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An Evolutionary Game Approach

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Abstract

Using an evolutionary game approach, this paper studies different equilibria in the electronic marketplace, and demonstrates that electronic transaction through a TTP is an evolutionarily stable strategy. According to the evolutionary game analysis, people will gradually adopt this strategy in the electronic marketplace.

Introduction

Electronic commerce arguably provides better efficiency for many types of business. However, the lack of trust and familiarity with the new digital economy makes many people apprehensive about moving to the electronic world. Fear of security breaches, mistrust in the products and services offered online, and the lack of legal structures are major obstacles to the growth of electronic commerce. Ba et al. (1998) argue that information asymmetry poses serious challenges to the growth and wide adoption of electronic commerce. One aspect of information asymmetry is security, and the other one, perhaps more significant, is the product quality uncertainty problem (Akerlof 1970). Certification authorities (CA) such as Verisign have emerged in recent years attempting to mitigate the security problem by helping authenticate online traders (Froomkin 1997). However, the current structure of CAs does not address the product quality problem. An authenticated online vendor (i.e., he holds a valid digital certificate) can still cheat consumers by selling counterfeit products or products that do not match up the promised quality. One consequence could be that in the electronic marketplace people only do business with well-established companies. Small or new online business entities consequently may be forced out of the market, which obviously impedes the adequate growth of electronic commerce. Using a game theoretic approach, Ba et al. propose a new design of trusted third parties (TTP) that not only issue digital certificate, but also protect the interest of online players by disseminating trading partner reputation. They have demonstrated that with the help of TTP - an extralegal economic incentive mechanism - the most profitable course for anyone wishing to do business online is to be honest.

The question is, will people use the services of trusted third parties? How does the electronic market evolve? Will individuals continue their electronic transactions without the extra protection of TTPs, as most of the transactions are done today, or will the transaction going through a TTP become the dominant strategy in the electronic market? This paper attempts to study the dynamics of the electronic market by identifying the different equilibria of the market and the characteristics of different strategies using an evolutionary game theory approach.

Research Model: Electronic Transactions with and without TTPs

In the global electronic market, vendors and buyers randomly match with each other and play a two-person game. Since a player can sometimes be a buyer and other times a seller, we model the game as a symmetric game. Building on the TTP model proposed by Ba et al (1998), we assume that each player has two strategies available for each business transaction in the electronic marketplace: electronic transaction without going through a TTP, and electronic transaction through a TTP.

In the electronic market, many products offered online are digital products, which, incorporating the unique advantages of the electronic media, are mostly experience goods. Their quality becomes known only after consumption (many information goods are purchased only once). Therefore quality uncertainty is a critical issue with respect to digital products. Conventional goods are also an important component in the electronic market. For example, it's more convenient to order books, CDs, or airplane tickets online than go to the physical stores or agencies. However, all transactions in the electronic market, regardless of conventional goods or digital goods, have security and quality uncertainty problems. The TTPs help mitigate the problems by tying a player's reputation to each transaction that he engages in. Business agents need to maintain and protect their reputation if they want to continue their business in the global electronic market. By obtaining a digital

certificate from a TTP, buyers and sellers get a guarantee about the quality of their transactions. But buyers and sellers that do not use the services of TTPs may be cheated. For example, they may end up with counterfeit products or products that do not match up the announced quality. Therefore, in our model, the payoff a for electronic transactions through a TTP is higher than the payoff a' for electronic transactions without a TTP: $a > a'$.

Let *ETTP* denote electronic transactions through a TTP, *E* electronic transactions without using the services of a TTP, then we have the following table with the respective payoff for each strategy.[1]

also that the mutants all are programmed to play some other (pure or mixed) mutant strategy $y \in \Delta$. The payoff to strategy $x \in \Delta$ is $u(x, y)$ when played against $y \in \Delta$. A strategy $x \in \Delta$ is evolutionarily stable if and only if it meets the following two conditions (Maynard Smith 1982, Weibull 1995):

$$u(y, x) \leq u(x, x) \quad \forall y,$$

$$u(y, x) = u(x, x) \Rightarrow u(y, y) < u(x, y) \quad \forall y \neq x.$$

The first condition is a Nash equilibrium requirement and the second one is a stability requirement which ensures that the ESS x can repel mutants such as y. If

Vendor

Consumer		E	ETTP
	E	a', a'	a', a'
	ETTP	a', a'	a, a

Table 1: Payoff to a player following the row strategy against a player following the column strategy: $a > a' > 0$

Obviously, there are two Nash equilibria in this game: (*E, E*) and (*ETTP, ETTP*). Which equilibrium will the trading partners play? We will use an evolutionary game theory approach to analyze the situation.

A fundamental concept in evolutionary game theory is that of an evolutionarily stable strategy (ESS). An ESS is a Nash equilibrium satisfying an additional stability property. That is, an ESS should be able to withstand the pressures of mutation and selection once it becomes established in a population. (Maynard Smith and Price 1973, Maynard Smith 1982).

Mathematically, the set of pure strategies is denoted $K = \{1, 2, ..., k\}$ and the associated mixed-strategy set, $\Delta = \{x \in R_+^k : \sum_{i \in K} x_i = 1\}$. Suppose that a small group of mutants appears in a large population of individuals, all of whom are programmed to play the same (mixed or pure) incumbent strategy $x \in \Delta$. Suppose

the conditions fail, then the strategy y is said to be able to invade x.

Theorem: In the electronic marketplace, ETTP is an evolutionarily stable strategy.

Proof.

i) Is $x = (1, 0)$ an ESS?

If $x = (1, 0)$, this means consumer and vendor all will play E, then $u(x, x) = a'$. No matter what y is, $u(y, x) \leq u(x, x)$ because $a' \geq Co(a', a')$ (Convex hull of a', a'). Therefore, Condition 1 is satisfied, and $x = (1, 0)$ is a Nash equilibrium strategy. Suppose $y = (0, 1)$, then $u(y, x) = u(x, x) = a'$. However, $u(y, y) = a$, and $u(x, y) = a'$, but $a \succ a'$, so $u(y, y) > u(x, y)$, then Condition 2 is not satisfied. Therefore, $x = (1, 0)$ is a Nash equilibrium strategy but not an ESS.

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[1] We may assume that there is no transaction if one player uses E and the other uses ETTP, then their payoff is (0, 0). However, we can get the same result that ETTP is the evolutionarily stable strategy.

ii) Is $x = (0,1)$ an ESS?

If $x = (0,1)$, this means consumer and vendor all will play ETTP, then $u(x,x) = a$. No matter what y is, $u(y,x) \leq u(x,x)$ because $a \geq Co(a',a)$. Therefore, Condition 1 is satisfied. Obviously, Condition 2 is also satisfied, because we cannot find a $y \in \Delta$ so that $u(y,x) = u(x,x)$. Therefore $x = (0,1)$ is an ESS.

Our proof shows that with the payoff structure $a > a' > 0$, ETTP is an ESS. In other words, individuals who try to use *ETTP* do better than those individuals who stick to the E strategy. Currently, many individuals adopt the *E* strategy. They may enjoy all the advantages associated with electronic transactions, however, they may also experience problems arising from the security and/or product quality uncertainty issues. Therefore, trusted third parties come into the picture. The conversion from *E* to *ETTP* basically is a learning process. At the beginning, only a small group of population may try to use *ETTP*. They provide a new channel to conduct electronic transactions, which can be considered a mutant strategy (*ETTP*). The information about the experience may be reported in the media, may be discussed in the news group, or spread through word of mouth. If those individuals who try *ETTP* do less well than those individuals who stick to the *E* strategy, then the individuals who use *E* have no incentive to modify their strategy and those who try *ETTP* will return to the incumbent strategy. However, with the services of *TTP*, *ETTP* is a better strategy that leads to a higher payoff. So sooner or later, the mutant strategy, *ETTP*, will successfully invade the electronic market. The individuals who currently use *E* will eventually change their strategy to *ETTP*.

Conclusion

Using an evolutionary game theory approach, we analyze the electronic marketplace, and demonstrate that electronic transaction through a TTP (*ETTP*) is an evolutionarily stable strategy. With the services of TTP, people can learn about their trading partners' reputation before they conduct transactions. Therefore, they do not have to be restricted to businesses with a household name. They can go for small companies in the market as long as these small companies have a good reputation. In a sense, thus, TTPs help small or new companies to compete in the electronic marketplace. This research has strong, practical implications for intermediaries in the cyberspace which offer services to protect market participants from

opportunistic behaviors. Currently there are several intermediaries that disseminate online product or service quality information. For example, Bizrate (www.bizrate.com) – a site that rates online merchants in different categories – uses information from consumers to keep track of merchants' reputations; Carfax (www.carfax.com) provides vehicle history information to people shopping for a used vehicle. eBay (www.ebay.com) – an online auction site – provides a Feedback Forum that allows customers to leave comments about their experiences with their eBay trading partners. Even though these intermediaries deal with a specific type of quality uncertainty problems, they could be treated as the operational business model related to Ba et al (1998) and this research paper.

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