Analyzing Economic Impact of Disruptive Technology Using Multi-Agent Simulation: Smart Payment Case

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Abstract. Disruptive technology creates disruptive impacts, although it takes time to identify radical technological change and analyze its subsequent economic impacts in the industry. Despite the characteristics of disruptive technology, empirical research in this area has focused on case studies and has not attempted time-variant simulation to investigate its long-time effects. To address this research void, this study adopts a multi-agent simulation technique to analyze long-time effects of a smart payment method which is regarded as a disruptive technology. Experimental results via the multi-agent simulation are meaningful and robust, and their practical implications are discussed.

Keywords: Disruptive Technology, Smart Payment, Mobile Payment, Traditional Payment, Multi-Agent Simulation.

1 Introduction

The recent advent of Web technology changes many aspects of our daily life, finances in particular. Mobile banking is now common, with mobile payments, defined as payment via mobile devices such as a cellular phone or smart phone [19, 22], being more typical than in-person bank visits. For the sake of clarity, we assume that mobile payment is based on general types of mobile phones and devices, and smart payment is used only on smart phones. Therefore, when "mobile payment" is mentioned, we are excluding that made via smart phones.

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This paper deals with the economic analysis of disruptive techniques, such as smart payment. A disruptive technology is a radical and disruptive technology system that neutralizes the existing technologies or market thresholds by offering completely new functions and properties [1, 5, 6, 8].

Smart payment has the potential of becoming a disruptive technique for the following reasons. First, smart payment is immediately accessible. This technique is, therefore, more readily accessed than is a credit card.

Second, smart payment looks "cool" to young generations and to the many consumers who seek individuality. Using mobile payments will allow for increased freedom, providing a sense of constant connectivity.

Third, smart payment provides more convenience than do credit cards. Smart phones are capable of providing several features of smart payment, such as real-time support of segmented and personalized shopping information, credit payment, mileage accumulation, and integration of advertising and coupons.

Despite these advantages of smart payment, it is necessary to consider additional fees that occur for parties using the smart payment method. When smart payment is adopted as a widely accepted payment method in the market, consumers are supposed to pay fees for its use, as do merchants, telecommunication companies, and financial institutions.

However, market analysis of the adoption of disruptive technology is a highly ill-structured problem that has not determined the efficiencies of the conventional approaches [5, 7]. Therefore, this study adopts a heuristic approach using a multi-agent simulation (MAS), and then applies it to the resolution of the research question: *"How does a disruptive technology like smart payment influence interested parties over time?"*

The main objectives of this study are as follows. First, interested parties are those market players who are going to actively use the method in question. In this study, there exist four types of interested parties: customers, merchants, telecommunication companies, and financial institutions. Second, the effects of smart payment on those four players are analyzed using longitudinal MAS.

2 Theoretical Background

2.1 Disruptive Technology

The term "disruptive technology" was first coined by Christensen and Bower [2], who further developed this concept in the 1997 book, *The Innovator's Dilemma*, in which the term "disruptive technology" was transformed into "disruptive innovation".

Disruptive technology involves a radical and disruptive technology system that neutralizes the existing technologies or market thresholds by offering completely new functions and properties.

As proposed by Adner [1], Charitou and Markides [5], Christensen [8], Christensen and Bower [6], Christensen and Raynor [7] and Gilbert [9], disruptive technology takes on the following five characteristics. First, the innovation underperforms with respect to the attributes valued by mainstream customers. Second, new functions that are provided by disruptive technology are not highly appreciated by mainstream customers. Third, disruptive technology is much simpler and less expensive, conventionally speaking, and it is offered at a lower price than are the current products. Fourth, at the time of its introduction, the innovation appeals to a low-end, price-sensitive customer segment, thus limiting the profit potentials for incumbents. Fifth, over time, further developments improve the innovation's performance with regard to the valued attributes of mainstream customers to such a degree that the innovation begins to attract more of these customers.

Ondrus and Pigneur [16] looked into disruptions of mobile payment from two perspectives, the move from credit card to mobile phone and the replacement of manager-oriented solutions with self-organized solutions strengthened by new market entries.

A wider use of credit cards and debit cards has already demonstrated that cash-based transactions are amazingly reduced. A move from physical to virtual payment tools is already providing sizable benefits to interested partners, such as customers, merchants, financial institutions, and telecom companies. There still remains uncertainty, however, in the adoption and use of mobile payment, and Ondrus and Pigneur [16] found the major reasons of such uncertainty to be lack of market maturity and the lack of policy standards.

2.2 Mobile Payment and Smart Payment

Smart payment is receiving more attention as smart phones have become popular. Therefore, this study will investigate transactions using mobile payment with a focus on smart payment, which has become a common payment method.

With the fast growth of mobile communications, smart payment has become more useful in the banking and financial industries, particularly with regard to bill payment. Such new converging technology has brought benefits to diverse partners, including banking and financial institutions and mobile communications companies and providers [11]. Also, researchers have begun to focus more on the importance of merchants to understand the functions of the mobile payment market [13, 20] as they have realized that the increasing number of these merchants has led to the success of mobile payment solutions [17].

Some say that it will be difficult for mobile payment to become the standard because of the complexity caused by the different interests arising from major partners, including financial and mobile communication businesses, which all consider mobile payment as an innovative business idea [11].

Markides [14] discusses radical product innovation rather than disruptive technologies. In his research, mobile payment was viewed as a radical product innovation, which may become disruptive for both the consumer and the producer. According to Markides [14], such innovations have been propelled by the distributors, not by the consumers.

This study assumes that smart payment is available only on smart phones, quite different from general mobile payments. Smart phones that enable convenient and secure mobile commerce services, such as electronic wallet, electronic payment, 3G broadband Internet access, and multimedia content, are then described [4]. Among these advantages, this study focuses on electronic payment functions supported by smart phones. Smart phones are capable of providing several features of smart payment, such as real-time support for segmented and personalized shopping information, credit card payment and mileage accumulation, and integration of advertising and coupons. Moreover, smart phones can provide many advantages supported by mobile payments.

2.3 Multi-Agent System

The multi-agent system is composed of multiple interacting intelligent agents. Multi-agent systems have a feature in which individual intelligent agents with diverse goals and abilities are utilized to solve problems [12, 15]. The agents are considered autonomous entities, such as software programs or robots. The interactions between them may be anti-social or cooperative, meaning that they may have a common goal or might pursue their own interests. To summarize what has been discussed so far, the features for a multi-agent system are as follows. Each individual agent has a limited capacity due to its incomplete information and ability to solve a problem, illustrating that no single agent can control the entire system. The data in this type of system is decentralized, leading to asynchronous computation capabilities.

Meanwhile, more research on the study trends related to multi-agent systems exists. Multi-agent systems have suggested a new generation of coordination within corporations [3, 21]. Also, Palmer [18] conducted a simulation test using a multi-agent system on a category-elaboration model to calculate the diversities and the accomplishments of work groups. Hahn et al. [10] studied social reputation through a flexible self-control mechanism using multi-agent system technology to determine the social simulation for the microscopic and macroscopic factors within the electronic market.

Simulation studies using multi-agent systems are actively in progress in the field of social science to coordinate organizational issues and to measure accomplishments.

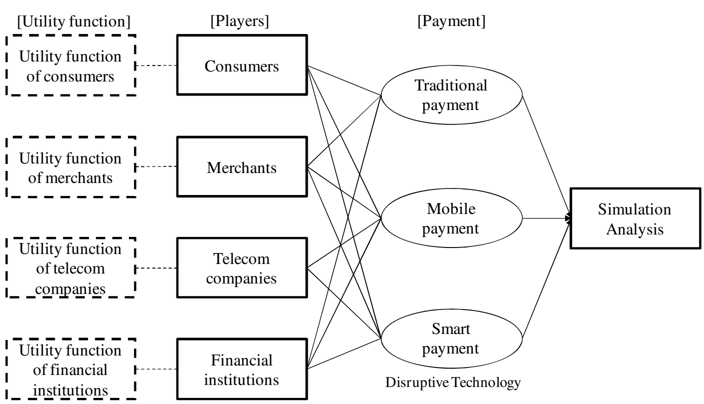

Fig. 1. Research Model

3 Research Methodology

3.1 Research Models

Our research model, as shown in Figure 1, assumes that there exist four players in a payment market, consumers, merchants, financial institutions, and telecommunication companies. Three types of payment methods are included, traditional payment, mobile payment, and smart payment. The technique adopted for this study is a multi-agent simulation (MAS).

3.2 Scenario

(1) Financial Institutions
The utility function of a financial institution (U_F) is described in Table 1.

Table 1. Utility Function of a Financial Institution

Item	Explanation
Utility function	• U_F = (TransNb x TransAvg x α TFee) + (MFee x CNb) - (MCost x CNb) - (TransNb x DiscAvg)
Detail components	• $Trans_{Nb}$ = number of transactions between consumers and merchants • $Trans_{Avg}$ = average amount per purchase (between \$0 and \$100) • α = ratio of fees between financial institutions and telecom companies (when $0.5 < \alpha \leq 1$) • TFee = merchant transaction fee (% of the purchase, e.g., 3%) • MFee = consumer credit card membership fee • C_{Nb} = number of participating consumers • M_{Cost} = maintenance cost incurred by issuing and maintaining plastic cards • $Disc_{Avg}$ = average discount amount per purchase

(2) Telecom Companies
The utility function (U_T) of a telecom company is explained in Table 2.

Table 2. Utility Function of a Telecommunication Company

Item	Explanation
Utility function	• U_T = ($Trans_{Nb}$x $Trans_{Avg}$ x (1- α)TFee) - (PT_{Cost} x M_{Nb}) - (ITD_{Cost}) + (C_{Roy} x C_{Nb})
Detail components	• $Trans_{Nb}$ = number of transactions between consumers and merchants • $Trans_{Avg}$ = average amount per purchase (between \$0 and \$100) • α = ratio of fees between financial institutions and telecom companies (when $0.5 < \alpha \leq 1$) • TFee = merchant transaction fee (% of the purchase, e.g., 3%) • PT_{Cost} = cost of the payment terminal • M_{Nb} = number of participating merchants • ITD_{Cost} = cost of the Information Technology • C_{Roy} = royalties of participating consumers • C_{Nb} = number of participating consumers

(3) Merchants
The utility function (U_M) of a merchant is described in Table 3.

Table 3. Utility Function of a Merchant

Item	Explanation
Utility function	• U_M = ($Trans_{Nb}$ x $Trans_{Avg}$ x $Profit_{Margin}$) - ($Trans_{Nb}$ x $Trans_{Avg}$ x TFee) - (($Send_{Cost}$ + CD_{Cost} + $Adver_{Cost}$) x C_{Nb}) + ($Marketing_{Eff}$ x C_{Nb})
Detail components	• $Trans_{Nb}$ = number of transactions between consumers and merchants • $Trans_{Avg}$ = average amount per purchase (between \$0 and \$100) • $Profit_{Margin}$ = the profit margin of the merchant • TFee = merchant transaction fee (% of the purchase, e.g., 3%) • $Send_{Cost}$ = cost incurred by shipping coupons and ads • CD_{Cost} = cost of the coupon discount • $Adver_{Cost}$ = cost of advertising • C_{Nb} = number of participating consumers • $Marketing_{Eff}$ = marketing effectiveness

(4) Consumers

The consumer utility function (U_C) is described in Table 4.

Table 4. Consumer Utility Function

Item	Explanation
Utility function	• U_C = ($Trans_{Nb}$ x $Trans_{Avg}$ x (Pay_{Sati} + Pro_{Sati} + Dis_{Ratio} + Point)) + $Info_{Sati}$ - MFee - $Phone_{Cost}$
Detail components	• $Trans_{Nb}$ = number of transactions between consumers and merchants • $Trans_{Avg}$ = average amount per purchase (range between \$0 and \$100) • Pay_{Sati} = payment satisfaction (the degree of satisfaction with the payment function) • Pro_{Sati} = product satisfaction (the degree of product satisfaction) • Dis_{Ratio} = discount rate • Point = points (i.e., mileage) • $Info_{Sati}$ = satisfaction with shopping and card information and automatic mileage search • MFee = consumer credit card membership fee • $Phone_{Cost}$ = phone costs incurred for using mobile and smart payments

4 Experiments

4.1 Multi-Agent Simulation

Four market players are included in our simulation and are represented by multi-agents. Multi-agents are modeled using NetLogo language. Figure 2 shows a NetLogo screenshot in which each utility graph is depicted.

For the sake of performing a MAS, it is assumed that a time period is one month, and simulation time is fixed to 48 time-lag periods (i.e., 4 years). A total of 100 simulations were conducted, and the MAS results are limited to average utility values revealed by the four players during the simulation time interval. The MAS procedure adopted for this study is addressed in Figure 3.

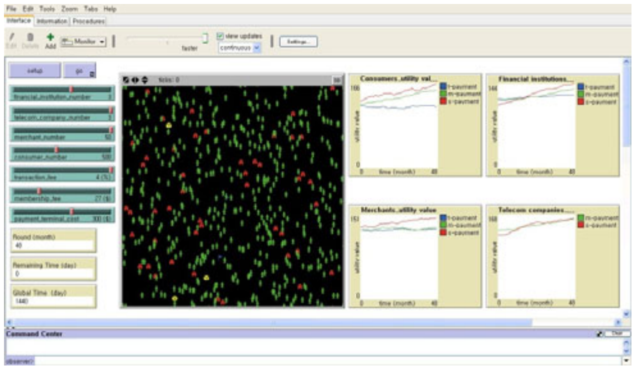

Fig. 2. NetLogo Display

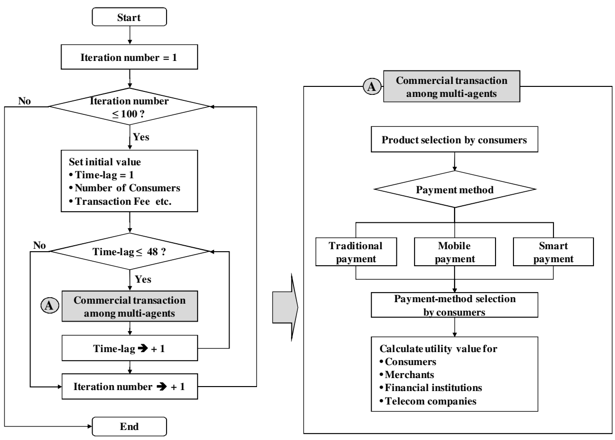

Fig. 3. Flowchart of MAS

4.2 Results and Discussion

Figure 4 shows the average utility value for the four players in three different payment methods. Figure 5 shows the trend pattern of utility value over four years (time-lag = 48). Figures 4 and 5 can be compared to induce implications.

First, at time-lag 1, consumers perceive that smart payment is the best option, followed by mobile payment and traditional payment. This fact is not surprising because smart payment provides various advantages for consumers, including personalized shopping information, card information, and an integrated payment function from which consumers can select the most convenient payment method. Moreover, through 48 time-lag periods, traditional payment shows no significant change in consumer utility value, while mobile payment does show a small change. In the case of smart payment, there is a significant increase in consumer utility value. Therefore, it can be concluded that smart payment becomes more disruptive in the market due to its significant advantages for consumers.

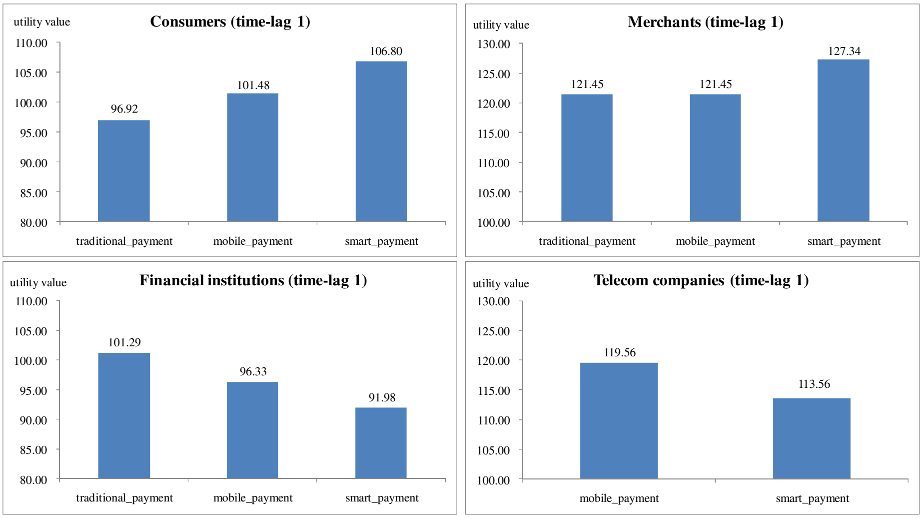

Fig. 4. Utility Value at Time-Lag 1 (Four Players and Three Payment Methods)

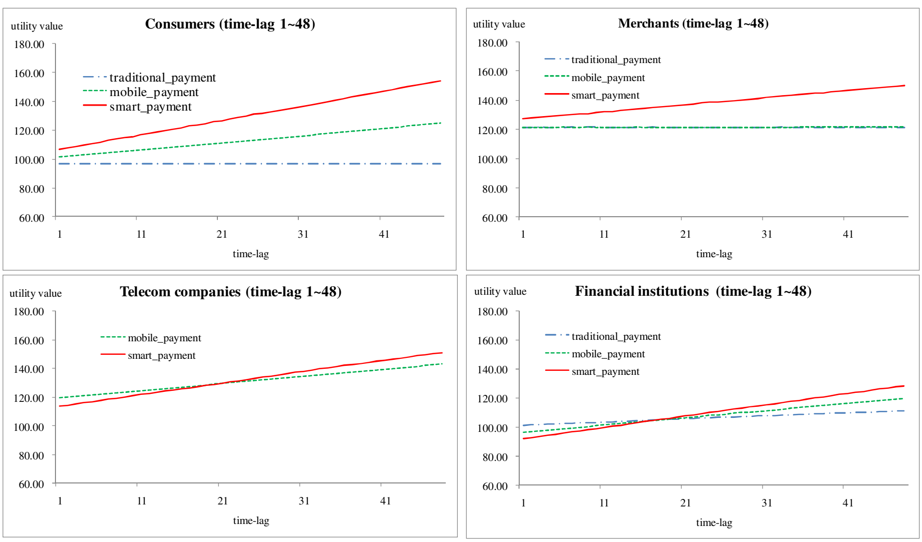

Fig. 5. Trend Patterns of Utility Value for 48 Time-Lag Periods

Second, at time-lag 1, it seems that merchants perceive the values of traditional payment and mobile payment as being nearly equivalent while those of smart payment are perceived as being more favorable because advertising costs can be saved. As with consumers, smart payment provides greater merchant utility over time.

Third, at time-lag 1, financial institutions perceive a very low value for smart payment because the transaction fee must be shared with the telecommunication companies. However, once the disadvantage of time-lag 1 is overcome, financial institutions will benefit most from smart payment due to the savings incurred by not having to issue plastic credit cards.

Fourth, at time-lag 1, telecommunication companies perceive mobile payment as the best payment method. Despite the initial IT costs that must be paid, over the 48 time-lags, smart payment will produce customer loyalty, leading to sales increases. Therefore, the long-term trend shows that smart payment is the most preferred payment method for telecommunication companies.

5 Concluding Remarks

The MAS results in this study reveal that smart payment will surely become a disruptive technology for mobile and traditional payments and that smart payment will be a very effective payment method for all four market players in the long-run. At the introductory stage, the values of smart payment were most appreciated by consumers due to its cutting-edge properties. From this study, we found that MAS can be used to derive a longitudinal pattern of effects resulting from the introduction of a new technology into the market. Further study topics include (1) integration of MAS and optimization techniques to resolve complicated decision problems and (2) the application of social network metrics among market players to analyze the economic impact of a new technology.

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