991), 637–666.
19. Friedman, E., and Resnick, P. The social cost of cheap pseudonyms. *Journal of Economics and Management Strategy*, 10, 2 (2001), 173–199.
20. Fudenberg, E., and Levine, D. *The Theory of Learning in Games*. Cambridge, MA: MIT Press, 1998.
21. Fudenberg, E., and Tirole, J. *Game Theory*. Cambridge, MA: MIT Press, 1991.
22. Gates, W. *The Road Ahead*. New York: Viking, 1995.
23. Gintis, H. A Markov model of production, trade and money: Theory and artificial life simulation. *Computational and Mathematical Organization Theory*, 3, 1 (1997), 19–41.
24. Hoffman, D.L.; Novak, T.P.; and Peralta, M. Building consumer trust online. *Communications of the ACM*, 42, 4 (1999), 80–85.
25. Hotelling, H. Stability in competition. *Economic Journal*, 39, 153 (1929), 41–57.
26. Hu, X.; Lin, Z.; Whinston, A.B.; and Zhang, H. Perceived risk and escrow adoption: An economic analysis in online consumer-to-consumer auction markets. In V.C. Storey, S. Sarkar, and J.I. DeGross (eds.), *Proceedings of Twenty-Second Annual International Conference on Information Systems*. Atlanta: Association for Information Systems, December 16–19, 2001, pp. 271–274.
27. Jarvenpaa, S.L.; Tractinsky, N.; and Vitale, M. Consumer trust in an Internet store. *Information Technology and Management*, 1, 1–2 (2000), 45–71.

28. Katz, M.L., and Shapiro, C. Network externalities, competition, and compatibility. *American Economic Review*, 75, 3 (June 1985), 424–440.
29. Kollock, P. The production of trust in online markets. In E.J. Lawler, M. Macy, S. Thyne, and H.A. Walker (eds.), *Advances in Group Processes*, vol. 16. Greenwich, CT: JAI Press, 1999, pp. 99–123.
30. Lee, B., and Yoo, B. Internalization of electronic “auction market” and information asymmetry in electronic commerce. Paper presented at the Workshop on Information Systems and Economics (WISE), Charlotte, NC, December 11–12, 1999 (available at www.gsia.cmu.edu/andrew/sandras/public/wise/pdf/blee01.pdf).
31. Lee, H. Do electronic marketplaces lower the price of goods? *Communications of the ACM*, 41, 1 (January 1998), 73–80.
32. Lee, H., and Clark, T. Market process reengineering through electronic market systems: Opportunities and challenges. *Journal of Management Information Systems*, 13, 3 (Winter 1996–97), 113–136.
33. Lindquist, J., and Sirgy, M.J. *Shopper, Buyer and Consumer Behavior*. Cincinnati, OH: Atomic Dog Publishing, 2002.
34. Malone, T.W.; Yates, J.; and Benjamin, R.I. Electronic markets and electronic hierarchies. *Communications of the ACM*, 30, 6 (June 1987), 484–497.
35. McDonald, J., and Tobin, J. Customer empowerment in the digital economy. In A. Lowy and D. Ticoll (eds.), *Blueprint to the Digital Economy: Creating Wealth in the Era of E-Business*. New York: McGraw-Hill, 1998, pp. 202–220.
36. Milgrom, P., and Roberts, J. *Economics, Organization and Management*. Upper Saddle River, NJ: Prentice Hall, 1992.
37. Resnick, P.; Zeckhauser, R.; Friedman, E.; and Kuwabara, K. Reputation systems. *Communications of the ACM*, 43, 12 (2000), 45–48.
38. Rosencrance, L. FBI: Internet fraud complaints up in 2002. *Computerworld*, April 10, 2003 (available at www.computerworld.com/securitytopics/security/cybercrime/story/0,10801,80200,00.html?nas=AM-80200).
39. Samuelson, L., and Zhang, J. Evolutionary stability in asymmetric games. *Journal of Economic Theory*, 57, 2 (1992), 363–391.
40. Sarkar, M.B.; Butler, B.; and Steinfeld, C. Intermediaries and cybermediaries: A continuing rule for mediating players in the electronic marketplace. *Journal of Computer-Mediated Communication*, 1, 3 (1996) (available at www.ascusc.org/jcmc/vol1/issue3/sarkar.html).
41. Sen, S., and Hernandez, K. A buyer’s agent. In C. Sierra, M. Gini, and J.S. Rosenschein (eds.), *Proceedings of Fourth International Conference on Autonomous Agents*. New York: ACM Press, 2000, pp. 156–162.
42. Strader, T., and Shaw, M. Characteristics of electronic markets. *Decision Support Systems*, 21, 3 (November 1997), 185–198.
43. Taylor Nelson Sofres Inc. Global ecommerce report 2002. Taylor Nelson Sofres Interactive, London, 2002 (available at www.tnsofres.com/ger2002/).
44. Taylor, P., and Jonker, L. Evolutionary stable strategies and game dynamics. *Mathematical Biosciences*, 40, 1–2 (1978), 145–156.
45. Young, H.P. The evolution of conventions. *Econometrica*, 61, 1 (1993), 57–84.
46. Young, H.P. Individual strategy and social structure: An evolutionary theory of institutions. Princeton: Princeton University Press, 1998.

Copyright of Journal of Management Information Systems is the property of M.E. Sharpe Inc. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.